Efficacy of Emamectin Benzoate (3.4 ME) in the Control of Caterpillar (*Spodoptera litura* F) in Tobacco (*Nicotiana tabacum* L) Crop in Tanzania

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Abstract

Tobacco (Nicotiana tabacum L.) plant leaf is affected by both abiotic and biotic factors of which caterpillar (Spodoptera litura) is the main pest. The control of caterpillar in tobacco has been through deltamethrin. Following the introduction of new insecticide Sumectin 3.4 ME with active ingredient 'emamectin benzoate', initiated a need to study its efficacy on caterpillar and other pests. The research was conducted in Chunya, Tabora and Kahama in Tanzania to test three rates of emamectin benzoate of 4, 8, 10 ml and an absolute control treatment. The emamectin benzoate rates were compared with the control treatment of 10 ml Decis 2.5 EC (Deltamethrin) mixed in 20 L of water. Results showed that emamectin benzoate at the rate of 10 ml in 20 L of water decreased significantly (P<0.001) levels of tobacco caterpillar (S. litura), other pests (aphids, beetles and grasshoppers) and also contributed on increased leaf yields than the control treatment at a similar rate. Therefore, the rate of 10 ml of emamectin benzoate per 20 L of water is recommended to control S. litura and other pests in tobacco plant to both seedbed and field.

Keywords: agrochemicals; insecticides; pests, pest-count; efficacy; treatment

Introduction

Tobacco (*Nicotiana tabacum* L.) crop is among the top three cash crops in Tanzania contributing to the gross domestic product (GDP) in terms of foreign exchange earner crop (BOT, 2016). The crop is the main source of income to majority of Tanzanian in the western and central zone (Kidane & Ngeh, 2015). Despite its economic importance, its yield is affected by abiotic factors such as low soil fertility, water deficiency and inadequate sunshine during the leaf growth stage (Tang *et al.,* 2020). However, other biotic factors such as pests also affects tobacco leaf yields. Tobacco caterpillar *Spodoptera litura* F. is the major pest of tobacco in seedbeds and fields. It is considered one of the main problems reducing good quality and healthy of tobacco seedlings (Sreedhar, 2018; 2020). The leaf damage by caterpillars ranged from 80 to 100% in severe incidence (Birah *et al.,* 2008). Most of farmers sprays pesticides repeatedly to reduce pest severity. However, less application of lower rate that meeting the minimum residual levels in soils is recommended by Cooperation Centre for Scientific Research Relative to Tobacco-CORESTA (Quadroni & Bettinetti, 2019).

In Tanzania, Decis 2.5 EC with deltamentrin as an active ingredient, has been used for over a decade now in managing insects such as caterpillar. However, its uses has been complained by tobacco growers based on its low efficacy in controlling pests, hence spending more income for insecticides (Mbujilo, 2020). Therefore screening for one more insecticides such as emamectin benzoate could promote availability and accessibility to the market level and meet tobacco growers expectation.

Safe alternatives methods for pest control, which has fewer environmental effects, are highly recommended (Brzozowski & Mazourek, 2018). Sumectin 3.4 ME, an emamectin benzoate, is a semi-synthetic derivative of the avermectin family of naturally-derived products. It is effective against lepidopteran insects that manage Spodoptera litura (Ahmad *et al.,* 2008; Sreedhar, 2020; Hegde & Gadad, 2017; Babu *et al.,* 2018; Ghosal *et al.,* 2018). Emamectin benzoate is the 4'-deoxy-4'-epi-methyl-amino benzoate salt of avermectin B I (abamectin). It is an analogue of avermectin, produced by the same fermentation system as abamectin employing Streptomyces avermitilis (Birah *et al.,* 2008). When ingested and contact modes of action has been considered to control caterpillars (Yen & Lin, 2004) effectively at different larval stages of 5, 7 and 9 days (Janakiraman & Gupta, 2002, Birah *et al.,* 2008, Mahapatro *et al.,* 2008).

The persistent residual toxicity of the emamectin benzoate was observed to exist for 20 days (Sreedhar, 2018; 2020), and hence effective for destruction of caterpillar at different larval stages. However, emamectin benzoate has not been used in the country for controlling caterpillar in tobacco. Therefore, the research was carried out to determine the effectiveness and rate of emamectin benzoate to control caterpillar Spodoptera litura F in tobacco.

Materials and methods

Study areas

The trial was conducted in three sites, Mtanila-Chunya, Tumbi-Tabora and Ulowa-Kahama. Mtanila-Chunya is located at latitude 07º 58' 59" South, longitude 33º 18' 59" East and altitude of 1439 meters above sea level (m.a.s.l) with an average annual rainfall of 750 mm. Tumbi-Tabora is at latitude 05º 03' 44.4" South, longitude 32º 40' 07.4" East and altitude of 1151 m a.s.l with an average annual rainfall of 950 mm. Ulowa-Kahama is at latitude 03º 50' 15.2016" South, longitude 32º 35' 37.7808" East, altitude of 1156 m a.s.l with an average annual rainfall of 990 mm.

Experimental design and methodology

Across the study sites, tobacco seed variety (K326) sourced from Tobacco Research Institute of Tanzania (TORITA) was sown in a seedbed (20 m length by 1.5 m width) into five sections, each section was applied with emamectin benzoate during the sowing time at Mtanila, Chunya and Ulowa Kahama. The treatment was not applied during sowing at Tumbi, Tabora. Two weeks before transplanting tobacco seedlings, emamectin benzoate was applied in seedbed at Mtanila, Chunya, and Decis 2.5 EC was used at Tumbi Tabora. Seedlings were transplanted in the field trials sixty days after maturity of the seedlings. At the sowing of tobacco seed and two weeks before transplanting seedlings to the field in Mtanila, Chunya went concurrently with the application of emamectin benzoate and had excellent efficacy in the control of caterpillars (Fig. 1).

The fields trials were arranged in Randomized Complete Block Design (RCBD) with three replications and five treatments. The plots size had 6 m width and 6 m length, making a total plot area of 36 m^2. Plant spacing was 0.5 m with row spacing and 1.20 m between row spacing. Therefore, the number of plants per row were 12, and the entire plant population per plot were 60. Five treatments were absolute control, standard Decis 2.5 EC (10 ml in 20 L of water), 4, 8 and 10 ml Sumectin 3.4 ME (emamectin benzoate 34 G/L) in 20 L of water. The above rate than standard 10 ml was not used in the study, as tobacco industry require minimal insecticides residual in tobacco leaf (Quadroni & Bettinetti, 2019). Therefore, the lower rate or equivalent to the standard is recommended for the insecticide trials for new products based on the efficacy performance.

Before applying Sumectin 3.4 ME insecticide across the sites, all plants were investigated to identify levels and kinds of pests to get the baseline data. Pest count performed before, and in a 4th and 8th weeks after application of insecticides on 21 December 2020, and 18 January 2021, respectively. This assessment was carried out on six (6) randomly selected plants from each treatment plot. In addition, the plants were tagged for identification purposes. Pests count before application of insecticides was on 23 November 2020 across the sites. Immediately after pests counting, insecticides were applied on the same day. Collected data were analyzed using STATISTICA 8th Edition software. Mean comparisons on the number of each pest were made by using Least Square Difference (LSD).

Results

Pests identification and counts before application of insecticides in the fields

The use of emamectin benzoate in caterpillar management was very effective in Mtanila, Chunya as compared to Ulowa, Kahama and Tumbi Tabora (Fig 1).

Pest identification and counts before insecticides application are presented in Table 1. Tumbi had a significant (P<0.001) large number of beetles (1.60), grasshoppers (14.66), and millipedes (4.30), and it was followed by the Ulowa. Across sites, aphids and stink bugs were not observed. Beetles, grasshoppers

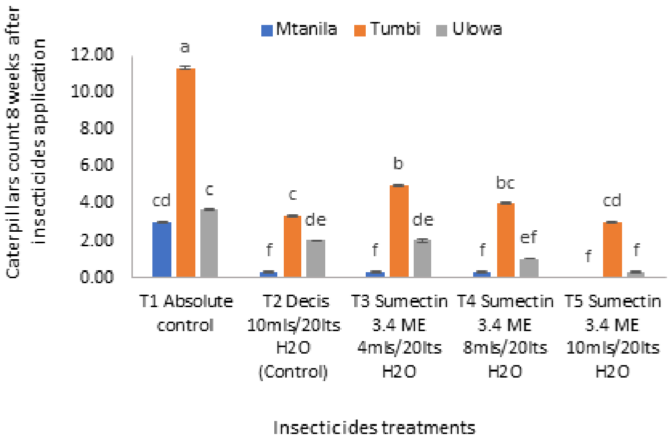

Figure. 1: Caterpillars count across the sites on 8 weeks after insecticides application

Table 1: Number pest before application of insecticides

	Aphids	Beetles	Caterpillars	G/hoppers	Millipedes	Stink Bug
Site:						
Mtanila-Chunya	-	0.00 ± 0.00^{b}	-	13.00 ± 1.09^{ab}	4.00 ± 0.33^{ab}	-
Tumbi-Tabora	-	1.60 ± 0.58^{a}	-	14.66 ± 0.69^{a}	4.33 ± 0.41^{a}	-
Ulowa-Kahama	-	1.73 ± 0.28^{a}	-	11.13 ± 1.27^{b}	3.00 ± 0.34^{b}	-
Treatment:						
T1 Absolute control	-	0.77 ± 0.27^{ab}	-	13.22 ± 1.10^{ab}	3.67 ± 0.47^{a}	-
T2 Decis 2.5 EC 10mls/20 L H_2O (Control)	-	1.11 ± 0.35^{ab}	-	11.22 ± 1.33^{b}	4.00 ± 0.58^{a}	-
T3 Sumectin 3.4 ME 4mls/20 L H_2O	-	0.88 ± 0.35^{ab}	-	12.11 ± 1.67^{ab}	3.33 ± 0.50^{a}	-
T4 Sumectin 3.4 ME 8mls/20 L H_2O	-	0.66 ± 0.29^{b}	-	12.55 ± 1.39^{ab}	3.55 ± 0.47^{a}	-
T5 Sumectin 3.4 ME 10mls/20 L H_2O	-	2.11 ± 1.02^{a}	-	15.55 ± 1.34^{a}	4.33 ± 0.50^{a}	-
2-Way ANOVA F Statistic						
Site (S)	-	6.47**	-	2.60ns	3.53ns	-
Treatment (T)	-	1.42ns	-	1.34ns	0.68ns	-
S × T	-	0.67ns	-	0.36ns	1.01ns	-

*Values presented are means ± SE (Standard Error); **, significant at, P ≤ 0.01; ns= non-significant; Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their respective Least Significance Difference (LSD) value at 5% error rate* and millipedes observed before insecticides application did not differed significantly across sites and treatments. Sites and treatments did not interacted significantly for beetles, grasshoppers and millipedes.

Pests identification and counts at a fourth week after application of insecticides

The pests observed across the sites were aphids, beetles, caterpillars, grasshoppers, and millipedes (Table 2). Like aphids, beetles were managed significantly at the 8 and 10ml Sumectin 3.4 ME mixed in 20 L of water, which had 0.44 and 0.11 for T4 and T5, respectively. The levels of caterpillars were reduced in T5 (0.66), and T4 (1.55) applied rate of 8 and 10 ml of Sumectin 3.4 ME, respectively. However, it did not differed significantly from the control treatment Decis 2.5 EC (1.44). Grasshoppers and millipedes levels were reduced significantly in Sumectin 3.4 ME rates of 8 and 10 ml than the Decis 2.5 EC control (T2) treatment. Application of 10 ml (Sumectin 3.4 ME) had a significant effect in controlling grasshoppers and millipedes than the control treatment Decis 2.5 EC.

Pests identification and counts eighth weeks after application of insecticides

Pests identified and counted eighth weeks after application of insecticides are shown in Table 3. The number of aphids and beetles were significant (P<0.001) large in Mtanila, than Tumbi and Ulowa. The number of caterpillars,

Table 2. Pest identification and count at a fourth week after application of insecticides

	Aphids	Beetles	Caterpillars	G/hoppers	Millipedes	Stink Bug
Site:						
Mtanila (Chunya)	44.60 ± 1.41^{a}	1.13 ± 0.31^{a}	1.66 ± 0.42^{b}	2.33 ± 0.59^{c}	1.20 ± 0.24^{b}	-
Tumbi (Tabora)	36.20 ± 8.78^{b}	0.46 ± 0.25^{a}	3.53 ± 0.67^{a}	4.60 ± 0.58^{a}	2.33 ± 0.43^{a}	-
Ulowa (Kahama)	14.73 ± 1.32^{c}	0.60 ± 0.24^{a}	1.47 ± 0.29^{b}	3.00 ± 0.4^{b}	1.13 ± 0.24^{b}	-
Treatment:						
T1 Absolute control	56.11 ± 10.39^{a}	1.77 ± 0.46^{a}	4.66 ± 0.89^{a}	6.77 ± 0.70^{a}	3.00 ± 0.47^{a}	-
T2 Decis 2.5 EC 10mls/20 L H_2O (Control)	38.88 ± 5.61^{b}	0.33 ± 0.16^{b}	1.44 ± 0.29^{c}	2.88 ± 0.26^{bc}	1.33 ± 0.29^{b}	-
T3 Sumectin 3.4 ME 4mls/20 L H_2O	21.78 ± 4.61^{c}	1.00 ± 0.37^{ab}	2.77 ± 0.57^{b}	3.11 ± 0.42^{b}	1.89 ± 0.45^{b}	-
T4 Sumectin 3.4 ME 8mls/20 L H_2O	20.67 ± 5.08^{c}	0.44 ± 0.24^{b}	1.55 ± 0.34^{c}	2.00 ± 0.33^{cd}	1.22 ± 0.22^{b}	-
T5 Sumectin 3.4 ME 10mls/20 L H_2O	21.77 ± 5.21^{c}	0.11 ± 0.11^{b}	0.66 ± 0.23^{c}	1.78 ± 0.46^{d}	0.33 ± 0.16^{c}	-
2-Way ANOVA F Statistic						
Site (S)	185.34***	2.00ns	16.24***	20.35***	12.79***	-
Treatment (T)	113.22***	4.32***	18.29***	36.69***	16.25***	-
S × T	50.08***	0.12ns	2.61*	0.77ns	3.00**	-

*Values presented are means ± SE (Standard Error); *, **, *** significant at $P \leq 0.05$, $P \leq 0.01$ and $P < 0.001$ respectively; ns= non-significant; Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their respective Least Significance Difference (LSD) value at 5% error rate.*

grasshoppers, millipedes, and stink bugs were higher at Tumbi than Mtanila and Ulowa. However, no significant differences in number of stink bugs were counted across sites.

The highest rate of 10mls of Sumectine 3.4 ME was effective than Decis 2.5 EC in managing aphids, caterpillars and millipedes management. Sites and treatments interacted significantly for the number of aphids, beetles, caterpillars, grasshoppers and millipedes.

Contribution of insecticides application on green and dry leaf yields

Green and dry leaf weight are presented in Table 4. Both green and dry leaf weight did not differ significantly across sites. Green (7592.56 kg/ha) and dry leaf (1523.65 kg/ha) weight measured in T1 did not differ significantly from T2 (Decis 2.5 EC), which had 8375.02 and 1675.19 kg/ha, respectively. Treatment T5 applied with 10mls of Sumectin 3.4 ME had

Table 3. Pest count at a eighth week after application of insecticides

	Aphids	Beetles	Caterpillars	G/hoppers	Millipedes	Stink Bug
Site:						
Mtanila (Chunya)	20.47 ± 1.37^b	0.53 ± 0.16^a	1.60 ± 0.50^b	1.13 ± 0.25^c	0.33 ± 0.12^c	0.46 ± 0.33^a
Tumbi (Tabora)	29.93 ± 8.69^a	0.80 ± 0.29^a	3.13 ± 0.62^a	4.13 ± 0.52^a	1.60 ± 0.29^a	0.20 ± 0.20^a
Ulowa (Kahama)	10.20 ± 1.21^c	0.86 ± 0.13^a	1.86 ± 0.25^b	3.00 ± 0.51^b	0.73 ± 0.15^b	0.26 ± 0.15^a
Treatment:						
T1 Absolute control	43.55 ± 10.79^a	1.77 ± 0.28^a	5.00 ± 0.78^a	5.33 ± 0.91^a	1.77 ± 0.43^a	1.22 ± 0.59a
T2 Decis 2.5 EC 10mls/20 L H_2O (Control)	27.44 ± 5.35^b	0.66 ± 0.16^b	1.55 ± 0.24^b	2.55 ± 0.29^c	0.77 ± 0.15^b	0.11 ± 0.11^b
T3 Sumectin 3.4 ME 4mls/20 L H_2O	10.77 ± 2.12^c	0.77 ± 0.22^b	2.33 ± 0.33^b	2.55 ± 0.55^c	1.00 ± 0.29^b	0.00 ± 0.00^b
T4 Sumectin 3.4 ME 8mls/20 L H_2O	9.66 ± 1.87^c	0.33 ± 0.17^{bc}	1.55 ± 0.24^b	1.77 ± 0.43^{bc}	0.66 ± 0.23^b	0.11 ± 0.11^b
T5 Sumectin 3.4 ME 10mls/20 L H_2O	9.55 ± 1.82^c	0.11 ± 0.11^c	0.55 ± 0.24^c	1.55 ± 0.41^c	0.22 ± 0.14^c	0.11 ± 0.11^b
2-Way ANOVA F Statistic						
Site (S)	73.79***	1.61ns	12.58***	51.63***	31.44***	0.32ns
Treatment (T)	103.524***	12.81***	32.04***	30.78***	14.72***	2.65*
S × T	48.95***	1.90ns	3.21**	4.76***	5.05***	0.14ns

*Values presented are means ± SE (Standard Error); *, **, *** significant at $P \leq 0.05$, $P \leq 0.01$ and $P < 0.001$ respectively; ns= non-significant; Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their respective Least Significance Difference (LSD) value at 5% error rate.*

significantly heavy green (12404.90 kg/ha) and dry leaf (2479.91 kg/ha) weight than the Decis 2.5 EC. There were no interactions between sites and treatments on green and dry leaf yields.

Table 4: Effect of application of insecticides on green and dry leaf yields

	Green Leaf Weight (kg/ha)	Dry Leaf Weight (kg/ha)
Site:		
Mtanila (Chunya)	9834.39 ± 644.18a	1966.87 ± 128.83a
Tumbi (Tabora)	9777.78 ± 713.91a	1955.56 ± 142.78a
Ulowa (Kahama)	9781.73 ± 644.27a	1958.78 ± 127.62a
Treatment:		
T1 Absolute control	7592.56 ± 452.45c	1523.65 ± 88.46c
T2 Decis 2.5 EC 10mls/20 L H_2O (Control)	8375.02 ± 498.72c	1675.19 ± 99.66c
T3 Sumectin 3.4 ME 4mls/20 L H_2O	9518.84 ± 229.85bc	1903.19 ± 46.23bc
T4 Sumectin 3.4 ME 8mls/20 L H_2O	11099.51 ± 882.04ab	2220.08 ± 176.35ab
T5 Sumectin 3.4 ME 10mls/20 L H_2O	12403.90 ± 832.02a	2479.91 ± 166.77a
2-Way ANOVA F Statistic		
Site (S)	0.00ns	0.00ns
Treatment (T)	7.44***	7.40***
S × T	0.06ns	0.05ns

*Values presented are means ± SE (Standard Error); *** significant at P <0.001; ns= non-significant; Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their LSD value at 5% error rate.*

fields was less effective (Fig. 1) because of the low residual in controlling the caterpillars to the new field location. Furthermore, the application of emamectin benzoate only in fields as it was done for the Tabora site was ineffective in controlling caterpillars. The seedlings transplanted to the fields from nurseries could have higher caterpillar's larva or pupa levels and hence increased caterpillars numbers in the fields (Fig. 1).

Discussion

This study noted for population variation between sites in reference to untreated (absolute control) during the eighth week after application of insecticides (Table 3). Site of Tumbi had the highest population of aphids (29.93), beetles (0.80), caterpillars (3.13), grasshoppers (4.13) and millipedes (1.60) compared to Mtanila site with aphids (20.47), beetles (0.53), caterpillars (1.60), grasshoppers (1.13) and millipedes (0.33). Variation of pest population could be due to the application of emamectin benzoate form the seedbed and at the transplanting in field for Mtanila site, while at Tumbi site only standard Decis 2.5EC was applied at seedbed. Threfore, application of emamectin benzoate in tobacco seedbed during sowing of tobacco seed, two weeks before and at transplanting at Mtanila, confirmed the efficacy of the insecticide caterpillars management (Fig. 1). On the other hand, application of emamectin benzoate in tobacco seedbed only during the sowing and at the transplanting in Kahama

Beetles, grasshoppers and millipedes appeared in early transplanted tobacco seedlings (Table 1). Beetles were feeding on the leaf, and millipedes on roots (Govorushko, 2019; Hafez *et al.,* 2019; Green *et al.,* 2020). The most deadly pest in tobacco, caterpillars, was observed in tobacco leaf in the fourth week after applying insecticides (Table 2). Considering that the transplanting of tobacco seedlings was done on 16 November 2020, it is evident that caterpillars were the most hazardous pest in tobacco. The appearance of caterpillars in fields four weeks after Sumectin 3.4 ME, indicating the possibility that caterpillars eggs were still embedded in some of the seedlings, which progressed to larva and pupa few days after transplanting (Sreedhar, 2018). The position where the larva is located within the seedlings (curled foliage) could be not reached easily by the applied insecticides (Sial & Brunner, 2010). Hence, the caterpillar's life cycle reached an adult stage within 30 days (Kariyat *et al.,* 2019).

With exception to absolute control (T1), the pest levels decreased during the 8th week after applying emamectin benzoate, probably due to the residual effects of applied Sumectin 3.4 ME (Sreedhar, 2018; 2020). Stink bugs appeared 8 weeks after applying insecticides (Table 3). Thus, implying that stink bugs prefer sucking from matured leaf and stem of the tobacco plant (McPherson and McPherson, 2000; Panizzi *et al.,* 2000) at the time of reduced insecticide concentrations. The T5, which applied a rate of 10 ml *(emamectin benzoate)*, had the significantly lowest pest levels indicating at that rate, had higher efficacy in controlling pests than other rates.

The higher rates of emamectin benzoate have also been observed to have significant systemic toxicity and controlled aphids, caterpillar and Helicoverpa armigera (Birah *et al.,* 2008; Teja *et al.,* 2019; Dagar *et al.,* 2020; Cheng *et al.,* 2021). Moreover, Thodsare & Srivastava (2014) and Dagar *et al.* (2020) indicated the toxicity of emamectin benzoate against tobacco caterpillars *(Spodoptera litura)*. Sites with higher caterpillar levels like Tumbi, lowest green weight (9777.78 kg/ha) were harvested as compared with lowest levels in Mtanila (9834.39 kg/ha) (Fig. 1). For the effective control of caterpillars, 10 ml of emamectin benzoate mixed in 20 L of water should be applied in a seedbed at the sowing, two weeks before transplanting seedlings to the fields and one week after transplanting.

Conclusion and recommendation

The current study showed that emamectin benzoate controlled caterpillars and other pests effectively and hence increased tobacco leaf yields. Application of 10 ml of emamectin benzoate mixed in 20 L of water should be used for insect pest management both at seedbed and fields. The insecticide (emamectin benzoate) should be applied during sowing in the seedbed, two weeks before transplanting seedlings and one week after transplanting tobacco seedlings in the field.

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