

Susceptibility of Different Species of Ticks (Acari: Ixodidae) to an Entomopathogenic Fungus in Tanzania

Never Zekeya^{1,2,*}, Ernest R Mbega², and Humphrey Ndossi¹

¹Tanzania Industrial Research and Development Organization (TIRDO), Dar es salaam, Tanzania

²Department of Sustainable Agriculture and Biodiversity Ecosystem Management, School of Life Science and Bioengineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

*Corresponding author: Never Zekeya, Department of Sustainable Agriculture and Biodiversity Ecosystem Management, School of Life Science and Bioengineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania, E-mail: nmwambela@yahoo.com

Received: 08 May, 2020 | Accepted: 27 May, 2020 | Published: 06 Jun, 2020

Citation: Zekeya N, Mbega ER, Ndossi H (2020) Susceptibility of Different Species of Ticks (Acari: Ixodidae) to an Entomopathogenic Fungus in Tanzania. J Anim Sci Res 4(2): dx.doi.org/10.16966/2576-6457.139

Copyright: © 2020 Zekeya N, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Ticks and tick-borne disease cause severe skin damage on livestock as well as wildlife mortifying animal health and byproduct for processing and tourism industries. Management of ticks by conventional acaricidal is environmentally and economically unaffordable in Tanzania. This study evaluated the effectiveness of a novel entomopathogenic fungi *Aspergillus oryzae* (TZ/P/2018/000035) against three species of ticks (Acari: Ixodidae); *Rhipicephalus appendiculatus*, *Hyalomma anatolicum* and *Amblyomma gemma* by spraying 0.2 mL/tick of 1×10^6 , 1×10^7 , 1×10^8 conidia/mL of *A. oryzae* and control (water and 0.5% triton x-100) in 35.5°C and 85% RH repeated at 20.5°C and 70% RH in the laboratory conditions at Nelson Mandela African Institution of Science and Technology, Arusha. Results showed that at 1×10^8 conidia/mL, *A. oryzae* caused high mortality rate averaging 88.2%, 72.5% and 67.9% within 6.25 ± 0.75 days, 7.55 ± 0.59 days and 11.9 ± 0.65 days in *H. anatolicum*, *R. appendiculatus* and *A. gemma* respectively, whereas in control the highest mortality rate reached 12.5%, 11.0% and 6.5% after 22.50 ± 1.2, 24.6 ± 0.9 and 28 ± 2.9 days in *R. appendiculatus*, *H. anatolicum* and *A. gemma* respectively at 20.5°C and 70% RH. It was also revealed that at 1×10^8 conidia/mL of *A. oryzae* reduced oviposition rate in *A. gemma* whereby 94.8 ± 10.74 eggs/female were laid compared to control that laid 354.15 ± 42.65 egg/female. Again, eggs averaging 166.20 ± 7.5 eggs/female were laid in *H. anatolicum* treated with *A. oryzae* at 1.0×10^8 conidia/mL compared to control that laid eggs averaging 416.25 ± 21.71/female in cold. This study revealed that *A. oryzae* was effective for control of ticks could be applied in agricultural fields to protect animal from tick's damage consequently improving animal products in processing industry in Tanzania.

Keywords: Animal Health; *Aspergillus oryzae*; Entomopathogenic fungi; Hides and skin damage; Tick diseases; Tanzania

Introduction

The occurrence and diversity of ticks' species and associated predicaments affect animal husbandry, wildlife and allied industry in Africa [1-3]. Hard ticks are reported as key parasites of cattle, goat and sheep causing high economic loss in Africa including Tanzania [4-6]. The most common and serious ticks of East Africa are *Amblyomma gemma*, *Rhipicephalus appendiculatus* and *Hyalomma anatolicum* affecting both domesticated and wild animals [7,8]. They affect animal health by direct parasitism and transmission of Tick Borne Diseases (TBDs) leading to low quality of animal products including milk, meat poor hides and skins due to lesion hindering utilization of animal products in industries [7,9-12]. The impact of hard ticks on skins is noticeably as they puncture direct through sucking blood leaving the skin wounded making hides unsuitable for tannery industry in Africa [12-14]. The deprived and reject hides and skins by tanning industry lower manufacturing capability and exportation

of leather products affecting economy of the country [15-17]. Impacts of ticks do not end on large mammals but also small ruminant and birds including ostrich leading to severe skin damage and loss [13,18-21]. However, poor animal keeping and grazing method such as free range landraces especially in pastoralist communities have been reported to amplify the problem in Africa including Tanzania [22-24]. The hard ticks especially the *A. gemma* and *R. appendiculatus* are the main cause of skins and hides damage in Africa [25,26] whereas *H. marginatum* infest bird skin as well. The overall effect of tick on animals and birds lead to downgrading of hides and skins and finally rejection by processing industries [16,15]. In Somalia and Ethiopia for instance, Ticks and Tick-Borne Diseases (TTBDs) have been reported to have high impact on tannery industry leading to sluggish in leather industry [27-29].

Management of ticks has been solely based on chemicals through spray and dipping of animals in chemical such as organophosphate

and organochlorine where resistance has been reported as well as negative impact to animals and environment [30-32]. Several studies have conducted is searching for new acaricidal compound for effective control of tick [33]. However, use of alternative methods such as botanicals and biocontrols has been reported to improve the quality of animal skin [18,31]. A study by Kalala W, et al. [34] reported the potential of *Commiphora swynnertonii* on control of tick in Tanzania. Other studies reported the effect of entomopathogenic fungi such as *Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium salliotae* and *Lecanicillium lecanii* against ticks [35-40] whereas *A. oryzae* has been reported to be effective against Camel tick eggs [41]. However, none of the study reported the acaricidal activity of *Aspergillus oryzae* on three deadly species of ticks namely; *Amblyomma gemma*, *Rhipicephalus appendiculatus* and *Hyalomma anatolicum* (Korch, 1844) in Tanzania. It is in this vein that new isolates of *A. oryzae* was screened for its efficacy against three species of ticks in Tanzania.

Material and Methods

Collection of ticks and identification

Ticks were collected at Oldoinyo was village in Arusha region and identification by the Tropical Pesticides Research Institute (TPRI) in which three species namely as *Amblyomma gemma*, the biggest female tick, *Rhipicephalus appendiculatus* and *Hyalomma marginatum* were identified. Fungal isolate; *Aspergillus oryzae* (TZ/P/2018/000035) previously isolated for management of *Tuta absoluta* was offered by Plant Biodefender Limited, Moshi-Tanzania

Preparation of *A. oryzae* concentration

Working concentration were prepared and selected based on [42] methods. Fungal isolate was sub-cultured on Potato Dextrose Agar (PDA) in Petri dishes to confirm its viability. After 5 days of full maturation, spores were gently scrapped from the media by suspending into 10 mL sterile distilled water with 0.1% Triton X-100 per Petri dish to make a stock suspension. After mixing suspension in a flask, the concentration of stock solution was accessed by a haemocytometer Neubauer (Manfield, German) that was 1.1×10^9 conidia/mL which was further diluted to get working concentrations of 1.0×10^6 conidia/mL, 1.0×10^7 conidia/mL and 1.0×10^8 conidia/mL by the addition of sterile distilled water.

Acaricidal activity of *A. oryzae* on adult ticks

Twenty ticks, ten (10) engorged female and (10) male adults' ticks with an average weight of (2.62 ± 0.60 g) *A. gemma*, (1.5 ± 0.27 g) *R. appendiculatus* and (0.9 ± 0.25 g) *H. anatolicum* were sprayed by 0.5 ml containing 1×10^7 and 1×10^8 conidia/mL of *A. oryzae* and control (containing water and 0.5% triton X-100). Treated ticks were placed in plastic lunch box (21 cm \times 12 cm \times 7 cm) lined with moist paper towel. All treated ticks were fed once a day by fresh blood by using plastic syringe. Tick mortality was recorded after every 48 hours whereas dead ticks were removed and incubated on moist petri dish for observation of fungal growth. The experiment was replicated four times. For the female ticks' bioassay, mortality was recorded post treatment to observe effect of treatment on oviposition until death.

Effect of *A. oryzae* on oviposition

Ovicidal effect of biopesticides was conducted according to [41] method with minor modification whereby fully engorged female ticks were exposed to at 1×10^6 , 1×10^7 conidia/mL, 1×10^8 conidia/mL and control by spraying 0.5 ml of suspension on ticks. Oviposition inhibition rate was determined by counting number of eggs laid per day dividing by number of treated engorged female ticks to obtain

average eggs laid. Weight of ticks before and after laying eggs was recorded to establish relationship between weight and oviposition rate.

Data and statistics analysis

Data on efficacy biopesticides against three species of ticks were presented as adult mortality rate, adult survival duration and oviposition rate that were analysed with the Proc GLM procedure of SAS, version 9.1 (SAS Institute, Cary, NC, USA) and tested for normality and homogeneity of variance. Mortality rate was transformed to log-10 for obtaining normally distributed data sets with equal variance. Adult survival duration and oviposition rate were subjected to analysis of variance (ANOVA) whereas adult mortality rate was subjected to Kruskal Wallis. Bonferroni was used to separate mean difference of adult mortality rate whereas Tukey's Honest Significant difference (HSD) was used to separate mean differences of Adult survival duration and oviposition rate at 5% level of significance.

Results

Time effect of *A. oryzae* on species of ticks

Effect of treatment on survival days of ticks varied significantly ($p < 0.0001$) between species of ticks at cold (20.5°C and 70% RH) and warm (35.5°C and 85% RH) conditions, with high activity in all concentrations of *A. oryzae* compared to control. *A. oryzae* treated ticks had lower survival duration in which survival time was reduced up to 6.25 ± 0.75 days in *H. anatolicum* than in *A. gemma* that survived for 11.9 ± 0.65 days whereas *H. anatolicum* and *A. gemma* in control survived for 31.95 ± 2.17 days and 41.35 ± 1.66 respectively (Table 1). However, the effect of treatment on species of ticks was insignificant ($p = 0.30$) although *A. gemma* survived longer compared to *R. appendiculatus* and *H. anatolicum* in both cold and warm conditions (Table 1).

Effect of *A. oryzae* on oviposition rate of engorged female ticks

The effect of treatment on mortality of engorged female ticks was evaluated by species due to variation in species fecundity. The effect of treatment on oviposition rate of engorged female *R. appendiculatus* varied significantly ($p < 0.0001$) in both warm and cold in which at warm temperature high oviposition rate was observed.

A. gemma treated with *A. oryzae* at 1.0×10^8 conidia/ml laid few eggs in cold temperature in 94.8 ± 10.74 compared to control that laid up to 354.15 ± 42.65 egg/female whereas an average of 166.20 ± 7.5 eggs/female were laid by *H. anatolicum* treated with *A. oryzae* at 1.0×10^8 conidia/ml compared to control that laid eggs averaging 416.25 ± 21.71 /female in cold condition (Table 2). In *H. anatolicum* the oviposition rate was significantly ($p < 0.0001$) different between treatments in warm and cold condition respectively, whereas *A. oryzae* at all concentration treated ticks laid few eggs than control (Table 2).

Effect of *A. oryzae* on mortality of female engorged ticks

The effect of treatment on mortality of engorged female ticks was evaluated by species due to variation in species morbidity. The effect of treatment on mortality of engorged female was significantly ($p < 0.0001$) warm and cold condition respectively, in which *A. oryzae* at 1.0×10^8 conidia/ml caused mortality within few days compared to lower doses 1.0×10^6 conidia/ml and 1.0×10^7 conidia/ml and control (Table 3). The effect of treatment on mortality of *H. anatolicum* varied significantly in both warm and cold condition ($p < 0.0001$), respectively (Table 3). There was also a significant ($p < 0.0001$) effect of treatment on survival of engorged female in warm and cold condition whereas *A. oryzae* at 1.0×10^8 conidia/ml induced up to 88.2%, 72.5% and 67.9%

in *R. appendiculatus*, *H. anaticum* and *A. gemma* respectively within 3 to 6 days compared to control where 12.5% mortality was reached in warm condition (Table 3).

Virulence of *A. oryzae* on ticks

From dead ticks treated with *A. oryzae* was observed and reisolated by placing dead ticks on moist petri dishes incubated at 30°C. After 3 to 10 days, mycelia developed on ticks cuticle treated with *A. oryzae* and sporulated covering the dead tick indicating the pathogenic activity on ticks. However, none fungal spore was observed to germinate from dead ticks in control plates (Figure 1).

Discussion

Animals are good source of food, income through tourism whereas byproducts especially hides and skins are essential raw materials in leather processing industry [43,44]. Ticks injuries and flushes on animal hides and skins lead to massive economic losses and rejection of raw material in tannery industry [16]. In Tanzania, hard tick *A. gemma* is common in cattle and wild animals causing high rate of ricketisia whereas *R. appendiculatus* occur in several hosts infesting appendages and ears [45,46]. Although use of chemical acaricide is prominent in Tanzania, it is economically and environmentally expensive [5]. This study revealed the potential of new

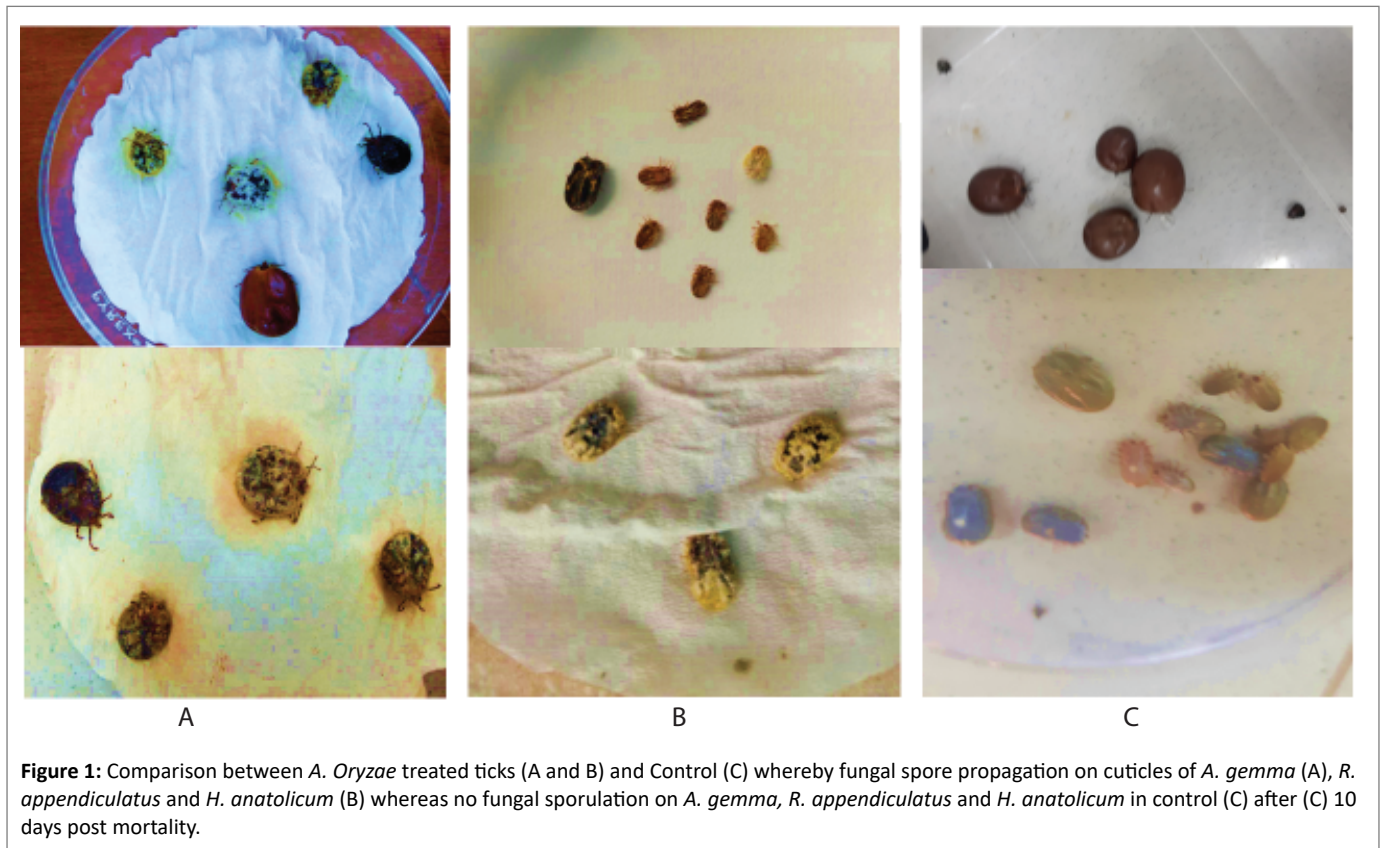


Table 1: Effect of *A. oryzae* on survival duration of three species of ticks after exposure to treatment conditions. Different letters show the significant difference where as similar letters show no difference between treatments at $p < 0.005$.

Experimental conditions			Tick species		
Treatment	Temperature and RH (%)	Concentration (conidia/mL)	<i>Amblyomma gemma</i>	<i>Hyalomma anaticum</i>	<i>Rhipicephalus appendiculatus</i>
Control	20.5°C+70	0.0	41.35 ± 1.6a	31.95 ± 2.17a	27.75 ± 1.4a
	35.5°C+85	0.0	28 ± 2.9ab	24.6 ± 0.9ab	22.50 ± 1.2a
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁶	16 ± 0.8b	11.0 ± 0.5b	13.07 ± 0.5b
	35.5°C+85	1.0 × 10 ⁶	12.9 ± 1.4bc	9.5 ± 0.3b	12.6 ± 0.3b
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁷	12.3 ± 1.5c	9.05 ± 0.4b	12.0 ± 0.3b
	35.5°C+85	1.0 × 10 ⁷	12.6 ± 0.5c	8.3 ± 0.6b	11.6 ± 0.4b
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁸	11.1 ± 0.9c	7.9 ± 0.3b	7.7 ± 0.4c
	35.5°C+85	1.0 × 10 ⁸	11.9 ± 0.6c	7.5 ± 0.5b	6.25 ± 0.75c
P-value			<0.0001	<0.0001	<0.0001

Table 2: Effect of *A. oryzae* on oviposition rate of three species of ticks after exposure to treatment conditions. Different letters show the significant difference where as similar letters show no difference between treatments at $p < 0.005$.

Experimental conditions			Tick species		
Treatment	Temperature and RH (%)	Concentration (conidia/mL)	<i>Amblyomma gemma</i>	<i>Hyalomma anaticum</i>	<i>Rhipicephalus appendiculatus</i>
Control	20.5°C+70	0.0	354.15 ± 42.6a	416.25 ± 21.71a	322.95 ± 44.25a
	35.5°C+85	0.0	377.5 ± 33.7a	428.55 ± 11.90a	355.95 ± 51.11a
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁶	306.9 ± 1.40b	367.25 ± 11.50b	301.25 ± 15.20b
	35.5°C+85	1.0 × 10 ⁶	375 ± 13.75b	359.50 ± 9.39b	310.6 ± 12.0b
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁷	218.2 ± 1.51bc	322.25 ± 8.00bc	227.9 ± 22.2c
	35.5°C+85	1.0 × 10 ⁷	276.6 ± 19.7bc	212.31 ± 7.28bc	254.6 ± 21.96c
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁸	94.8 ± 10.74c	166.20 ± 7.52c	105.7 ± 13.67d
	35.5°C+85	1.0 × 10 ⁸	138.8 ± 12.5bc	198.5 ± 6.20bc	110.16 ± 11.46d
P-value			<0.0001	<0.0001	<0.0001

Table 3: Effect of *A. oryzae* mortality rate of three species of ticks after exposure to different treatment conditions. Different letters show the significant difference where as similar letters show no difference between treatments at $p < 0.005$.

Experimental conditions			Tick species		
Treatment	Temperature and RH (%)	Concentration (conidia/MI)	<i>Amblyomma gemma</i>	<i>Hyalomma anaticum</i>	<i>Rhipicephalus appendiculatus</i>
Control	20.5°C+70	0.0	4.5%a	10.5%a	8.2%a
	35.5°C+85	0.0	6.0%a	11.0%a	12.5%a
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁶	36.2%b	41.0%b	40.7%b
	35.5°C+85	1.0 × 10 ⁶	39.9%b	51.5%b	53.2%b
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁷	48.5%bc	57.0%bc	58.5%bc
	35.5°C+85	1.0 × 10 ⁷	53.6%bc	57.3%bc	64.6%bc
<i>A. oryzae</i>	20.5°C+70	1.0 × 10 ⁸	57.4%c	62.5%c	68.7%c
	35.5°C+85	1.0 × 10 ⁸	67.9%bc	72.5%b	88.2%bc

isolate of *A. oryzae* for control of ticks. This study revealed that *H. anaticum* and *R. appendiculatus* were more susceptible to fungal *A. oryzae* compared to *A. gemma* that laid higher number of eggs and survived longer. However, at high concentration of 1.0 × 10⁸ conidia/mL both warm and cold conditions *A. oryzae* had high activity on three species of ticks whereas *R. appendiculatus* was more susceptible to than *H. anaticum* and *A. gemma* [47]. Less susceptible of *A. gemma* at all treatment conditions could be due to high food reservoir keeping it firmer and more active for long time than other ticks and resist to acaricidal in most East African countries [26].

Other studies have also revealed the potential of entomopathogenic fungi for control of several species of ticks [38,48]. Acaricidal activity of entomopathogenic fungi including *Scopulariopsis brevicaulis* on *Hyalomma anaticum* and *Amblyomma spp* has also been reported [48-50]. This study revealed that *A. oryzae* was more virulent compared to control on ticks although the infectivity increased with rise in concentration in all species of ticks. The mode of action was through cuticle fungal penetration and infection as *Aspegillus* species like other fungal spp developed a symbiotic relationship with host ticks and caused pathogenic effect [51].

Other studies reported the activity of *M. anisopliae* and *B. bassiana* against the deadly *H. anaticum* in laboratory [52]. However, more

studies show that a combination of entomopathogenic fungi with other compounds increases virulence toward insect in which *B. bassiana* and acaricidal showed enhanced acaricidal activity [53]. In current study, the oviposition rate was very low in ticks treated with *A. oryzae* compared to control in which high number of eggs were laid this could be due to infertility effect caused by entomopathogenic fungi [51]. Despite of *A. gemma* having the highest weight than *R. appendiculatus* and *H. anaticum*, high number of eggs were laid by *Hyalomma* species due to high fecundity rate at warm laboratory condition in which other studies revealed similar situation. Low oviposition rate was observed in fungal treated ticks in contrast to control which could be due to virulence effect of *A. oryzae* that caused death prior to oviposition [53]. Even though *A. gemma* possessed heavy weight than *H. anaticum* and *A. appendiculatus*, its fecundity rate declined after treatment with *A. oryzae* showing that fungal pathogenesis extended and inhibited egg oviposition and finally ticks died with their heavy weights. *A. oryzae* exhibited mortality at all concentration against all species of ticks, however death on *A. gemma* was delayed compared to *H. anaticum* and *R. appendiculatus* which could be due to have hard exoskeleton that absorb slowly spores. In most treatment appendages of ticks showed highest and early virulence than other parts indicating that *A. oryzae* attack first insect appendages (cuticles) to slow down movement and thereafter causes death. Despite the mortality in

control after long time of exposure to treatment, no fungal mycelia were reisolated from incubated dead ticks showing the death occurred natural unlike in fungal treated ticks. This substantiate that, fungal biopesticides are the best are natural control of ectoparasite pest as could have dual application in agricultural farms or grazing lands as both plant and animal pest control if sprayed in pastoral areas [35].

Conclusion

A. oryzae was effective in controlling three species of ticks that threaten animal husbandry and leather industry in Tanzania. Hence this study recommends further field experiment on application of *A. oryzae* as direct spray on animals or soil in grazing environment could be potential for management of ticks and mosquitoes to control skin damage for health animals and protect from Vector Borne Diseases (VTBDs) for improving quality of hides and skins for tanning industry in Tanzania.

Declaration

Authors declare that no competing interest exist.

Funding

This work was supported by Deutscher Akademischer Austauschdienst (DAAD) grant number: 57221138.

Acknowledgement

Authors acknowledge DAAD/RUFORUM in region /in country scholarship for funding this study. The Tropical Pesticide Research Institute (TPRI) is also acknowledged for assistance in tick identification, Mr Meshack Mollel and other cattle keepers in the area where visited are all acknowledged for their assistance during ticks, hides and skins collection in Longido, Monduli and Arusha districts.

References

- Selmi R, Ben Said M, Ben Yahia H, Abdelaali H, Messadi L (2020) Molecular Epidemiology and Phylogeny of Spotted Fever Group Rickettsia in Camels (*Camelus Dromedarius*) and Their Infesting Ticks From Tunisia. *Transbound Emerg Dis* 67: 733-744.
- Kebede N, Fetene T (2012) Population dynamics of cattle ectoparasites in Western Amhara National Regional State, Ethiopia. *J Vet Med Anim Health* 4: 22-26.
- Mohammed K, Admasu P (2015) Prevalence of Ixodid Ticks in Small Ruminants in Selected Districts of Fafen Zone, Eastern Ethiopia. *Europ J Appl Sci* 7: 50-55.
- Mukolwe SA (2018) Diversity of ticks and tick-borne protozoan parasites from livestock and wildebeests at the Maasai-mara wildlife-livestock interface, Narok county, Kenya. Doctoral dissertation, University of Nairobi, Kenya.
- Wandiga SO (2001) Use and distribution of organochlorine pesticides. The future in Africa. *Pure Appl Chem* 73: 1147-1156.
- Aktas M, Dumanli N, Angin M (2004) Cattle infestation by Hyalomma ticks and prevalence of Theileria in Hyalomma species in the east of Turkey. *Vet Parasitol* 119: 1-8.
- Muhanguzi D, Byaruhanga J, Amanyire W, Ndekezi C, Ochwo S, et al. (2020) Invasive cattle ticks in East Africa: morphological and molecular confirmation of the presence of *Rhipicephalus microplus* in south-eastern Uganda. *Parasite Vector* 13: 1-9.
- Villinger J, Jeneby M, Ong'amo G, Otiende MY, Makhulu EE, et al. (2020) Pathogens, endosymbionts, and blood-meal sources of host-seeking ticks in the fast-changing Maasai Mara wildlife ecosystem. *bioRxiv*.
- Yacob H, Atakly H, Kumsa B (2008) Major ectoparasites of cattle in and around Mekelle, Northern Ethiopia. *Entomol Res* 38: 126-130.
- Yacob H, Yalew T, Dinka A (2008b) Ectoparasite prevalences in sheep and in goats in and around Wolaita sodd, Southern Ethiopia. *Revue de Médecine Vétérinaire* 159: 8-9.
- Ferede B, Kumsa B, Bsrat A, Kalayou S (2010) Ticks of donkeys in central Oromia regional state, Ethiopia. *Revue Méd Vét* 161: 121-126.
- Abdela N (2016) Important Cattle Ticks and Tick Borne Haemoparasitic Disease in Ethiopia: A Review. *Acta Parasitol Glob* 7: 12-20.
- Kebede MC (2013) Effect of Small Ruminant Ectoparasites in the Tanning Industry in Ethiopia: A Review. *J Anim Sci Adv* 3: 424-430.
- Beyecha K, Kumsa B, Beyene D (2014) Ectoparasites of goats in three agroecologies in central Oromia, Ethiopia. *Comp Clin Path* 23: 21-28.
- Abebayehu T, Kibrom M (2010) Study on Ectoparasitic Defects of Processed Skins at Sheba Tannery, Tigray, Northern Ethiopia. *Trop Anim Health Prod* 42: 1719-1722.
- Berhanu W, Negussie H, Alemu S, Mazengia H (2011) Assessment on Major Factors That Cause Skin Rejection at Modjo Export Tannery, Ethiopia. *Trop Anim Health Prod* 43: 989-993.
- Tadesse A, Fentaw E, Mekbib B, Abebe R, Mekuria S (2011) Study on the prevalence of ectoparasite infestation of ruminants in and around Kombolcha and damage to fresh goat pelts and wet blue (pickled) skin at Kombolcha Tannery, Northeastern Ethiopia. *Ethiopian Veterinary Journal* 15.
- Ghosh S, Azhahianambi P, de la Fuente J (2006) Control of Ticks of Ruminants, With Special Emphasis on Livestock Farming Systems in India: Present and Future Possibilities for Integrated Control—A Review. *Exp Appl Acarol* 40: 49-66.
- Engelbrecht A, Hoffman LC, Cloete SWP, Van Schalkwyk SJ (2009) Ostrich leather quality: a review. *Anim Prod Sci* 49: 549-557.
- Abebe R, Tatek M, Megersa B, Sheferaw D (2011) Prevalence of Small Ruminant Ectoparasites and Associated Risk Factors in Selected Districts of Tigray Region, Ethiopia. *Glob Vet* 7: 433-437.
- Abunna F, Tura J, Regassa A (2013) Status of Tick Infestation in Small Ruminants of Bedelle District, Oromia Region, Ethiopia. *Global Veterinaria* 8: 459-462.
- Isse F, Said A, Ali M (2017) Hard Tick Distribution of Camels in and around Galkaio District, Somalia. *Glob J Med Res* 17
- Adrian M, Nonga Hezron E, Mdegela Robinson H (2012) Tick infestations in extensively grazed cattle and efficacy trial of high-cispermethrin pour-on preparation for control of ticks in Mvomero district in Tanzania. *BMC Vet Res* 8: 224.
- Okello-Onen J, Tukahirwa E, Perry B, Rowlands G, Nagda S, et al. (2003) The Impact of Tick Control on the Productivity of Indigenous Cattle Under Ranch Conditions in Uganda. *Trop Anim Health Prod* 35: 237-247.
- Muruthi WC (2015) Phenotypic and Molecular Characterization of Hard Ticks (Acari: Ixodidae) Sampled from Wild Herbivores from Lake Nakuru and Tsavo National Parks in Kenya. *Kenyatta University*.
- Nejash AA (2016) Review of Economically Important Cattle Tick and Its Control in Ethiopia. *Advances in life Science and Technology* 42: 51-64.
- Abebe R, Fantahun T, Abera M, Bekele J (2010) Survey of ticks (*Acari: Ixodidae*) infesting cattle in two districts of Somali Regional State, Ethiopia. *Vet World* 3: 539-543.

28. Gashaw BA, Mersha CK (2013) Pathology of Tick Bite Lesions in Naturally Infested Skin and Hides of Ruminants: A Review. *Acta Parasitologica Globalis* 4: 59-63.
29. Tolossa YH (2014) Ectoparasitism: Threat to Ethiopian small ruminant population and tanning industry. *J Vet Med Anim Health* 6: 25-33.
30. George JE, Pound JM, Davey RB (2004) Chemical Control of Ticks on Cattle and the Resistance of These Parasites to Acaricides. *Parasitology* 129: 353-366.
31. Martinez-Velazquez M, Castillo-Herrera GA, Rosario-Cruz R, Flores-Fernandez JM, Lopez-Ramirez J, et al. (2011) Acaricidal effect and chemical composition of essential oils extracted from *Cuminum cyminum*, *Pimenta dioica* and *Ocimum basilicum* against the cattle tick *Rhipicephalus (Boophilus) microplus* (Acari: Ixodidae). *Parasitol Res* 108: 481-487.
32. Rao Z Abbas, Muhammad Arfan Zaman, Douglas D Colwell, John Gilleard, Zafar Iqbal (2014) Acaricide resistance in cattle ticks and approaches to its management: The state of play. *Vet Parasitol* 203: 6-20.
33. Sajid MS, Iqbal Z, Khan MN, Muhammad G (2009) *In Vitro* and *In Vivo* Efficacies of Ivermectin and Cypermethrin against the Cattle Tick *Hyalomma Anatolicum Anatolicum* (Acari: Ixodidae). *Parasitol Res* 105: 1133-1138.
34. Kalala W, Magadula J, Mdegela H (2014) Evaluating Acaricidal Activity of *Commiphora swynertonii* (Burrt) bark Exudate against common Ticks in Tanzania. *Int J Herb Med* 2: 19-25.
35. Kaaya GP (2003) Prospects for Innovative Tick Control Methods in Africa. *Int J Trop Insect Sci* 23: 59-67.
36. Kirkland BH, Westwood GS, Keyhani NO (2004) Pathogenicity of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* to Ixodidae tick species *Dermacentor variabilis*, *Rhipicephalus sanguineus*, and *Ixodes scapularis*. *J Med entomol* 41: 705-711.
37. Maniania NK, Nchu F, Ekesi S (2007) 10 Fungal pathogens for biocontrol of ticks.
38. Pirali-Kheirabadi K, Haddadzadeh H, Razzaghi-Abyaneh M, Bokaie S, Zare R, et al. (2007) Biological Control of *Rhipicephalus (Boophilus) Annulatus* by Different Strains of *Metarhizium Anisopliae*, *Beauveria Bassiana* and *Lecanicillium Psalliotae* Fungi. *Parasitol Res* 100: 1297-1302.
39. Angelo IC, Fernandes ÉK, Bahiense TC, Perinotto WM, Moraes APR, et al. (2010) Efficiency of *Lecanicillium lecanii* to control the tick *Rhipicephalus microplus*. *Vet Parasitol* 172: 317-322.
40. Sun M, Ren Q, Guan G, Liu Z, Ma M, et al. (2011) Virulence of *Beauveria Bassiana*, *Metarhizium Anisopliae* and *Paecilomyces Lilacinus* to the Engorged Female *Hyalomma Anatolicum Anatolicum* Tick (Acari: Ixodidae). *Vet Parasitol* 180: 389-393.
41. Habeeb SM, Ashry HM, Saad MM (2017) Ovicidal Effect of Chitinase and Protease Enzymes Produced by Soil Fungi on the Camel Tick *Hyalomma dromedarii* Eggs (Acari: Ixodidae). *J Parasit Dis* 41: 268-273.
42. Zekeya N, Mtambo M, Ramasamy S, Chacha M, Ndakidemi PA, et al. (2019) First record of an entomopathogenic fungus of tomato leafminer, *Tuta absoluta* (Meyrick) in Tanzania. *Biocontrol Sci Technol* 29: 626-637.
43. Alves RRN, Mota ELS, Dias TLP (2018) Use and commercialization of animals as decoration. In: Nobrega Alves RR, Albuquerque UP (eds) *Ethnozooology: Animals in our Lives*. Academic Press 261-275.
44. Nsubuga D, Banadda N, Kiggundu N (2019) Innovations in Value-Addition of Agricultural By-Products in Uganda. *J Environ Prot Sci* 10: 1493-1506.
45. Lee S, Kim JY, Yi MH, Lee IY, Fyumagwa R, et al. (2019) Comparative microbiomes of ticks collected from a black rhino and its surrounding environment. *Int J Parasitol Parasites Wildl* 9: 239-243.
46. Oundo JW (2019) Pathogens and blood feeding patterns of questing ticks in Maasai Mara wildlife ecosystem, Kenya. Doctoral dissertation, University of Nairobi, Kenya.
47. Sun M, Ren Q, Guan G, Li Y, Han X, et al. (2013) Effectiveness of *Beauveria Bassiana* Sensu Lato Strains for Biological Control Against *Rhipicephalus (Boophilus) Microplus* (Acari: Ixodidae) in China. *Parasitol Res* 62: 412-415.
48. Fernandes ÉK, Bittencourt VR, Roberts DW (2012) Perspectives on the potential of entomopathogenic fungi in biological control of ticks. *Exp Parasitol* 130: 300-305.
49. Elham AS, Shigidi MT, Hussan SM (2013) Activity of *Scopulariopsis brevicaulis* on *Hyalomma anaticum* and *Amblyomma lepidum* (Acari: Ixodidae). *J Med Sci* 13: 667-675.
50. Gindin G, Samish M, Zangi G, Mishoutchenko A, Glazer I (2003) The susceptibility of different species and stages of ticks to entomopathogenic fungi. *Ticks and Tick-Borne Pathogens* 283-288.
51. Wasinpiyamongkol L, Kanchanaphum P (2019) Isolating and identifying fungi to determine whether their biological properties have the potential to control the population density of mosquitoes. *Heliyon* 5: e02331.
52. Tavassoli M, Ownag AG, Meamari R, Rahmani S, Mardani K, et al. (2009) Laboratory evaluation of three strains of the entomopathogenic fungus *Metarhizium anisopliae* for controlling *Hyalomma anaticum* and *Haemaphysalis punctata*. *Iran J Vet Res* 3: 11-15.
53. Sun M, Ren Q, Liu Z, Guan G, Gou H, et al. (2011) *Beauveria bassiana*: Synergistic effect with acaricides against the tick *Hyalomma anaticum anaticum* (Acari: Ixodidae). *Exp Parasitol* 128: 192-195.