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Water quality effects on organophosphate acaricidal efficacy against the *Rhipicephalus appendiculatus* ticks. A case of Glenlussa and Sunnyside, Zvimba East District, Mashonaland West Province, Zimbabwe

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Abstract

Cattle losses due to January disease caused by the vector, *Rhipicephalus appendiculatus*, which transmits *Theileria* parasite, is a major constraint to livestock productivity. Farmers in Glenlussa and Sunnyside rely on scarce water and mostly organophosphate based acaricides for the vector control. Tick persistence post-dipping using recommended dose sparked interest to investigate effect of water quality on organophosphate acaricidal activity against Brown-ear ticks. Water was analysed at EMA laboratories. Susceptible ticks were collected from Southern-side Lake Chivero Recreational Park. A RCBD was used with two factors, water and acaricide concentration, each at four levels, and treatments replicated in 3 blocks. Engorged adult female ticks were immersed for 30 minutes in serial dilutions at 25°C of organophosphate (3.75, 5, 5.75 and 6.25% m/v), with open-well, pond, weir + stream and borehole water. Ticks, incubated at 27°C and 80% RH to oviposition (7 days), had mortality recorded at varying post-exposure times. Results were analysed using Excel and SAS two-way analysis of variance (ANOVA). At 5% m/v recommended dose, July open-well water had highest mortality (73.3%) and no significant difference ($p>0.05$) in mortality observed among the four water sources. January borehole water recorded highest mortality (73%). Ca, Mg, NO3- and carbon waste effluent contributed to water hardness which, though not always, resulted in significant difference ($p<0.05$) in mortality, unlike with pH ($p>0.05$). LC99.9 was >6.25% m/v concentration. Water quality influenced organophosphate efficacy. The study suggested need to vary acaricide concentration with season for higher tick mortality.

Keywords: acaricide; January disease; pollution; susceptible; water quality

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1. Introduction

Parasites and diseases continue to impede growth of the livestock sector in Zimbabwe. The country recorded a 9 % mortality rate in the national beef herd in 2019 (MLAFWRR, 2020) and more than 50 000 cattle died of tick-borne disease in year 2018 (Colon, 2019). They are among the most severe factors that impact livestock production and productivity (Lamy et al., 2012). Majority of cattle owners in Africa are resource poor communal farmers (Sungirai et al., 2016) and their herds are frequently attacked by tick borne diseases. Highest number of cattle deaths recorded in Mashonaland West province in the same period have been attributed to theileriosis caused by the brown ear tick (*Rhipicephalus appendiculatus*) and is among the worst affected (MLAFWRR, 2020). Control of tick borne diseases in Zimbabwe is based primarily on the control of their vectors through dipping using spray solutions. The spread and increase in the number of the *R. appendiculatus* and theileriosis cases is generally attributed to shortage of acaricides and drugs. According to FAO (2004) some tick species are becoming resistant to organophosphates.

Efficacy of an organophosphate against different tick species is greatly influenced by operational, genetic and biological factors. These include under dosing, overdosing and frequent exposure of ticks to an acaricide (Rodríguez-Molano, Torres and Monrroy, 2020). Organophosphates have been reported to have strong stripping effect that is gradual and continuous. This is due to change in volume of dip solution and higher solubility of organophosphate to lipids in the hair coat (Janquera, 2014).

Chemical industry, the dairy sector and other industries make use of large volumes of water. Their effluent discharge has contributed to groundwater quality degradation (Murwira et al., 2014). Most farmers use polluted water to replenish dip tanks which could affect the efficacy of acaricides. Scientific research carried out in fields of crop protection and weed science indicate that quality of water influence performance of herbicides and insecticides (Tharp and Sigier, 2013). Most of these crop protection chemicals for example have been found to work best at limited pH levels ranging from 4-7 and in water whose hardness does not exceed 150 parts per million (Whitford, 2009). Crop based organophosphates are more sensitive to alkaline hydrolysis (Fukuto, 1990), and this reduces their solubility. Soil sorption coefficient (Kd) and soil organic carbon sorption coefficient (Koc) indexes reflect how strongly pesticides adsorb to soil and other particles suspended in water.

Zimbabwe is a semi-arid country, with water that is unevenly distributed both in time and space (Davis and Hirji, 2014), consequently that has influenced quality of water available for both human and livestock consumption. Scarcity of safe water has resulted in the utilisation of waste water for livestock production and is related to the emergency of dangerous animal diseases hampering productivity and increased economic losses, (Elahi et al., 2017). Testing of water which should be done regularly (ADE, 2019) is mostly restricted to borehole water meant for human consumption and is done at certified labs. Water for dip tank use is usually perceived to be clean merely by considering its physical appeal. Manufacturers provide a blanket dosage rate of acaricides for dipping though water quality differs with season and anthropogenic related influences.

Tick persistence soon after dipping has been noted with concern and 11 percent mortality rate of cattle due to January disease was recorded in Glenlussa and Sunnyside area in the 2019/20 season (AGRITEX reports, 2021). These were confirmed deaths from post mortems done by the Veterinary department. Nationwide, a 9 percent mortality rate in the national beef herd in 2019 was reported (MLAWRR, 2020). Therefore, in view of this, a deliberate investigation on effects of water quality on organophosphate acaricidal activity against the *R. appendiculatus* was determined.

2. Water samples collection and analysis

Water sources were identified in the area of study and categorised as borehole water, stream + weir, pond and open well water. Environmental Management Agency Laboratory sampling procedures were adhered to for water tests. For borehole water, the borehole was run 2-3 minutes early in the morning to get a sample from the mainline using a sterilised plastic container. Stream + weir, pond and open well water was collected at depths of 15 cm below the surface water as described by Rasolofomanana, (2009), near centre, ±1-50 metres from the edges depending with the water source. Random sampling was done from each water source category. Samples from each source were collected once per season in two different seasons and in triplicates in January 2021 during peak rains and in July 2021 prior to rains.

Twenty-four (24) water samples were collected and stored in a refrigerator at 4 ºC prior to analysis at EMA laboratory. The AIT-DD procedure suggested by FAO (2004) was adopted and a modification done to determine if water quality affects the activity of an organophosphate acaricide on the brown ear tick. The chemical analysis method was used to determine water quality. The samples were analysed for pH, turbidity, ions such as nitrates (NO_3^{2-}), phosphates (PO_4^{3-}), iron (Fe), calcium (Ca) and magnesium (Mg) and total hardness. To determine water chemical composition from selected water sources, EMA standards which is SADCAS accredited, and ZAS standards were adopted. Laboratory chemical analysis method used to test for calcium and magnesium levels was the Titrimetric SOP/CMO4. These ions largely contribute to total hardness and to a lesser extent manganese and iron. Titrimetric SOP/CM36 test for total hardness was adopted. Spectrophotometric SOP/CM23 and SOP/CM28 were used to test for nitrates and phosphates. Electrode SOP/CM27 tested for pH in the water samples and Nepholometric SOP/CM39 for turbidity. The sampling stations were identified using the global positioning system (GPS) for easy identification.

2.1 Tick sample collection

A total of 500 adult engorged ticks were collected from cattle at various points and transported in a cardboard box container with perforations for tick identification and preparation at the Chinese Agricultural Technology Demonstration Centre (CATDC) at Gwebi College of Agriculture. Engorged adult ticks were collected early morning 3 to 8 days or 14 to 17 days after dipping for weekly dipping in summer and fortnightly in winter, respectively. Collected tick samples were put in a refrigerator at 4 ^{o}C for up to 5 days before the experiment. The period allowed for collection of sufficient number of ticks for the experiment. When macrocyclic lactones are used collection of the ticks is after 3 days from treatment as stated by Rodriguez-Vivas et al. (2018). Adult female engorged ticks in 150 mm glass tubes were put in an incubator at 27 ^{0}C and a relative humidity within the range 85- 95 % for a period of 1-2 days. Ticks that had laid eggs pre- and post-treatment were discarded.

2.2 Organophosphate acaricide

A commercially available organophosphate acaricide used in the study area was picked for use in the experiment. The acaricide was tested at different concentrations that is 3.75 % m/v (lower dose), 5% m/v (recommended dose), 5.75% m/v and 6.25 % m/v (above recommended dose). The mechanism of action of organophosphate involves inhibition of acetylcholinesterase activity irreversibly at synapse junction to produce continuous nerve discharges that lead to paralysis and death (Rodríguez-Molano et al., 2020). Susceptible ticks die within 24 hours post application of the acaricide (Yegon, 2019). The acaricide was applied by immersing the ticks for 30 minutes. The activity of the acaricide was analysed at 4, 8, 12 and 24 hours after application in three replicates.

3. Study design and treatments

A 2x2 factorial design was used with acaricide and water as factors, each at 4 levels, laid in a Completely Randomised Design. The acaricide was coded A and tested at 75%, 100%, 115% and 125% levels of strength of the 5% m/v concentration value recommended while the water samples were also coded W with W1 being borehole water, W2 stream + weir, W3 pond water, and W4 open well water. Total number of treatments was 16 replicated three times to give a total of 48 plots with 10 ticks in each replicate. The treatments were tested against adult female engorged forms of the brown ear ticks.

Sampling containers for 24 samples of borehole, weir + stream, pond and open well water collection were prepared using the acid wash procedure (USEPA, 2012). Sample bottles were washed brushing with a phosphate free detergent and rinsed thrice with cold tap water. 10% hydrochloric acid (HCl) was used for rinsing the bottle and finally rinsed with de-ionised water three times. Bottles with a lid were labelled to indicate sampling site, date and time of sampling.

The experiments involved assessing efficacy of the organophosphate acaricide at two different times of the year: Summer (water collected in month of January) and winter (water collected in month of July). Adult engorged brown ear ticks mortality at 3.75, 5, 5.75 and 6.25 % m/v aqueous solution of organophosphate and borehole, weir + stream, pond and open well water was tested in each case.

3.1 Data Analysis

Data entries were done in Excel package and cleaned. Data on mortality of adult engorged brown ear ticks and larvae were exported to Statistical Analysis System (SAS) statistical package for analysis. Mortality data on ticks was converted to ranks through the Proc. Frequency and Proc. Rank procedures. Analysis of data was done using the Proc. GLM and SGPlot procedures of SAS.

4 Results and discussion

Water quality analysis: Laboratory chemical water analysis from open well, ponds, weir + stream and borehole water sources showed varying levels of cations (Ca, Fe, P and Mg), anions (NO_3^-, SO_4^{2-}), pH, total hardness and turbidity. The analysis done at EMA Zimbabwe laboratory indicated that water hardness was highest for pond water and lowest for borehole water for the January collection, Table 1.

Table 1. Chemical analysis of water samples collected in January vs July 2021

Parameter	Mon	**Ca** (mg/l Ca)	**Fe** (mg/l Fe)	**Mg** (mg/l Mg)	**NO_3^-** (mg/l N)	**pH**	**P** (mg/l P)	**SO_4^{2-}** (mg/l SO4)	**Total Hardness** (mg/l $CaCO_3$)	**Turbidity** (NTU)	**Band Class**
Open well	Jan	30.5	0.18	45.3	1.67	7.65	0.32	19	263	340	Green
	Jul	31.7	<0.01	26.63	2.14	6.73	<0.01	25	189	0.14	Green
Ponds	Jan	37.0	3.5	53.72	0.64	6.93	0.54	4	313	164	Yellow
	Jul	39.5	<0.01	40.7	1.16	6.72	<0.01	11	340	6.89	Red
Weir+Stream	Jan	21.6	2.6	52.6	570.1	7.12	0.26	89	270	676	Red
	Jul	23.9	1.12	45.8	1.21	6.92	<0.01	14	216	104	Red
Borehole	Jan	37.6	0.2	30.33	6.47	7.46	0.11	6	219	2.32	Blue
	Jul	45.5	0.35	22.25	20.03	7	<0.01	7	205	0.12	Green

Classification of water samples using band classes was done using EMA and SAZS standards.

NTU: Nephelometric Turbidity Units; mg/l: mg/l: milligrams per liter

On the July water collections, pond water showed an increase in water hardness while borehole water at neutral pH showed a decline in water hardness. Four band classes (green, yellow, red and blue) suggested by EMA Effluent and Solid Waste Disposal Regulations of 2007 were observed (Environmental and Management Authority (EMA), 2021). Borehole and pond water quality changed from blue to green band and yellow to red band respectively with change in season (January - August). Weir + Stream and open well maintained the red and green bands, respectively. Band classes yellow and red is unsafe water indicating contamination and not within safe limits for drinking. Blue and green bands show safe water for use.

The tests indicate that water quality changes overtime for example, nitrate level in weir +stream water declining from 570.1 mg/l N during peak rains to 1.21 mg/l in the dry season. Borehole and pond water quality attained green and red bands from blue and yellow, respectively. Water quality is very important as it can negatively affect production by binding pesticides interfering with their solubility and increased risk of disease spread in animal husbandry (Ikaya and Arimoro, 2024).

Turbidity levels were high in summer due to run-off and soil loosening falling to low levels in winter. Turbidity determines the amount of suspended solids in water such as minerals or organic matter for example, soil particles and algae and is analysed using amount of light scattered in water. More suspended particles cause greater scattering hence high turbidity value. It is influenced by heavy rains leading to erosion. Algae growth and bacterial degradation of organics in water also give rise to high turbidity values (NTU) (Rasolofomanana, 2009). Iron levels increased from 0.2 to 0.35 in borehole water. This can suggest human influence of fertiliser application and systems interaction to balance nature as water plants absorb the nitrates. Changes in water table level could be a contributing factor to the variation in quality between summer and winter seasons.

Effects of seasonal water quality on tick mortality

The study analysed differences in tick mortality due to variation in quality of water collected in January and July 2021. Open well and borehole water collected in the month of January 2021 showed highest mortality, and for both months January and July, pond water had the least mortality at 6.25 % m/v, Figure 1.

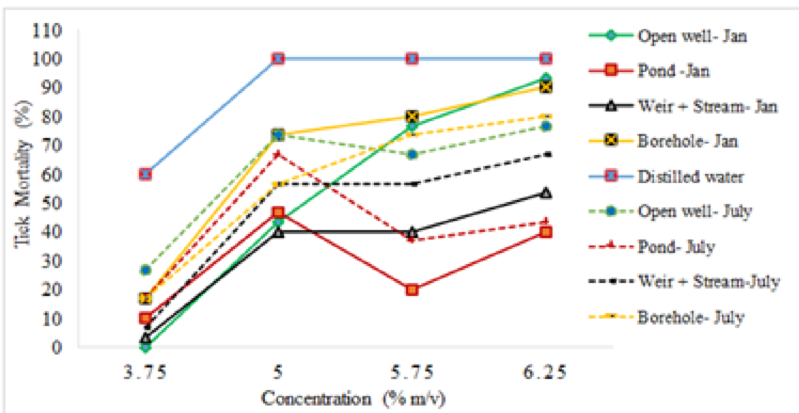

Figure 1. Comparison of tick mortality at different seasonal water qualities

Water drawn in summer from open well and borehole water sources recorded highest mortalities of 93% and 90% respectively at 6.25% m/v concentration to indicate that the acaricide was more effective. At the same concentration of 6.25% m/v, pond water collected in January and July months recorded lowest mortalities of 40% and 43.3 %, respectively, compared with other water samples from different water source categories and month period. Increased concentration rate from 3.75% to 5% resulted in sharp increase in tick mortality in both seasons. Rate of increase in tick mortality fell on increasing the concentration rate above the 5% recommendation to 5.75% m/v concentration.

The findings of the study suggested the need to increase concentration levels of the acaricide to above 6.25% during winter for effective tick control, which is a 100% tick mortality at the least concentration (LC99.9). In summer open well and borehole water provided better results in tick mortality ($\geqslant$ 90%) at 6.25% m/v. Thus, the 6.25% m/v dose can be used for tick control with reduction in dipping intervals to kill ticks that will have survived the acaricide. The 5.75 % is risky and costly dose when used by farmers to control ticks in winter due to more money spent and time to treat disease affected animals which when they fail to recover, high mortalities are experienced. Higher doses in winter (> 6.25% m/v) should be aimed at to kill sufficient number of ticks and avoid their multiplication at faster rate. If not so the dipping intervals of two weeks which are long can result in higher tick infestations as observed in the study surviving ticks laying numerous number of eggs capable of hatching.

Brown–ear tick mortalities in aqueous solution of organophosphate acaricide and water collected in January summer and winter at different time intervals

Only borehole and distilled water had some mortalities after 4 hours of exposure, Figure 2. Open well water recorded zero mortality of *R. appendiculatus* at 3.75% m/v concentration while weir + stream water had 3% mortality followed by pond with 10 % and borehole water 17% mortality, Figure 2.

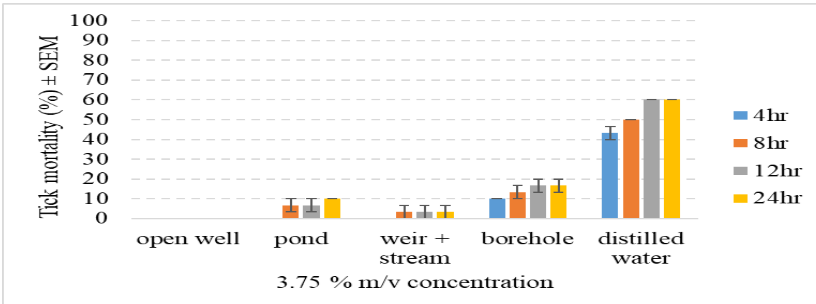

Figure 2. Mortality of Brown-ear ticks at 3.75 % m/v concentration at various time intervals

Control experiment had the highest cumulative mortality of 60 % at 12 hours after tick exposure to acaricide. Increased tick activity was observed at the lower concentration of organophosphate based acaricide in treatments.

Acaricide performance at 3.75% m/v dose against engorged adult female ticks. Under application of acaricide than the recommended dose resulted in less than 20% mortality in ticks using open well, ponds, weir + stream and borehole water. While the dose factor can contribute to tick mortality in Glenlussa and Sunnyside, water quality also has an impact on tick mortality as observed in the study. Under application could be caused by poor resource availability and lack of understanding of calibrations. Low dose application influence efficacy of an acaricide as has been found in previous studies done by Rodríguez-Molano, Torres and Monrroy, (2020). This could be the reason for the current challenge being faced of tick persistence soon after dipping in study area. Influence of water quality was further determined at correct dose (5 % m/v) and doses above the recommended dilution ratio.

Control treatment had highest cumulative mortality of 100 % followed by borehole water treatment with 73 % mortality, Figure 3.

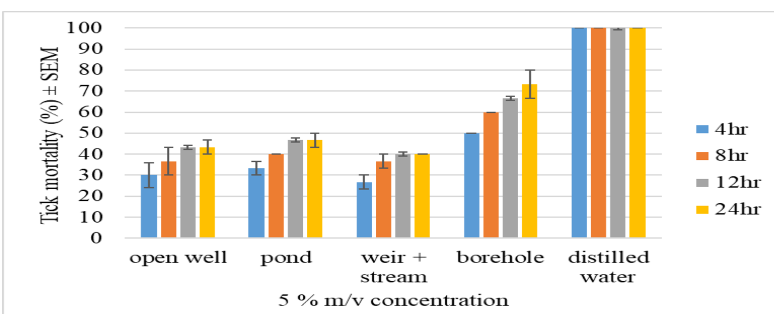

Figure 3. Mortality of Brown-ear ticks at 5 % m/v concentration with varying exposure time

However, there was no significant difference ($p > 0.05$) in cumulative mortality among open well, pond and weir + stream water treatments at the prescribed dose of 5% m/v concentration. Tick mortalities were below 50%.

Acaricide performance at 5 % m/v dose against engorged adult female ticks. The low tick mortalities were attributed to a change in water quality. During peak rains, water movement downslope led to sediment accumulation in weir + stream and pond water from tilled agricultural land within proximity distance of ±1 kilometre. The land was also fertilised with nitrate, sulphate, potash and potassium based fertilisers. Soil loosening from open well wall due to rise in water table level resulted in soil accumulation in the water source. A turbidity value of 676 NTU (Table 1) of weir + stream water and the red band class indicated sediment collection in the water source. Apart from tillage, soil mining in the study area gave the water its characteristic opaque colour. High adsorption of soil particles on the organophosphate led to reduced efficacy of the acaricide which confirms studies by Whitford (2009). The 5% m/v concentration was the least concentration required to kill 50% (LC50) of the *R. appendiculatus* using borehole water.

With increased concentration rate to 5.75 % cumulative mortality in open well treatment increased to 77 %, declined to 20 % in pond water, a change in solubility of the acaricide, and remained at 40 % in weir + stream and less significantly in borehole water, Figure 4.

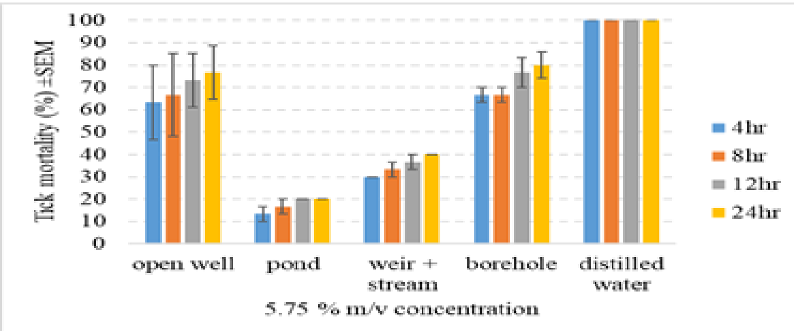

Figure 4. Mortality of Brown-ear ticks at 5.75 % m/v concentration with varying exposure time

Acaricide performance at 5.75 % m/v dose against engorged adult female ticks. Concentration of 5.75 % m/v became the LC50 for the R. appendiculatus using open well, borehole water and distilled water. At this concentration of the organophosphate solution, low tick mortality would continue to be observed at Glenlussa and Sunnyside leading to high tick infestations and possible built of tick acaricide resistance to the acaricide.

At 6.25% m/v concentration the control experiment maintained its highest mortality with open well having a 93% mortality, Figure 5. Subsequently, pond, weir + stream and borehole water recorded an increase in cumulative mortality at all levels of time intervals with the increased concentration. Mortality between open well and borehole was not significantly different ($p > 0.05$) as between pond and weir + stream but significant ($p < 0.05$) between the pair treatments.

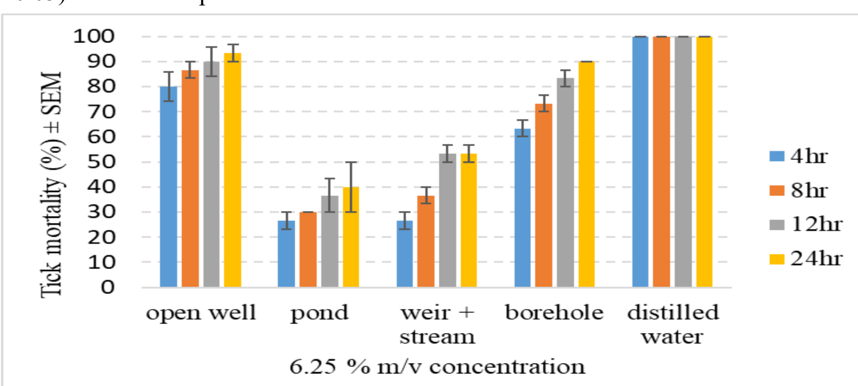

Figure 5. Mortality of Brown-ear ticks at 6.25% m/v concentration with varying exposure time

Acaricide performance at 6.25% m/v dose against engorged adult female ticks. Pond and weir + stream are more open sources of water that have direct contamination from non-point sources of pollution. Increasing the concentration rate would not bring significant change in mortality of ticks. Thus, increasing the concentration further than the suggested would contribute to tick resistance or an improved tick mortality but with a cost implication to burden the low resourced farmers who would otherwise skip dipping and prolong the dipping interval not recognising the recommended weekly summer dipping.

Brown –ear tick mortalities in aqueous solution of organophosphate acaricide and water collected in the month of July. At the lowest concentration level of 3.75% m/v, *R. appendiculatus* ticks were observed to have increased activity as seen by increased locomotion, stretching of legs and a rhythmic body movement due to breathing. Cumulative mortality recorded in open well, pond, weir + stream and borehole was below 27% and at 60% in control experiment, Figure 6.

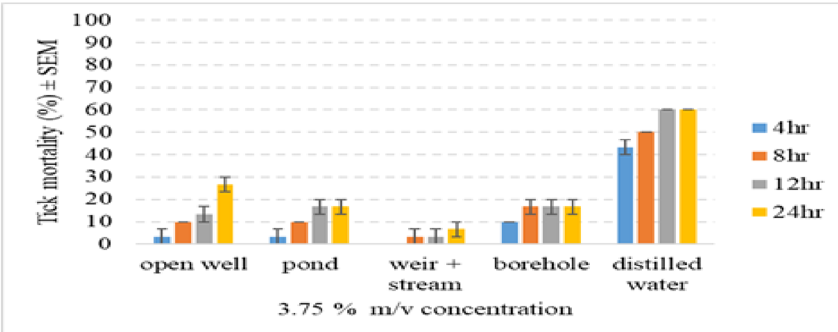

Figure 6. Mortality of Brown -ear ticks at 3.75% m/v concentration

Acaricide performance at 3.75% m/v dose against engorged adult female ticks. Recorded mortality in open well treatment suggested a change in water quality from peak rains into dry season. Table 2 shows July falling levels of turbidity and water hardness compared to water samples collected in January, Table 1. However, band class red is not reflective of an improvement in water quality and it is attributed to source which are pond and weir + stream. The low concentration (3.75% m/v), though some positive change in mortality noticed, remained a factor causing the low mortality in tick.

Acaricide performance at 5% m/v dose against engorged adult female ticks. Cumulative mortality of *R. appendiculatus* in the range 50 to 75% was observed in open well, pond, weir + stream and borehole water treatments at 5% m/v concentration with no significant difference ($p > 0.05$) in mortality from all water samples, Figure 7.

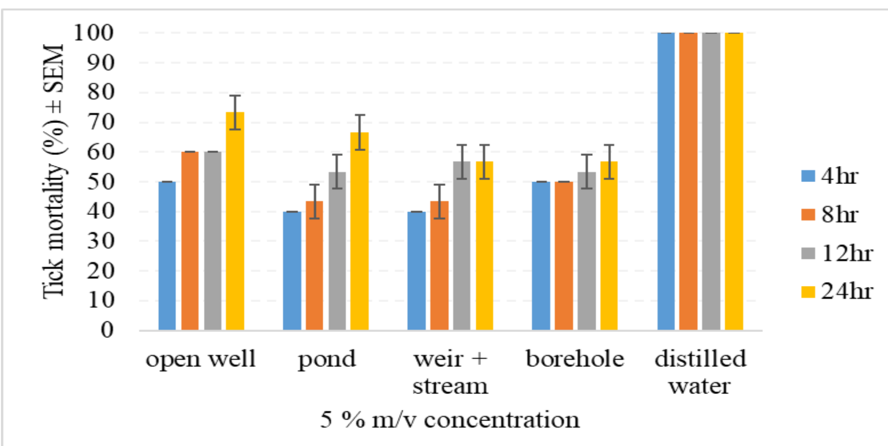

Figure 7. Mortality of Brown-ear ticks at 5% m/v concentration

A ±20% increase in mean mortality from water samples of open well, pond and weir + stream was observed. At 5% m/v concentration, the study showed that the dose is lethal to more than 50% of engorged female adult ticks. The control treatment was lethal to 100% of the ticks. The least concentration lethal (LC 99.9) of the first four water samples (Figure 7), to all sample ticks fell out of the range 3.75– 6.25 % m/v and could not be established. Borehole water table level during the dry season fell to low point with calcium and nitrate levels increasing to 45.5 mg/l Ca and 20.03 mg/l N. Calcium is the major contributor to water hardness. Associate effect or calcium interaction with nitrates and other ions could have caused temporary hardness of water. Engorged female ticks could also have metabolised quickly the acaricide as survival mechanism.

Acaricide performance at 5.75% m/v dose against engorged adult female ticks. At 5.75% m/v acaricide concentration, open well and pond water treatment had a decline in mean mortality at all the time intervals (4 hr, 8 hr, 12 hr, 24 hr), Figure 8. Open well water treatment was also observed to have a reduction in tick mortality at the 8th and 24th hour.

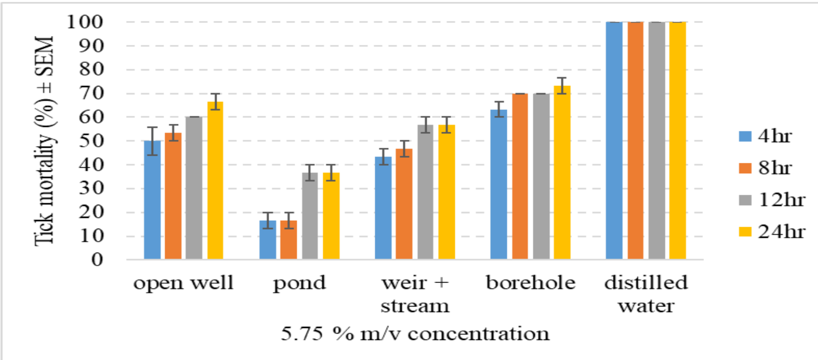

Figure 8. Mortality of Brown-ear ticks at 5.75% m/v concentration

Increase in water hardness to a level of 340 mg/l $CaCO_3$ of pond water would have resulted in low tick mortality due to partial solubility of the organophosphate acaricide. Presence of other parameters Fe, NO_3^-, P and SO_4^{2-} from pig waste during the dry period could have influenced activity of the organophosphate against tick mortality. Organic waste interfered with the acaricide through adsorbing on its surface. Carbon waste reduced efficacy of the acaricide by making the solution weaker.

Acaricide performance at 6.25% m/v dose against engorged adult female ticks. As mean mortality in pond water treatment increased to 43.3% from 36.6% at 6.25% m/v and 5.75% m/v respectively there was no significant difference in mortality observed at 6.25% m/v concentration, Figure 9.

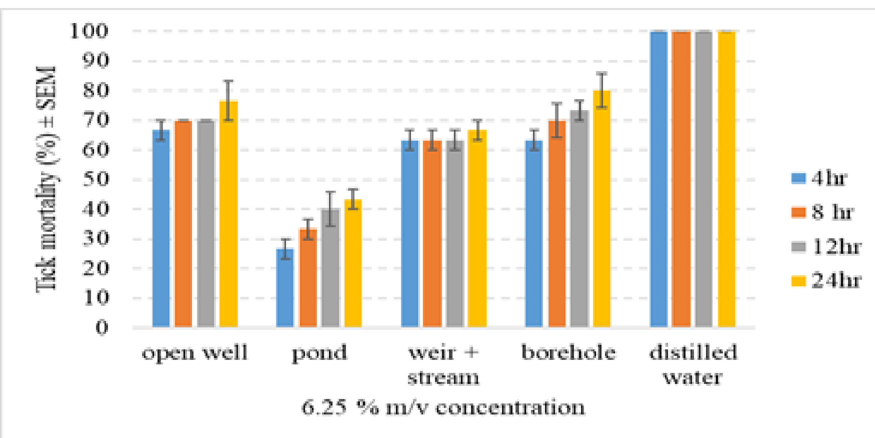

Figure 9. Mortality of Brown-ear ticks at 6.25% m/v concentration

At the highest concentration level of 6.25% m/v, 100% mortality was not achieved from open well, ponds, weir + stream and borehole water treatments. The control experiment achieved complete mortality of susceptible ticks using distilled water.

Tick mortality after exposure to organophosphate–based acaricide at varying water pH. At pH 6.93 lowest group mean mortality of 18.3% at 4 hours was observed, Figure 10.

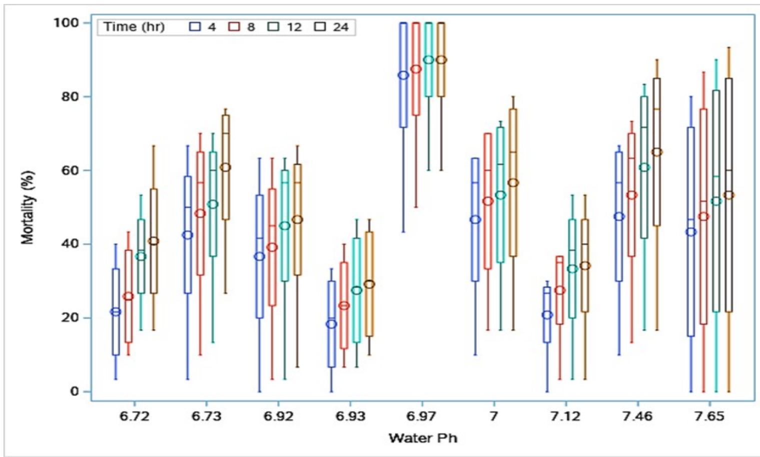

Figure 10. Mortality at varying water pH and exposure times

The control experiment with susceptible tick species and distilled water had highest group means of mortality (100%) in all the time intervals at pH 6.97. This was followed by mortality of 20.8% and 21.7% at pH 7.12 and 6.72, respectively. Below the neutral point mortality is rising and falling and also above the neutral pH scale it follows the same trend. The treatments were subjected to 3.75% m/v, 5% m/v, 5.75% m/v and 6.25% m/v concentrations. The least and maximum observed values from box plot correspond to mortalities at 3.75% m/v and 6.25% m/v concentrations, respectively. Mortalities at 5% m/v and 5.75% m/v were within the group minimum and maximum values range. The treatments were subjected to two way SAS ANOVA with mortality percentage, varying time intervals and pH levels as the factors. There were no significant differences ($p > 0.05$) in mortality due to pH variation. This suggested that the water quality was within the normal pH levels for best results of agricultural chemicals as found by Tharp and Sigier (2013) in their previous study.

Tick mortality after exposure to organophosphate–based acaricide at varying water hardness.

The control experiment, had the highest mortality, group median above 80% and upper quartile of 100% at 4, 8, 12 and 24-hour time intervals at water hardness level of 0 ml/L $CaCO_3$, Figure 11.

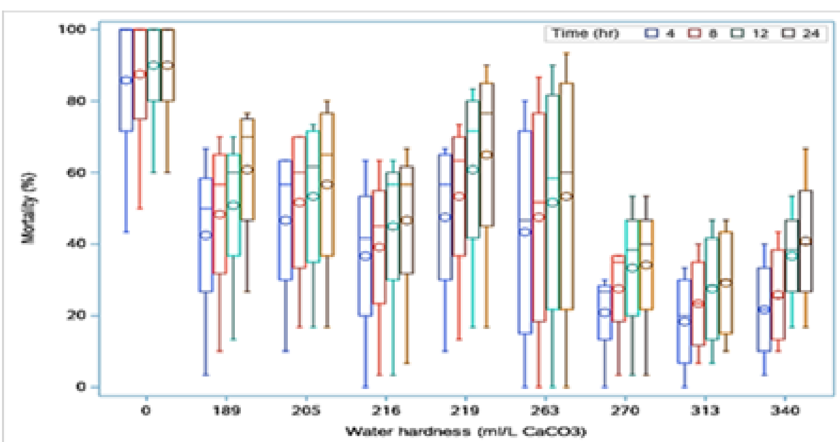

Figure 11. Mortality at varying water hardness and exposure times

There was a subsequent decline in cumulative mortality with increase in water hardness (189-340 ml/L $CaCO_3$) from the open well, pond, weir + stream and borehole water samples collected and subjected to 3.75% m/v, 5% m/v, 5.75% m/v and 6.25% m/v concentrations. Water hardness of 313 ml/L had the least group mortality. Mean group mortality were significantly different ($p < 0.05$). Change in water volume from one source to another could be the manipulating factor influencing the presence of calcium, magnesium and other ions causing water hardness.

The study analysed differences in tick mortality due to variation in quality of water collected in January and July

2021. Open well and borehole water collected in the month

5. Conclusion

Differences in water quality from various sources found in Glenlussa and Sunnyside area were found to affect efficacy of the organophosphate acaricide against the Brown ear ticks. Water quality vary with season and its deterioration require over application of the acaricide to maintain desired higher levels of tick mortality. Varying water hardness caused differences in tick mortalities while pH had no effect. Borehole water and open well water provided better quality water compared to pond and weir + stream water. Tick survival at higher concentration than the normal dose suggested some form of resistance of the tick to the organophosphate acaricide. The study recommends community support by drilling boreholes to provide safe water for use in livestock production. Pond water and weir + stream water should be avoided as they provided contaminated water influencing the efficacy of the acaricide. In winter months, doses of the organophosphate should be above the maximum concentration used in the study for open well and borehole water. Further research needs to be done to determine the level of the *R. appendiculatus* tick resistance to organophosphate acaricide in use.

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