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Research Article
Management of *Zonocerus variegatus* with Pyrrolizidine Alkaloid Attracticide Bait

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Abstract

Background and Objective: *Zonocerus variegatus* is native to sub-Saharan Africa but assumed pest status following the accidental introduction of the exotic Siam weed, *Chromolaena odorata*. Both the insect and the weed cause economic damage in agriculture, forestry and conservation. *Zonocerus. variegatus* is strongly attracted to the flowers of *C. odorata* from which the insect sequesters pyrrolizidine alkaloids (PAs) for protection against its natural enemies and diapausing eggs. The present study aimed to reduce field populations of *Zonocerus variegatus* below economic injury level using a pyrrolizidine alkaloid attracticide bait. **Materials and Methods:** Field trials were conducted to determine efficacy of a novel PA based attracticide bait developed for the field management of *Z. variegatus* in open fields at the Forest Savannah Transition and Semi-deciduous ecological zones of Ghana. Part of the study also investigated the attraction of *Z. variegatus* to various parts of the developed PA based attracticide bait in an open field and a citrus nursery in a Randomized Complete Block design. **Results:** Most hoppers were attracted to the inside of the PA based bait where the attracticide was placed. The results on the field efficacy trials showed an efficiency of about 0.3% knock down per trap of field population of *Z. variegatus*. The 3rd to 5th instar larvae of *Z. variegatus* persist in the field for about 100 days; a period when the PA based attracticide bait will be most effective in reducing populations of the insects. **Conclusion:** This study therefore concludes that the PA based attracticide bait will reduce dry season populations of *Z. variegatus* as well as in surveillance studies.

Key words: *Zonocerus* grasshoppers, insect-plant interactions, attracticide baits, pyrrolizidine alkaloids used as insect lures

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

About two decades ago a proposal was made regarding the possibility of managing field populations of *Z. variegatus* (Linnaeus, 1758) by treating sources of pyrrolizidine alkaloids (PAs) with low doses of chemical insecticides and used as PA-based attracticides[1].

In the developed world, use of attracticides developed from food and sex pheromone lures has long replaced the application of chemical insecticides in invertebrate pest management[2]. The use of lure-toxicants combining sex pheromones has a high success rate in the Integrated Pest Management (IPM) of insect pests[3,4].

Seasonal outbreaks of *Z. variegatus* infestation on food crops in sub-Saharan Africa are mainly managed by the respective Government Agencies of Agriculture with minimal participation by peasant farmers. The closest attempt to extend a technology to manage *Z. variegatus* to peasant farmers in sub-Saharan Africa in the 1990s was the development of a wooden box trap incorporated with fungal pathogens[5].

Recent studies have demonstrated that treating the dry roots of *C. odorata*, which contain PAs with as low as 1.0% w/v Carbofuran® 3G yields a potent attracticide with a great potential for the management of *Z. variegatus* at the community level[6]. The efficacy of such an attracticide would depend on its validation in the field as demonstrated by Hafsi *et al.*[7] and Tewari *et al.*[8]. In this study, it is hypothesized that the use of the PA attracticide would reduce field populations of Zonocerus grasshoppers below economic injury levels.

The present study therefore aimed to assess the efficacy of a novel PA-based attracticide for the field management of *Z. variegatus* in Ghana in West Africa.

MATERIALS AND METHODS

Comparative attraction of *Z. variegatus* to a bucket-bait: A bucket-bait was made from a plastic bucket with holes made with a hot iron rod on the sides for ventilation and large enough for entry of 3rd to 5th instar larvae of *Z. variegatus*. The bucket was inverted with the base serving as roof. A wire-gauze of 15 cm mesh was cut and fitted to the lower and upper third of the inverted bucket for placement of the PA-attracticide. The bait consisted of 300 g weight of the dry roots of *C. odorata* soaked in a 1.0% (w/v) Carbofuran® 3G(CAS 1563-66-2), for 30 min and dried for 3 h in the sun. Prior to each test, the height of the vegetation was determined and the height of the bucket bait adjusted to correspond to the height of the field vegetation. A schematic diagram of the bucket bait is illustrated in Fig. 1.

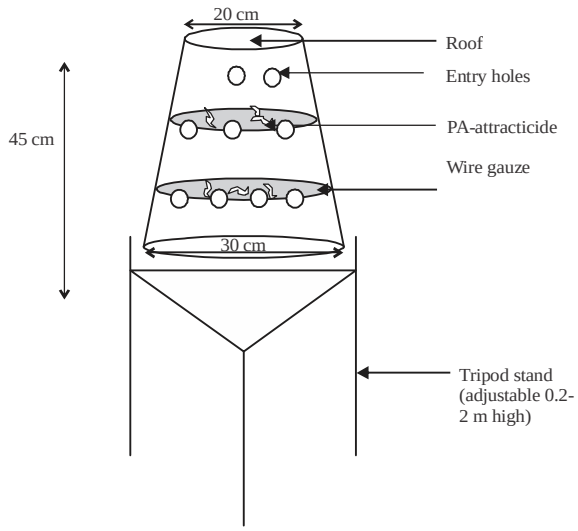

Fig. 1: Schematic diagram of bucket bait

Two trials were carried out in a 0.2 ha citrus nursery and a 0.4 ha fallow field in Kumasi, Ghana with *Z. variegatus* populations of 22,800 and 10,200 insects/ha respectively. Three bucket baits were placed at the edge of the field spaced 5 m, in the morning from 9:00 am to 5:00 pm and counts of *Z. variegatus* attracted to the different parts of the bait i.e., the stand, side and inside of the bucket made at 30 min intervals. The heights of the citrus nursery and fallow field were 0.6 and 1.2 m, respectively. The tripod stand could be adjusted from 0.2 m up to 2 m. The mean collection of hoppers from the three buckets was calculated each day and repeated for 10 days, each day representing a replication. Summary statistics was used to compute the means using GraphPadPrism® 5:00 version for windows[9].

Field efficacy trials of PA-based bait for management of *Z. variegarus*: The bucket bait was tested for its effectiveness in fields at Ejura and Kumasi in the Forest Savannah Transition and Semi-deciduous ecological zones of Ghana, respectively. The predominant stages of hoppers in the field were the 3rd to 5th instars. At Ejura, the experiments were conducted in an open fallow field of mixed vegetation and a cassava farm while in Kumasi data was collected in a citrus nursery and a cabbage farm infested with *Z. variegatus.* A pre-study field population of *Z. variegatus* at each particular field was determined, using the method described by Lomer *et al.*[10]. This ranged from 9.600-108.800 insects/ha on land sizes between 0.1 and 0.6 ha.

In all, 12 field trials, 6 each at Ejura and Kumasi were conducted with the bucket attracticide bait, each replicated three times, giving a total of 36 traps. Untreated dry chopped roots of *C. odorata* in a bucket bait served as control and the number of *Z. variegatus* attracted and knocked down by the PA-attracticide in the buckets within an 8 h period recorded each day, beginning at 8:00 or 9:00 am, depending on weather conditions.

Statistical analysis: The percentage knock down Roubos *et al.*[11] of *Z. variegatus* per population within the 8 h of experimentation (within a 2 m radius from bait) was compared with the t-test using Graph Pad Prism 5.00® statistical package[9]. Knock down was determined with the formula:

$$K = \frac{X}{P} \times 100 \quad (1)$$

where, K = Knock down, X = number of insects knocked down in an 8 h period and P = field population of insect.

RESULTS

Comparative attraction of *Z. variegatus* to bucket-bait: Significantly, more insects were attracted to the inside of the bucket bait per half hour in both trials 1 and trial 2 in the citrus nursery and fallow field, respectively. The mean attraction of *Z. variegatus* to the inside of the bucket bait per 30 min was 32.9 ($p<0.05$) (Fig. 2). There were no significant differences in attraction of hoppers/half hour to the stand and side of the bucket bait with values 0.4 and 2.7. The results observed in the second trial followed a similar pattern as in the first trial. Mean attraction of hoppers per half hour to the inside of the bucket bait in trial 2 was 7.6 ($p<0.05$) (Fig. 2) and significantly higher than the attraction to the stand (0.4 per half hour) and side (0.5 per half hour) of the bucket bait. Notably, the attraction of *Z. variegatus* to the inside of the bucket bait per half hour in trial 1 was higher than in trial 2. The total number of hoppers attracted per half hour to the bucket bait was 391 and 87 representing 0.4 and 0.1% of the field population respectively for trials 1 and 2.

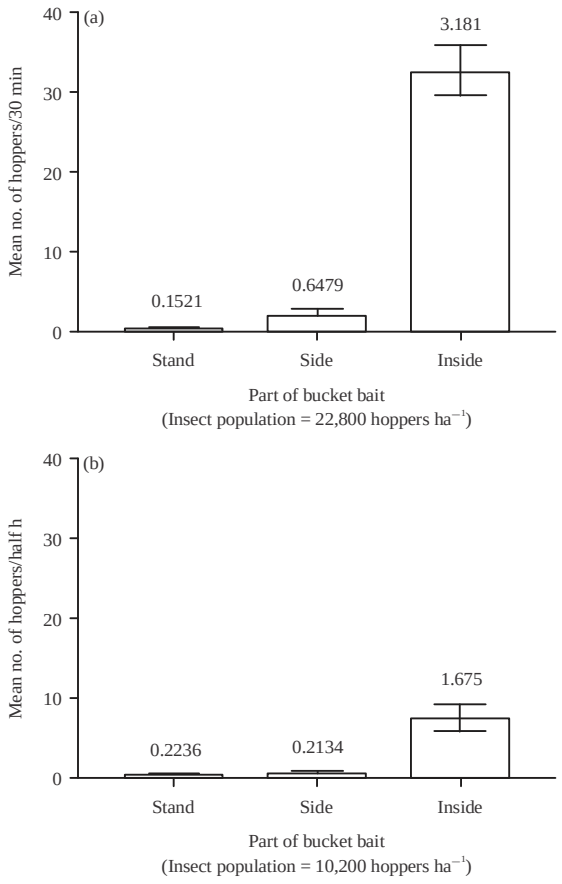

Fig. 2: Attraction of nymphs of *Z. variegatus* to bucket bait containing the roots of *C. odorata* in the field. Bars indicate standard error of means

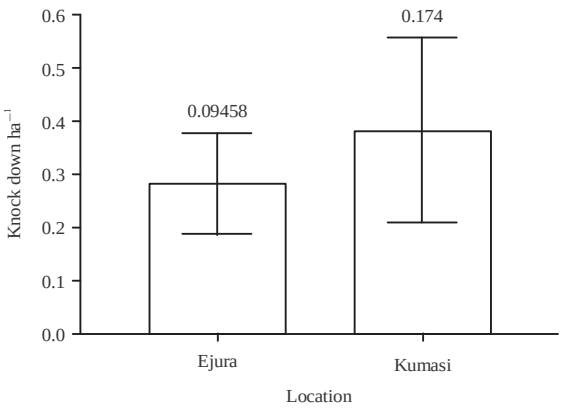

Fig. 3: Percent knock down of *Zonocerus variegatus* attracted to bucket baited traps at Ejura and Kumasi. Bars indicate standard error of means

Field efficacy of bucket bait with *C. odorata* root attracticide: The percent knock down of *Z. variegatus* per ha recorded at Ejura and Kumasi is presented in Fig. 3. There were no insect knock down recorded in the untreated controls. Mean percent knock down of *Z. variegatus* at Ejura was 0.3±0.09% (range 0.1-1.2%) while the Kumasi location recorded a mean of 0.4±0.17% (range 0.1-0.7%). The comparison of the percent knock down per ha at the two locations was statistically the same, with values recorded in Kumasi slightly higher.

DISCUSSION

It is not surprising that insects preferred the inside of the bait since the plume of PA molecules was more concentrated inside the bucket. Secondly, the insects naturally needed to reach and feed on the roots, which were placed inside the bucket.

In the field trials, a mean of 0.35% of the field population was knocked down by the bucket bait per day, irrespective of the location and field population of hoppers. Knock down has been used in assessment of attracticide formulations on insects1[11]. Generally, insects knocked down by the attracticide bait died within 30 min of ingestion of the lure toxicant and could last up to 26 h. Hoppers spend 2-15 mins on the attracticide baits but not necessarily consuming the poisoned roots. The evolutionary adaptation of self-amputation by insects corroborates the results of this study[12,13].

The efficacy of the attracticide in the field depended on the conditions of the environment such as temperature, field population of insects, wind speed and direction, the insect's physiological condition among others. Boppre[14] stated that the attraction of insects to PA-lures depended on competition with natural sources of PAs and abundance of insects in the area. Losel *et al.*[15] observed density related factors on the efficacy of attracticides. It is interesting to note that successes with the use of lure-toxicants has been achieved with insect management in recent years[16] and gives hope for the management of *Z. variegatus* in sub Saharan Africa.

In Ghana, the dry season populations of *Z. variegatus* which cause economic damage to crops usually hatch from late July while the flowers of *C. odorata* which contain PAs that could compete with the PA-attracticides in the field appear in mid-November. The period between these two dates is about 100 d. Notwithstanding the expected progressive decrease in population of hoppers per day and decrease in trap efficiency, it can be inferred that a substantial number of hoppers would be removed from the population during this period when 3rd to 5th instar larvae of *Z. variegatus* are predominant in the field before the flowering of *C. odorata*.

Considering the simplicity and cost effectiveness of the attracticide bait, peasant farmers can easily adopt it as a prophylactic management strategy for *Z. variegatus* at the community level. Cost benefit analysis on use of attracticides has been investigated in New Zealand with promising results[17]. This bait could also be used as a component of IPM, particularly for surveillance purposes as documented by Brockerhoff *et al.*[17] and Horie *et al.*[18].

CONCLUSION

Zonocerus variegatus is most attracted to the inside of the developed PA based attracticide bait. The developed PA based attracticide bait has a 0.3% knock down per trap of field population of *Z. variegatus*. The results hold promise in mitigating 2nd-5th instar nymphs of *Z. variegatus* in the field in a cost effective and prophylactic approach.

SIGNIFICANCE STATEMENT

This is the first study describing the use of a PA based attracticide bait to manage field populations of *Zonocerus variegatus*.

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