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COMPARING THE MOLLUSCICIDAL ACTION OF METALDEHYDE, OXAMYL, POTASSIUM NITRATE AND A BOTANICAL INSECTICIDE FOR MANAGING LIMACOLARIA SPP INFESTING BANANA PLANTATIONS IN CAMEROON

Tientcheu Cheke Bernadette Limunga[1]
Ekwa Yawa Monono[2+]
Afui Mih Mathias[3]
Nambangia Justin Okolle[4]

[1]*Cameroon Development Corporation (CDC), Tiko Banana Plantations, South West Region, Cameroon.*
Email: benicheks@yahoo.com Tel: (+237) 674806244
[2]*Institute of Agricultural Research for Development (IRAD) Ekona, South West Region, Cameroon.*
Email: ymekwado@yahoo.com Tel: (+237) 675595865
[3]*Department of Botany and Plant Physiology, University of Buea, Cameroon.*
Email: afuimih@yahoo.com Tel: (+237) 676003271
[4]*African Research Centre on Bananas and Plantains (CARBAP) Njombe, Littoral Region, Cameroon.*
Email: okollejustin@yahoo.com Tel: (+237) 674534786

(+ Corresponding author)

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ABSTRACT

Snails are an emerging problem in banana production in Cameroon due to the damages caused on the banana fruits. They attack the banana fruits resulting in aesthetically disfigured fruits. This study was carried out to compare the effectiveness of selected agrochemicals in the laboratory and the field for the control of the snails. The agrochemicals compared were Bromorex® (chilli pepper extracts), Potassium Nitrate, Vydate® (Oxamyl), and Limace® (Metaldehyde). Laboratory results showed that snail mortality caused by the different treatments after 7 and 14 days was highest for Limace (37% and 100% respectively). Limace® had the highest mean percentage (86.4%) of snails at the snail zone as compared with the control (6.1%) which was the least. Field results showed that plants treated with Limace® had the lowest mean number of snails counted on the corms and pseudostems during the 12-week period while the Control (2.67snails/plant) had the highest mean value followed by Bromorex®. But the mean number of living snails with plant treated with Potassium Nitrate, Vydate® and Limace® increased from the 10th week albeit less than 1 snail/plant. During the first three weeks plants treated with Limace® and Vydate® the number of dead snails was relatively higher (1.6 snails/plant and 1.08 snails/plant respectively). Of the four treatments assessed, Limace® was most effective in the management of snails followed by Vydate®. Limace® controlled the snails best both in the laboratory and on the field at concentrations of 5 g per container (7x7x13 cm) and 50 g per banana mat respectively.

Contribution/Originality: This research is one of the very few researches that have compared the molluscicidal effects of different chemical groups on *Limacolaria* species, an emerging pest of crops. In addition, it is one of the few researches that have tested molluscicides effects on *Limacolaria* spp. in the field.

1. INTRODUCTION

Banana is one of the world's most important crops grown by small and large scale producer's alike (Edward & Fredy, 2012). It seems to be the most exported and consumed fruit in the world (FAO, 2015). The cultivation of banana plays an important role in the economic and community development of the world because it is an important source of energy and revenue for the rural population (Donato et al., 2006; Monono, Ngale, Dopgima, & Njukang,

2018) especially in Central and West Africa (Jacobsen, Fogain, Mouassom, & De Waele, 2004; Noupadja, 2000; Okolle, Fansi, Lombi, Sama Lang, & Loubana, 2009). The fruits are known to be highly nutritive, rich in carbohydrates and a good source of vitamins (Ajoh, Bhabatosh, Nishith, & Sourav, 2011; Arvanitoyannis, Mavromatis, Grammatikaki-Avgeli, & Sakellariou, 2008; Debabandya, Sabyasachi, & Namrata, 2010; Honfo, Hell, Coulibaly, & Tenkouano, 2007; Honfo., Kayodé, Coulibaly, & Tenkouano, 2007). Banana also contains low protein levels and can be used to produce large amount of recombinant proteins (i.e. vaccines) (Arvanitoyannis et al., 2008)] and easily digestible than many other fruits (Debabandya et al., 2010).

FAO (2015) reported that in 2013, the quantity of bananas and plantains produced were more than 145 million metric tons in over 130 countries on more than 11 million hectares of land. According to FAO (2010) the annual production of banana was estimated at about 95 million tons and both bananas and plantains served as staple foods for at least 4000 million people in the world especially in sub-Saharan countries. Cameroon is one of the 20 major plantain and banana producing, consuming, and exporting nations in Africa. The total amount of banana and plantain production was estimated at 5,300,000 metric tons in 2013 with dessert banana accounting for 29% whereas plantain and other cooking bananas accounted for 71% (FAO, 2015). In Cameroon banana production has been threatened by a series of abiotic and biotic stresses such as *Cosmopolites sordidus*, burrowing nematodes, black sigatoka, mealy bugs, aphids and recently, white flies and snails (Okolle et al., 2009; Okolle. et al., 2018; Okolle.., Bernadette, Yawa, Mercy, & Mathias, 2019).

There is not adequate information on mollusca as crop pests. Isolated literatures have documented some increasing problems caused by terrestrial gastropods to agriculture across the world (Barker, 2003; Ebenso et al., 2005; Halwart, 1994; Shankar, Uma, & Amit, 2016; Vanitha, Karuppuchamy, & Sivasubramanian, 2011). In Cameroon, banana plantations are affected by pests and diseases such as borer weevils, lesion nematodes, black sigatoka, mealy bugs (Okolle et al., 2009; Okolle et al., 2018) with snails becoming an emerging pest especially on export bananas (Fongod, Focho, Mih, Fonge, & Lang, 2010; Okolle.. et al., 2019; Shankar et al., 2016). *Limicolaria* spp. has been reported to be most current pest damaging banana and plantain in Cameroon (Okolle et al., 2019) such that is was suggested to may have been a greater pest than *A. fulica*or and *A. marginata* (Mead & Palcy, 1992). *Limicolaria* species (snail) which belongs to the Family Achatinidae (Floyd, Roda, & Robinson, 2007). This species have been reported to attack yam, bean, pepper, cucumbers, okra, sweet potato, and Jerusalem artichoke (Floyd et al., 2007; Mead & Palcy, 1992). In India, the giant African snail had been reported as a serious threat to many crops including *Musa* species (Nazeer, 2011). These Molluscs cause damage to banana fruits by eating the peeling, leaving slimy trails and feaces on the fruits (Shankar et al., 2016) and these damages seriously affect the physical appearances of the fruits and therefore make many fruits not fit for exportation (Okolle et al., 2019). Land Mollusc pests are serious problems every year with damage involving considerable financial losses inflicted on cereals, potatoes, vegetables, lettuce, carrots, cabbage, maize, clover as well as other agricultural and horticultural crops (Floyd et al., 2007; Mead & Palcy, 1992; Sallam & El-Wakeil, 2012). In addition, these snails feed on leaves of very young plants (suckers) creating feeding holes on them (Shankar et al., 2016). Thus, the problems can be avoided or partially controlled through the use of pesticide.

Since the emergence of this problem, most or all management techniques have focused on the use of metaldehyde to attract and kill or physically pick and kill the snails. Furthermore, considering the environmental and health effects that usually accompany the application of synthetic pesticides, there is a growing need to evaluate the efficacy of alternatives to these synthetic pesticides. Following a preliminary laboratory experiment carried out in African Research Centre on Bananas and Plantains (CARBAP) Njombe, Cameroon, a botanical insecticide (Bromorex) was reported to be a potential molluscicide. The objective of this research was to compare the molluscicidal effects of the commonly used metaldehyde with that of oxamyl, urea and a botanical insecticide.

2. MATERIALS AND METHODS

2.1. Study Area

Cameroon Development Corporation (CDC) is the second largest employer after the government. This corporation principally cultivates rubber, oil palm and banana (Jude & Muluh, 2013). Most CDC's operational plantations are mainly found in the Southwest and Littoral Regions of Cameroon. For the banana plantation, they are mostly found in Fako Division of the South West Region. The sites of this crop are therefore influenced by the local climatic conditions and soil type (Jude & Muluh, 2013). Holforth farm is located in Tiko Sub Division which has a hot climate with an average temperature of 23.8 minimum to 30.6 maximum a year, an average rainfall of 210.2 mm and an average humidity of 83.8%. It has silty top soils and clay sub soils with varying amounts of gravel in the sub soils. The Laboratory studies were carried out at the Entomology laboratory at IRAD (Institute of Agricultural Research for Development) Ekona (4°16′44″ N and 9°17′50″ E) in the South West Region of Cameroon (Monono et al., 2018).

2.2. Pesticides Applied in the Plantation

The Cameroon Development Corporation (CDC) is an agro-industrial company which depend mostly on synthetic pesticides, therefore several pesticides are been applied in the banana plantation such as herbicides (e.g gyphosate), nematicides (oxamyl), fungicides, insecticides-nematicides (terbufos) Table 1.

Table-1. List of pesticides used by C.D.C in the banana plantation.

Pesticides	Types	Active Ingredient	Formulation
Basta®	Herbicides	Gluphosinate Ammonium(200 g/L)	Soluble liquid
Cyclone®	Herbicides	Gluphosinate Ammonium(200 g/L)	Soluble liquid
Glyphader®	Herbicides	Gluphosinate Ammonium(200 g/L)	Soluble liquid
Glyphosalm ®	Herbicides	Glyphosate 360 g/L	Soluble liquid
Cyclone®	Herbicides	Gluphosinate Ammonium(200 g/L)	Soluble liquid
Forza®	Herbicides	Gluphosinate Ammonium(200 g/L)	Soluble liquid
Bastion®	Insecticides Nematicides	Carbofuran 100 g/kg	Granules
Counter®	Insecticides Nematicides	Terbufos 100 g/kg	Granules
Mocap®	Insecticides Nematicides	Ethoprophos 15%	Granules
Vydate®	Insecticides Nematicides	Oxyamyl 240g/L	Emulsifiable concentrate
Limace®	Mollucicides	Metaldehyde 5%	Granules
Bastion®	Nematicides	Carbofuran 100 g/kg	Granules
Baycor®	Fungicides	Bitertanol 500 g/L	Suspension concentrate
Bravo®	Fungicides	Chlorothalonil 750 g/L	Suspension concentrate
Chloroplant®	Fungicides	Chlorothalonil	Suspension concentrate
Comet plus®	Fungicides	Fenpropimorph 375 g/L, Pyraclostrobin 100 g/L	Oil miscible flowable concentrate
Dithane®	Fungicides	Mancozebe 430 g/L	Suspension concentrate
Folcure®	Fungicides	Tebuconarole 25 g/L	Emulsion,oil in water
Impulse®	Fungicides	Spiroxamine	Emulsifiable concentrate
Mangrate®	Fungicides	Imzalil	Soluble granule
Manzate®	Fungicides	Mancozebe	Waterdispersible granule
Opal®	Fungicides	Epoxyconazole	Emulsifiable concentrate
Penncozeb	Fungicides	Mancozebe 80%	Wetable powder
Sico®	Fungicides	Difenoconazole 250 g/L	Emulsifiable concentrate
Siganex®	Fungicides	Pyrimethanil 600 g/L	Sspension concentrate
Tern®	Fungicides	Fenpropiden 75%	Emulsifiable concentrate
Volly®	Fungicides	Fenpropimorphe 880 g/L	Oil miscible liquid
Ivory®	Fungicides	Mancozebe 800 g/kg	Wettable powder.
Dithane®	Fungicides	Mancozebe 600 g/L	Spreading oil

2.3. Fertilizer Application in the Plantations

The fertilizer application programme is shown on Table 2. This was done using a calibrated cup (10 L bucket). Application was done around the plant base in a band of about 10 to 15 cm and at a distance of 30 cm away from the plant forming a semi-circle for the follower and a circle for the replant. One hundred grams was applied per plant. Booster doses of potassium nitrate, urea, ammonium sulphate or potash could be applied whenever necessary or recommended. Five hundred and forty grams (540 g) of Dolomite was applied when supplied.

Table-2. Fertilizer application programme for the farm.

Cycle	1	2	3	4	5	6	7	8	9	10
Periods(weeks)	1-5	6-10	11-15	16-18	19-23	24-27	33-37	38-42	43-47	48-52
Duration weeks	5	5	5	5	5	10	5	5	5	5
Quantity/plant (g)	100	100	100	100	100	100	100	100	100	5
Quantity/Ha (Kg)	185	185	185	185	185	185	185	185	185	5
Bags/Ha	3.7	3.5	3.7	3.5	3.7	3.5	3.7	3.5	3.7	5
Cycle/year	5	5	5	5	5	5	5	5	5	5

Note: Fertilizer (NPK 14-3-30+2mgo+5S) application.

2.4. Laboratory Experiment

Two synthetic pesticides, a botanical pesticide and a synthetic fertilizerwere used namely Vydate® (active ingredient oxamyl) a nematicide with insecticide properties, Limace® (metaldehyde) – molluscicide. It has an active ingredient of 5% metaldehyde and has a granule formulation. It acts by ingestion or by contact with leg which prevent rehydration. Bromorex® (chilli pepper extracts) – a botanical insecticide and Potassium Nitrate (a fertilizer). This experiment was carried out for two weeks, with five treatments Table 3.

Table-3. Laboratory treatment composition.

Treatment	Name of treatments
T1	Untreated control (20 mL of tap water).
T2	Bromorex® – (1% v/v) (20 mL solution applied per container)
T3	Potassium Nitrate (5 g/container)
T4	Vydate® (1% v/v solution per container) (20 mL solution applied per container)
T5	Limace® (5 g/container or treatment zone)

One thousand snails were collected from plants in the plantation and put in a perforated plastic bag. Immature fruits were then harvested from bunches of toppled plants in the field. Together with the snails, they were taken to the Entomology laboratory at IRAD Ekona.

In the laboratory, 20 containers, each measuring 7 cm in length by 7 cm in width and 13 cm in height with a tight-fitting perforated lids were selected, washed, wiped and air dried for 20 minutes. Soil dug from the research centre was put in the containers and moistened with tap water. At the centers of the containers, rings or circles were demarcated and considered as treatment zones (i.e. where the different treatments were applied). Banana pieces from the immature fruits were placed at four corners of the dish (none treatment zone). Ten snails, each measuring about 3.8 x 1.5 x 1.3 cm for length, width and height respectively, were placed in the central portions of the circles or rings (non-treated portions at the centers of the containers) Figure 1. Each treatment had 4 replicates and there were 10 snails per replicate, implying 40 snails per treatment, making a total of 200 snails for the entire experiment.

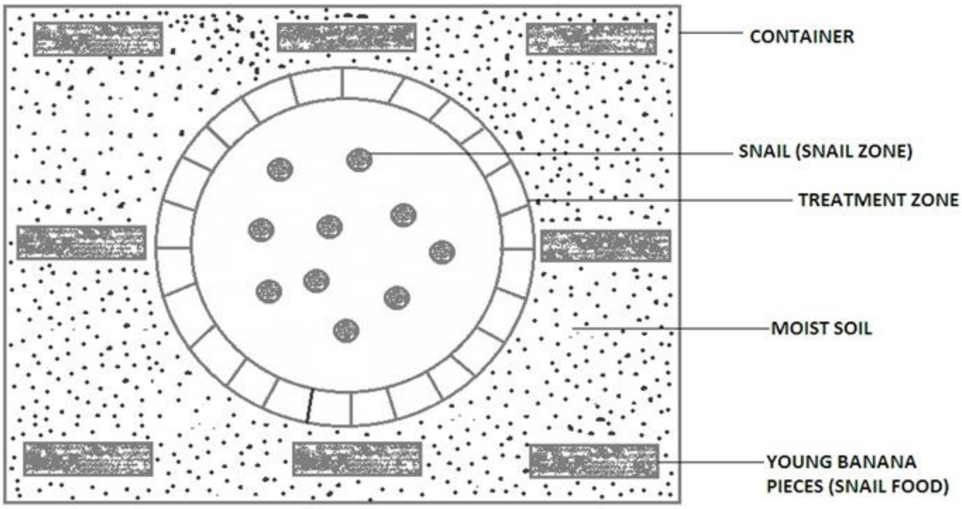

Figure-1. Experimental layout in the laboratory for each container.

For Bromorex® and Vydate®, 20 mL of the prepared solutions were applied in a circle around the snails on the soils (Treatment Zone). For Potassium Nitrate and Limace®, 5g of the granules were also spread in a circle around the snails while for the control, tap water was used.

Data was collected daily for two weeks. The data were number of snails dying (cumulative), number of snails at the treated zones and behaviour of snail were also observed and recorded i.e. how they die, how they reacted to the pesticide (repulsion).

2.5. Field Experiment

This experiment was carried out in the Holforth plantation in a highly infested field. The area was chosen based on its site history of snail infestation of the area. The Experimental design chosen was a randomized complete block design with five treatments Table 4 each having three replicate. There were a total of 24 plants per treatment, 8 plants per replicate and 120 plants for the experiments. Each treatment was separated by three plants in a row.

Table-4. Field treatment composition.

Treatment	Name of treatment
T1	Untreated control (Nothing applied).
T2	Bromorex® (0.125%v/v) –50 mL solution applied per plant
T3	Potassium nitrate (50 g per plant)
T4	Vydate® (0.5%v/v) 15 mL solution applied per plant.
T5	Limace® (50 g per plant)

Before applying the treatments each plant was thoroughly inspected for the presence of snails and those found were handpicked and disposed out of the plots. This was followed by preparation of 50 mL Bromorex and 15 mL Vydate solutions that were then applied in a circle around the corm region of the banana plant using calibrated container. For plots receiving Potassium Nitrate and Limace®, 50g of the granules were also spread in a circle around the plants on the soil while no treatment was applied for the control plants.

During the field experiment, data was collected weekly for three months (April to June). The data collected were on the number of living snails found on pseudostems, number of snails found around corm as well as number of dead snails on soil around the corm.

2.6. Data Analyses

Data collected was analyzed using descriptive statistics and subjected to analysis of variance (ANOVA). The Z-test was used to compare means with two large samples. All analyses were carried out using StatDisk Software

(Mario, Gilmartin, Solberg, & Abueisaad, 2003). Pertinent means from the ANOVA were separated using Tukey's test (Fowler, Cohen, & Javis, 1998). Statistical significance was set at $p \leq 0.05$.

3. RESULTS

3.1. Treatment Effects in the Laboratory

The percentage of snails at the snail zone (the percentage of snails not able to move across treatment barrier from Day 1-7) was significantly high in most treated containers than in the control containers Figure 2.

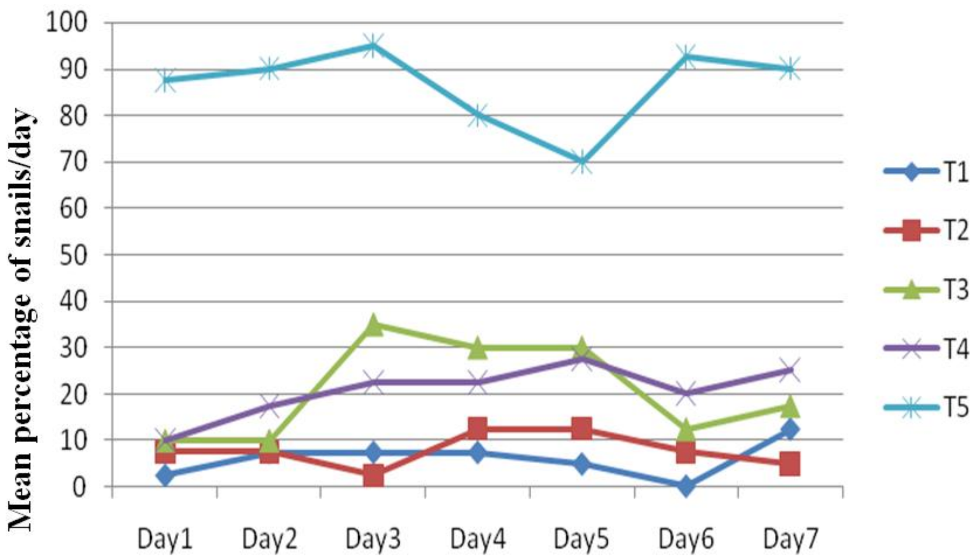

Figure-2. Percentage of snails remaining within the snail zone.
Note : T1= Untreated control T2= Bromorex®T3=potassium nitrate T4= Vydate® T5 = Limace®.

It was observed that Limace® had the highest mean percentage (86.4%) of snails at the snail zone as compared with the control (6.1%) which was the least. In the Limace® treated plot, mortality of the snails occurred slowly and most were immobile, food was not touched, and they were unable to move from the snail zone past the treatment zone to get food. No mortality of snail was recorded in containers treated with Bromorex®, Potassium Nitrate and the Control after 7 days Table 5. Snail mortality caused by the different treatments after 7 and 14 days are shown in Table 5 with varied mortalities for Limace®, Vydate®, Potassium Nitrate®. Highest mortality was recorded from Limace® treatment after 7 and 14 days Table 5, accompanied with mucus production in some snails and there were also mould on dead snails in this treatment. Snails in the Vydate® treatment were sluggish, moving very slowly but regain rapid mobility from day 7. Most snails in the Potassium Nitrate containers were found buried deep in the soil found at the snail zone and aestivation was very common with this treatment.

Table-5. Percentage of snails dying as a result of the different treatments.

Treatment	Mortality (%)	
	After 7 days	After 14 days
T1 (Untreated control)	0	0
T2 (Bromorex®)	0	0
T3 (Potassium Nitrate)	0	5
T4 (Vydate®)	17	44
T5 (Limace®)	37	100

3.2. Snail Mortality in the Field

Limace® treated plants had the lowest mean number of snails counted on the corm and pseudostem during the 12-week period while the Control (untreated) and Bromorex® treated plants had the highest mean value Figure 3. Generally, as shown in Figure 3 there were more living snails on plants treated with Bromorex® and the Control.

The highest mean number of living snails was recorded from the Control) (2.67snails/plant). Although the mean number of living snails was relatively low for Potassium Nitrate, Vydate® and Limace® from the 1st to the 9th week after application of the treatment, the numbers increased from the 10th week albeit less than 1 snail/plant Figure 3.

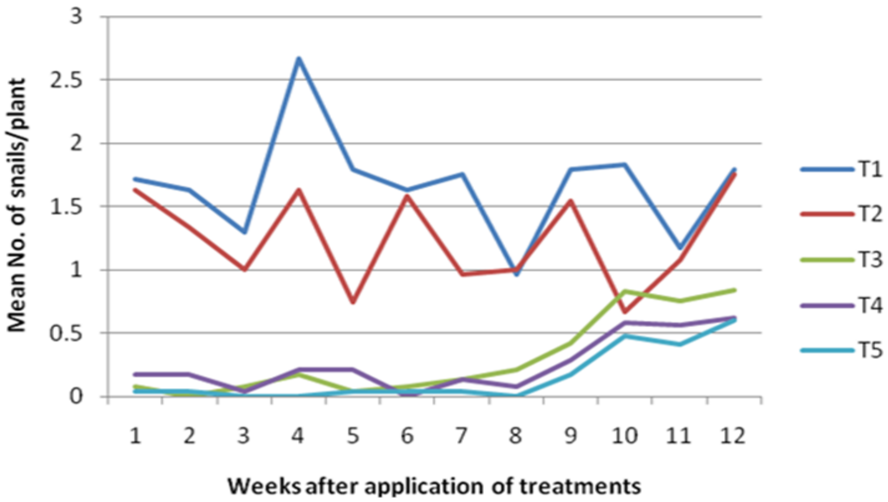

Figure-3. Mean number of living snails during a period of 12 weeks after application of treaments.
Note : T1= Untreated control, T2= Bromorex®, T3= Potassium Nitrate, T4= Vydate®, T5 = Limace®

The number of dead snails was relatively higher in the Limace® and Vydate® treatments (with means of 1.6 snails/plant and 1.08 snails/plant respectively) during the first three weeks Figure 4. From the 5th week after application of the treatments, the mean numbers dropped in all treatments and was less than 0.4 snail/plant Figure 4.

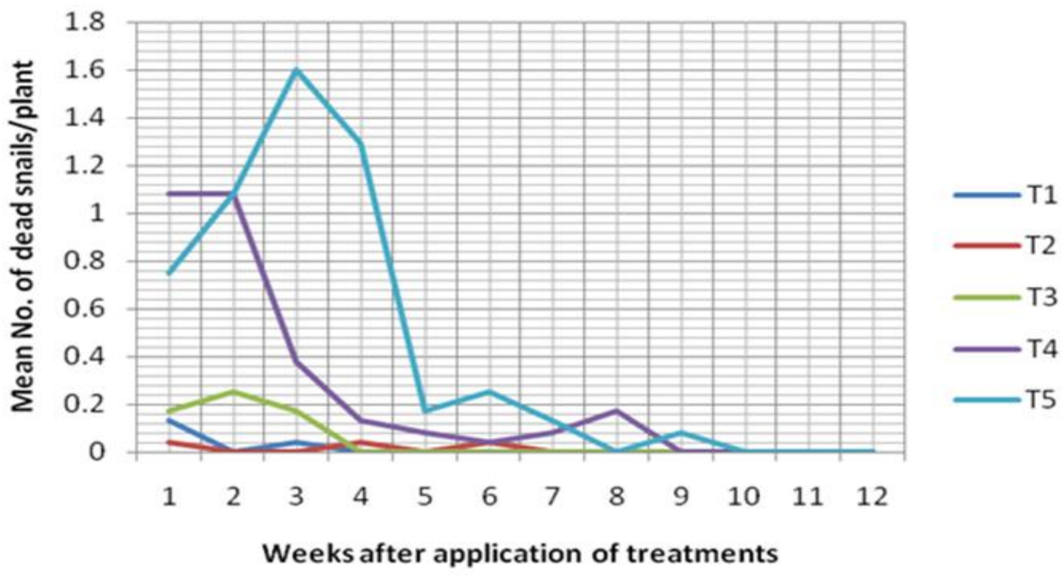

Figure-4. Mean number of dead snails during a period of 12 weeks after application of treatments.
Note: T1= Untreated control T2= Bromorex® T3=potassium nitrate T4= Vydate® T5 = Limace® in CDC Tiko Banana Plantation, Cameroon.

4. DISCUSSION

The application of pesticides (molluscicides) is today regarded as the most pragmatic approach to control terrestrial mollusc pests and there has been extensive research and development of these, although there is renewed interest in non-chemical approaches in response to concerns over adverse environmental effects (Barker & Watts, 2002). During this study, Limace® and Vydate® recorded very significant level of dead snails in the laboratory and within the first four weeks after application in the field. Asran, Fatma, Hashem, and Keshta (2011) in their study reported that after the seventh day from treatment application, mortality percentage reached up to (76%, 44% and 42%) at 0.5 concentrations, (80%, 66% and 54%) at 1% concentration and (88%, 70% and 68%) at 1.5% of concentration for Metaldehyde, Secnor and Oxamyl, respectively. Also the field trials proved that the highest toxic action against *Theba pisana* snails was Metaldehyde followed by Secnor and Oxamyl. The results proved that response of the experimental snails increased positively with increasing of the used concentration for all the tested compounds.

According to Jurry and Thomas (1998) reduced applications of metaldehyde pellets were effective in controlling gastropod pest. Other chemicals with possible molluscicidal effects include the nematicide Vydate® with active ingredient oxamyl. Vydate® is a broad spectrum insecticide/nematicide for the control of pests. Their active ingredient is oxamyl with a liquid formulation. Vydate® was used by Chabrier, Hubervic, and Quénéhervé (2005) to evaluate its efficacy against banana nematodes in Martinique especially *R. similis* and *Cosmopolites sordidus*. Insufficient control was seen for *Cosmopolites sordidus* and for *R. similis* temporary control was observed. Although we did not quantify, we observed that some snails in the Limace® container produced excess mucus when in contact with the chemical. Some synthetic molluscicides have also been shown an increased in mucus secretion as one of the first reactions of gastropods to many stressors, including mechanical stimuli or chemical irritation caused by molluscicidal chemicals (Barker & Watts, 2002; Godan, 1983; Triebskorn, 1989; Triebskorn & Ebert, 1989). This was also reported by Ebenso et al. (2005) who reported that at the concentration of 50 mg/mL within 24 h one snail extruded excess mucus and as the concentration increased to 400 and 500 mg/mL within the first 24 h, snails in their study began to swell around the anterior region. Triebskorn and Ebert (1989) reported that one of the main effects of the extruded mucus is to form a protective barrier preventing direct contact between the toxin and the epithelia of the skin or digestive tract, so reducing the toxicity of the chemicals.

Due to this protective barrier phenomenon from getting direct contact to the toxin, this turn to repel the snails from getting close to plants treated with Limace®, Vydate® and potassium nitrate. But if the snails gets in contact with Limace®, Vydate® and potassium nitrate the mortality percentage will increase.

Bromorex® an organic repellant made of mustard and Chilli vinegar used against insects did not show any positive report in this study. This may be as a result of low dosages apply on the snails or as a result of large molecular weight of the active ingredients. Barker and Watts (2002) reported that the mucus extruded on the body surface provides a significant barrier to uptake of pesticides of large molecular weight by molluscs active in treated environments. Both means of control depend on high application rates of active ingredient and they are more indiscriminate in their effects on fauna than bait formulations. Lindqvist, Lindqvist, and Tiilikkala (2010) used Birch tar oil, a new biological plant protection product against mollusks and they noticed that the application render the snail inactive for several months. But it was not toxic. The barrier was effective in repelling snails. The repellant effect on Birch tar oil when used alone was short term. This indicates that botanicals need to be mixed with other pesticides to increase the concentration or effect on snails.

Potassium nitrate (KNO_3) may kill snails or make their environmental conditions unsuitable for their life (El-Sayed, 2001; Ismail, 2009). Some researchers tried to cutoff the compatibility between *Schistosoma trematodes* and their intermediate hosts using molluscicides either chemical or natural materials, where molluscicides interrupt the life cycle of the parasite and help for eliminating the disease (Kader & El-Din, 2005). Potassium nitrate (KNO_3) showed no significant effect on snail mortality and number of snail/plant. This result is in line with Muir, Sutton, and Owens (1991) who reported that when $NaNO_3$ and KNO_3 were used as the nitrate source for *Penaeus monodon* larvae there were no significant differences in the mortality. This might be as a result of lack of contact of Potassium Nitrate (KNO_3) with water. This water can increase potassium ions (K^+) which might, at elevated levels, be highly toxic to organisms (Romano & Zeng, 2007).

5. CONCLUSION

Snails constitute a serious problem in banana production causing horticultural damages. The infestation is severe during heavy rains in June to October but this is not during dry season. Limace® and Vydate® were effective in the control of snails. Although mortality of snails was low in the Potassium Nitrate treatment, this agrochemical caused snails to aestivate in this study

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