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ORIGINAL ARTICLE

Field assessment of the efficacy of *Tephrosia vogelii* leaf extracts for control of ticks on naturally infested cattle in the field condition

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Abstract *Tephrosia vogelii* (*T. vogelii*) is a known tropical leguminous herb for fixing nitrogen in the soil and as pesticide properties. Its crude leaf extract was evaluated as a natural acaricide to control ticks on naturally infested traditionally reared cattle in selected areas of Monze District of Zambia. Experimental animals were selected from herds of cattle with poor or no history of any conventional tick control and were divided into six treatment groups of five animals per set which were sprayed with 5, 10, 20 and 40% w/v of *T. vogelii* leaf extract bio-acaricide solution. A negative control group of five animals were sprayed with ordinary water, while a positive group with a commercial acaricide (Amitraz®) at a recommended dosage of 1:500 dilution. Half-body tick counts then doubled were conducted on each animal, before and at twenty-four hourly intervals of: 24 (1 day), 48 (2 days), 96 (3 days), 192 (4 days), 384 (5 days) and 768 (6 days) after treatment. The observed tick reductions were found to be statistically significant at all treatment levels (p value < 0.001). With this performance, there was evidence to show that the herbal extract was effective against ticks. The results showed significant and sustained efficacy *T. vogelii* extract from day 2 to day 6 after treatment. There was no significant difference at 5, 10, 20 and 40 w/v in the observed efficacies between low and high concentrations of the bio-acaricide used. We conclude that *T. vogelii* could be used to spray animals against ticks, especially in low-income communities and also in setups where organic farming is practiced.

Keywords Leaf extracts · Small-scale farmer · *Tephrosia vogelii* · Ticks · Cattle

Introduction

Ticks are vectors of a number of tick-borne diseases (TBDs) in domestic and wild animals. Major TBDs and their vectors in the sub-Saharan region are theileriosis, which is transmitted by *Rhipicephalus appendiculatus* and *R. Zambezienses*; babesiosis; anaplasmosis transmitted by *Boophilus microplus* and *B. decolaratus;* and cowdriosis transmitted by *Amblyomma variegatum* and *A. hebraeum* (Masiga 1996; Makala et al. 2003). TBDs in the sub-Saharan countries are responsible for direct and indirect economic losses in livestock production, especially among traditionally managed livestock. TBDs control is mainly through the vector tick control; however, conventional methods of tick control have proven to be ineffective, especially among small-scale livestock farmers due to high cost of acaricides and development of tick resistance to commonly used acaricides, mainly because of inadequate acaricide preparation methods. Consequently, this has resulted in increased outbreaks of TBDs among small-scale

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farmers in Zambia and elsewhere in the region. It is because of these challenges which have prompted researchers to consider introducing more affordable and environmental friendly non-conventional tick control methods (Georghiou and Lagunes-Tejada 1991; Georghiou 1986). It is well documented that one of the major constraints affecting cattle productivity in Zambia is the persistence of parasitic diseases (Masiga 1996). In 1993, it was estimated that theileriosis control in Africa was in excess of US$168 million (Eisler et al. 2003). TBDs and their vector tick bites, which affect more than 80% of cattle worldwide, have continued to be one of the most serious public health problem limiting livestock productivity in general (FAO 1984; Latif and Jongejan 2002; Carroll et al. 2004). Ticks and TBDs are responsible for high cattle morbidity and mortality, resulting in decreased meat and milk production; loss of draught power; reduced availability of manure; and increased cost of control. It was estimated that 20 to 30 percent financial losses on heavily tick-infested animals can be attributed to nagging irritation, disrupted feeding and depreciation in value of the damaged skins and hides (Biswas 2003). This study was conducted to assess the efficacy of *Tephrosia vogelii* (*T. vogelii*) crude leaf extract use as an alternative acaricide for naturally infested cattle under field conditions and reared in areas with no known tick control intervention programs.

Tephrosia plants are found in many tropical countries where they are used as a hedge, as a nitrogen-fixing plant in the soil, as a shade, as an insecticide, especially against aphids and in grain post-harvest preservation against weevils. It has been observed that because of these disadvantages associated with commercially available chemical acaricide products in circulation, the adoption of alternative methods could minimize such problems (Wharton 1983). It was further noted that because of these disadvantages associated with commercially available chemical acaricide products currently in circulation, the adoption of alternative methods could minimize such problems (Wharton 1983). The synthesis of new chemical acaricides in view of the development of tick resistance poses a serious threat to most farmers worldwide.

It has further been suggested that intensive tick control in a multipurpose livestock system such as the one existing in Zambia is not justified in the absence of other serious TBD's policies (Lane and Crosskey 1996; Pegram et al. 1986).

In many countries of tropical and subtropical regions, control of ticks is a priority (Lodos et al. 2000). The escalating tick and TBD's of cattle, which mainly attack blood and the lymphatic systems, have created an increase in the demand for alternative control strategies in order to reduce livestock losses (George et al. 2004; Rajput et al. 2006). Care of traditional animals by traditional livestock farmers is to some extent based on their knowledge, skills, methods, practices and beliefs in the indigenous knowledge passed on from generation to generation (McCorkle et al. 1996). Many livestock owners complement dipping with other tick control measures including herbal preparations, old motor oil, household disinfectant, paraffin, pour on acaricide and manual removal of ticks and sometimes smearing animal dung (Hlatshwayo and Mbati 2005).

Due to the high cost of commercial acaricides currently in use to control ticks, ethno-veterinary remedies in the management of livestock diseases have been advocated as an alternative in tick control (Njoroge and Bussmann 2006). Ethno-knowledge and validation of medicine and veterinary products offer a wide range of herbs to be evaluated for their insecticidal and acaricidal properties (Ghosh et al. 2007).

Materials and methods

Study area

Field study was conducted from January 2015 to April 2015 at Njola Veterinary Camp (16°13.425 S and 27°47.534 E; elevation 1178 m), located 30 km east of Monze town in Monze District in the Southern Province of Zambia. Monze town is located on the great north road about 185 km south of the capital Lusaka. The district, which has an estimated human population of about 200,000, shares its border with Mazabuka, Namwala, Pemba and Gwembe districts (DVO/Monze Annual Report 2009). The district is renowned for its traditional small-scale livestock activities prone to a number of livestock diseases. The major tick-borne diseases are East Coast fever, anaplasmosis and heartwater (DVO/Monze Annual Report 2009). The estimated livestock population is about 152,000. There are three main seasons, namely hot-wet season which runs from late November through to April; cool and dry period is from May to August; and hot-dry season from September to October. The mean annual temperature is between 21 and 29 °C.

The study area was selected because there were poor tick control practices due to lack of facilities (dip tank, spray race or hand sprayer) within the radius of 20 km. Few farmers would move their animals to a distance of about 20 km (Km) to find the dip tank, while others do not move them. Also, during the crop season, animal movements were restricted, even going to dip tank, for fear that the animals could destroy maize fields. As such, tick infestation and tick-borne diseases were generally high (Figs. 1, 2).

Fig. 1 Location of Zambia

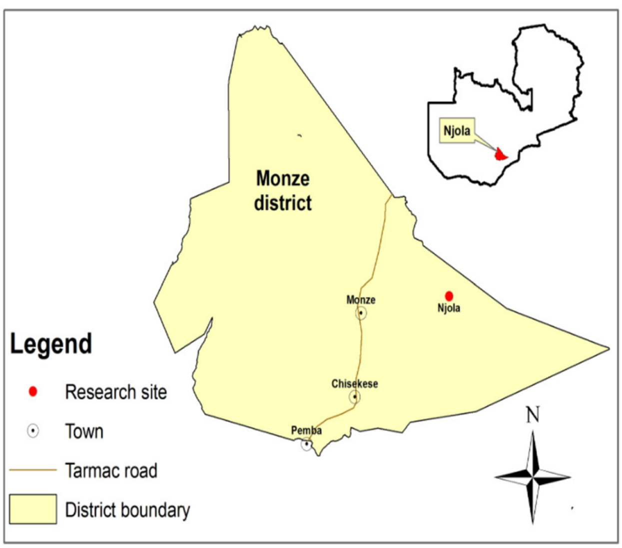

Fig. 2 Njola Veterinary Camp in Monze District

Types of ticks

According to Speybroeck et al. (2002), there is significant variability in the species composition and relative abundance of ticks across the country with all major genera being reported in most parts of Zambia. However, Tandon (1991) has provided a detailed account of the geographic distribution of ixodid ticks in each district of Zambia. The specific geographical distribution of tick species is difficult to establish as the type of habitat in which species are found is widely distributed than their current geographical range (Walker et al. 2003; Horak et al. 2002). According to Mtshali et al. (2004), tick distribution and occurrence differ with vegetation type. In Zambia, it is known that there is significant variability in the species composition and relative abundance of ticks across the country with all major genera being reported in most parts (Speybroeck et al. 2002 and Berkvens et al. 1998). Tick counts were done according to Keiser (1987) and (Walker et al. 2003) by half-body tick counts and then doubled to obtain the whole tick burden and were carried out in situ on daily interval for at least a week post-treatment during the period of January to March which is a peak season for ticks. Three tick species that were present on different animals at the time of field study were *Rhipicephalus appendiculatus, Rhipicephalus* (*Boophilus*) *microplus*, and *Amblyomma variegatum.*

Animals

Thirty local Zebu and Sanga breeds of cattle were purposely selected from seven herds in the same communal grazing area used by small-scale livestock farmers in Njola Veterinary Camp who volunteered to participate in the experiment. The identity or name, age and sex of the selected animals were recorded at the beginning of the study for easy identification. Selection criteria of experimental animals were based on: (1) visible tick infestation; (2) age of 1 year and above ($\geq$ 1 year); (3) history of East Coast fever (ECF) cases and/or other TBD's in the area; (4) both male and female cattle were used; and (5) the herds had poor history of tick control practice. The animals were divided into six groups of five cattle per treatment group.

Botany of *Tephrosia vogelii*

Tephrosia vogelii (*T. vogelii*) is native to tropical Africa, and it is found growing naturally in wide and varying habitats which include savannah vegetation, grasslands, forest margins and shrub land, wasteland and fallow fields (www.worldagroforestry.org). *Tephrosia is a Genus of legumes which belong to the family Fabaceae with about 300 vogelii species* (Zambia-ICRAF Agroforestry Project 2009). *Tephrosia vogelii*, commonly known as the "fish bean" or "fish-poison bean," is used by farmers in Africa to control pests on livestock, in cultivated fields as an organic pesticide, and as a medicine for skin diseases and internal worms (PACE 2013). It can be used as a cover crop, a hedge and/or for shelter while fixing nitrogen in the soils where it is planted. *The common names of Tephrosia vogelii are: fish bean, fish-poison bean, Vogel's Tephrosia* (http://www.worldagroforestry.org). Physically, this plant has branches and stems with long and/or short white or rusty brown hair coat.

Some uses of *Tephrosia vogelii*

Although *T. vogelii* has been known to have many uses in agriculture and human health, the effectiveness of *Tephrosia vogelii* in the control of Acarina has not been fully exploited in developing countries where its use is required the most (Matovu and Olila 2007). The dichloromethane extract from the roots and leaves was tested against staphylococcus aureus, *Escherichia coli* and staphylococcus paratyphi (Wanga et al. 2007), and the roots decoctions are used to treat constipation. It is also used in plant protection and storage. *T. vogelii* powders have been found to be very potent natural pesticides in maize or beans storage. *T. vogelii is* very useful in soil enrichment through nitrogen fixation. It has a high potential of improving soil fertility when used in improved fallow situations (Balasubramanian and Sekayange 1992). *T. vogelii* plantations have been reported to increase subsequent maize yields in Tanzania (Mgangamundo 2000). *T. vogelii* and other species have been grown for crop protection in Eastern and Southern Africa.

T. vogelii has been found to be a potential source of non-residual insecticide. The principle active ingredient of *T. vogelii* is rotenone (Zambia-ICRAF Agroforestry Project 2009; Blommaert 1950). *Tephrosia* species contain complex mixtures of rotenoids and other flavonoids (Gomez-Garibay et al. 2002) which are known to be mitochondrial chain inhibitors, inhibiting cellular respiration in almost every living organism including insects and mammals. These compounds block the enzymes glutamate and succino-dehydrogenase and thus H+ transport (Neuwinger 2004). *T. vogelii* has a wide range of rotenoid compounds: tephrosin, deguelin and 6a 12-dehydrodeguelin (Lambert et al. 1993). Rotenone is a compound which has no color or smell; it has an empirical formula of C23H22O6 and a molecular weight of 394.41

The pharmacokinetics of rotenone is attributed to the mitochondrial electron transport destruction in the cells, which hinders the utilization of oxygen in the respiration process of the organism, leading into cell death (Islam 2006). Despite the toxic properties of rotenone to fish and arthropods, it is relatively safe to humans and animals when ingested, as the changes in the gut transform it into less toxic substances before it enters the bloodstream where its toxicity matters (McClay 2000).

Preparation of *T. vogelii* extracts

The preparation of extract was mixed depending on the region. The preparation of the extract was Modified employed on the formulas found to cover a wide range of dilutions. Some prepared one part of the soaked leaves in five parts of water, while some others one thousand leaves in 20 l of water (Zambia-ICRAF Agroforestry Project 2009). In this study, fresh leaves from *T. vogelii* plants were harvested and divided into 1, 2, 4 and 8 kg portions. Each weighed portion was pounded in a mortar and soaked in separate buckets of 20 l water for overnight. The *T. vogelii* leaf extracts were filtered through a muslin cloth to extract 5, 10, 20 and 40% w/v concentrated solutions which are used as bio-acaricide to spray on the respective groups of experimental animals. About 3–4 l of the extract solutions was sufficient to spray on one animal in the study group. A 175-g ordinary bathing soap was added to each 20 l of the extract as a sticking agent. A knapsack sprayer was used to spray the whole body of the animals per concentration while restrained in standing position.

A chemical acaricide called Amitraz prepared at a recommended 12.5% by volume (i.e., 1:500 v/v) is used as a positive control, while negative control group animals were sprayed with ordinary water. Each animal was sprayed with 4 l of prepared solution. Amitraz is a triazapentadiene compound used in flea collars of dogs and is a member of the amidine chemical family, as an insecticide and acaricide (Malmasi and Ghaffari 2010). It is known to lead overexcitation and consequently paralysis and death in insects. Because Amitraz is less harmful to mammals, it is among many other purposes best known as an insecticide against mite or tick infestation of dogs (Corta et al. 1999).

Data analysis

Data generated were recorded in Excel spreadsheet. Descriptive statistics (mean, percentage and graphs) were used to express the results of the data. *T* test was used to determine whether there was a significant difference in the mean tick counts between the lower concentrations of 5%w/v and the higher concentration of 40%w/v. Also, analysis of variance (ANOVA) was used to evaluate whether there was any significant difference in the treatment outcome among groups from day 1 to 5 of treatment. STATA® statistical package version 12 was used to analyze the data, and the significance level was set at 95% ($p = 0.05$). The incidence rate ratio (IRR) was evaluated by comparing the negative control and the different efficacies of the concentrations. Log-rank test result on treatment groups' analyses was used to determine whether there was any difference in tick survival times at given *T. vogelii* leaf extract concentrations used in this study.

Results

All *T. vogelii* leaf extract concentration levels gave a reduction in tick counts after application. Table 1 shows the efficacy on reduction in tick load infestation on cattle

Table 1 Summary values for number of ticks by concentration of *T. vogelii* leaf extract

Concentration (W/V)	Mean tick count	SD
0.05	4	6
0.10	10	15
0.20	9	15
0.40	7	11
+ve control (Amitraz)	10	18
−ve control (water)	35	5

under the field condition after application of the plant leaf extracts of *T. vogelii* on cattle. The mean tick's counts reduced from 32 on day 0 to 5 in 5 days. The observed tick reductions were found to be statistically significant at all treatment levels (p value < 0.001).

Figure 3 shows the overall reduction pattern in tick counts after treatment. There was a significant reduction in tick loads on animals within 24 h after treatment and remained steadily low for close to a week before reinfection began to show on day 6 (Fig. 3). The presence of ticks reduced from day 1 to day 6. The general impression shows that the acaricidal effects of the crude leaf extracts on ticks were significant.

Figure 4 shows the relationship between the mean tick count and period of time at which the reduction in ticks was noted after the crude extracts of the *T. vogelii* were sprayed on animals at different concentration levels. There was a drastic reduction in ticks post-treatment from day 1, 2 to day 6. All the four treatments (5, 10, 20 and 40%) concentrations, including the positive control, induced mortality on the ticks.

Table 1 shows the comparison of summary values of tick counts post-treatment, i.e., comparison of positive (Amitraz) and negative control (water) groups with the different *T. vogelii* leaf extract-treated groups at 0.05–0.40 concentration levels. It was noted that the lowest treatment concentration level of 0.05 had significantly lower mean

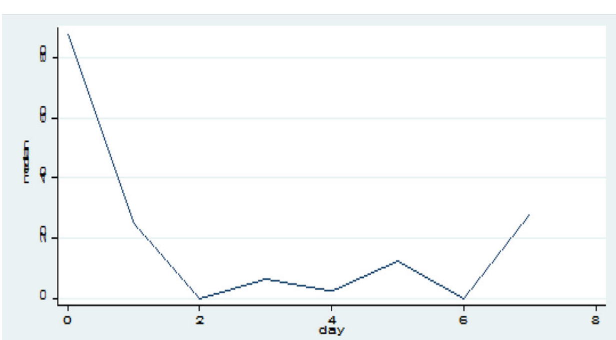

Fig. 3 Mean tick counts on cattle body post-treatment with different concentrations of *T. vogelii* leaf extract showing a sudden reduction in tick burden 2 days post-treatment and remaining low until day 6

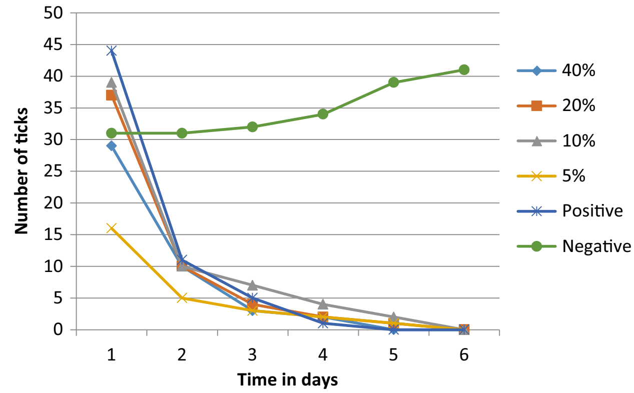

Fig. 4 Distribution of daily mean tick load on cattle under the field condition following treatment with different concentrations of *T. vogelii* extract

count of ticks than the positive control and all the other treatment concentration levels of 0.10–0.40.

Table 2 shows the mean tick counts from day 0 before any treatment and then after treatment. There was a reduction in ticks as days passed. Of course, it also shows that the tick burden on average was low.

The incidence rate ratio (IRR) is calculated using the Poisson regression model to compare the efficacies of the *T. vogelii* leaf extract-treated groups' concentrations and the positive and negative control groups, which is indicated in Table 3. The numbers of tick counts were observed from each concentration treatment group of 0.05, 0.10, 0.20 and 0.40. Each group had different numbers of ticks on animals on day 0. The average tick counts were converted to the

Table 2 Progressive daily distribution of number of ticks on cattle body surface under the field condition

Days	Mean tick count	SD	Min	Max
0	32	14	10	68
1	13	9	3	34
2	8	10	0	34
3	6	11	0	38
4	6	13	0	42
5	5	14	0	44

Table 3 Result of Poisson regression model parameters on tick reduction percentage

Concentration	Incidence rate ratio (IRR)	*P* (*z*)	95% (CI)
0.05	0.122	0.000	0.073–0.204
0.10	0.295	0.000	0.180–0.482
0.20	0.260	0.000	0.162–0.416
0.40	0.209	0.000	0.130–0.335
+ve control	0.288	0.000	0.170–0.489
−ve control	34.889	0.000	24.261–50.171

percentage of number of ticks counted on each group on day 0. The results in Table 3 show reductions in tick counts at all concentrations levels used. Five percent w/v concentration of *T. vogelii* leaf extracts had the highest reduction rate of ticks of 88%, while 0.10, 0.20 and 0.40% w/v gave 71, 74 and 80% reduction in tick counts, respectively. The association between leaf extract concentrations used and tick mean count reduction was significant.

Further analysis from ANOVA indicates that the calculated *F* value of 1.277704 was less than *F* critical value of 3.238872, and the calculated *P* value of 0.315 was larger than the critical value of 0.05. This shows that there was no significant difference among the means of the varying treatment groups.

The overall outcome in the four different concentrations was that the box plot shows similar trends in the killing effect or reduction in ticks on animals (Fig. 5). The result further shows that the median concentration in box plots for 0.05 and 0.10% was symmetrical, while box plots for concentration 20 and 40% had different symmetrical appearance. The performance of extracts further proves its effectiveness in killing action.

The mean efficacies of each concentration level used were demonstrated from day 1 to day 5 as shown in Fig. 6.

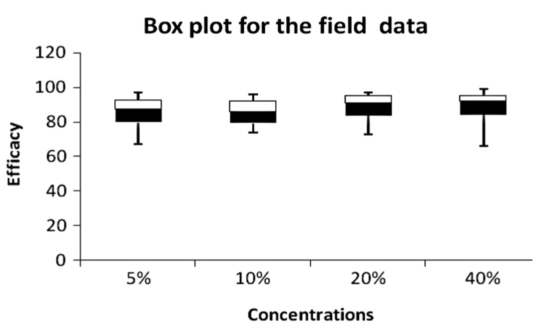

Fig. 5 Overall pattern of response for each group per concentration indicating the medians of efficacy

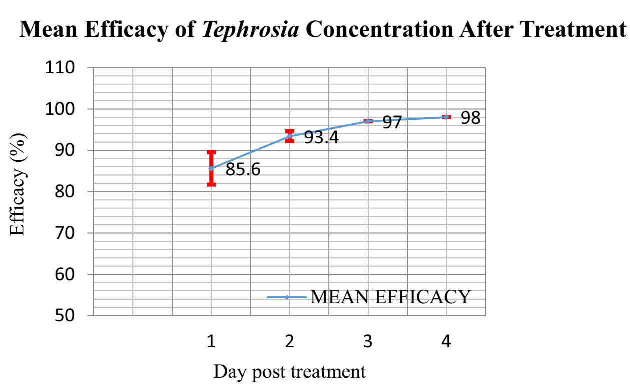

Fig. 6 Progressive increase in mean efficacy of all the concentrations of *T. vogelii* leaf extract from day 1 post-treatment

There was a progressive increase in the efficacy of *T. vogelii* leaf extracts, resulting in reduction in the number of ticks on sprayed animals. From day 1, the efficacy was above 50% of tick reduction from different concentrations. The summary of daily mean efficacy ranged from 85.6% on day 1 to 98% on day 5.

Discussion

This study aimed to evaluate the efficacy of different concentrations of *Tephrosia vogelii,* a tropical leguminous herb, crude leaf extract as a natural acaricide to control ticks on naturally infested traditionally reared cattle in selected areas of Monze District of Zambia. Control of ticks and tick-borne diseases is mainly known to be done using a wide range of approaches which include commercial acaricides like organophosphates, carbamates and pyrethroids, which unfortunately have led to various problems such as development of tick-resistant strains, residual environment pollution, indiscriminate killing of useful arthropods and the high cost of purchase (Ghosh et al. 2007). In many places in Zambia, different preparations have been used by local farmers for the purpose of controlling ticks on the livestock, without enough proof of which concentration to depend on for daily use within economical usage. In this study, all the preparations gave good results. The results obtained in this study (Table 1) demonstrated the reduction in ticks after application of the leaf extract of *T. vogelii*. The mean tick's counts reduced from 32 on day 0 to 5 in 5 days. This showed that the extracts' effectiveness was high. Under the field condition, all the four treatment groups allotted to different *T. vogelii* extract concentrations of spray gave similar tick count reduction responses compared to controls. In Zambia, preliminary studies using crude *T. vogelii* water-soluble extracts in the field experiments showed that at a concentration of 10% w/v it was possible to protect cattle from tick infestation (Kaposhi 1993). The results from this study show that tick reductions were found to be statistically significant at all treatment levels (p value < 0.0001). Despite a slight difference in efficacy in the treatment groups, statistically different levels of concentration had similar effects. In this study, even at a low concentration of 5%, there was a significant reduction in tick numbers compared to what has been observed in previous studies. An experiment done in Zimbabwe on the tick control indicated that there was a decline in the number of engorged ticks from different dilution levels after treatment with *T. vogelii* on dairy animals (Gadzirayi et al. 2009). This study provides further evidence to show that the herbal extract is effective against ticks. According to the PACE project in central Kenya, the use of *T. vogelii* as an acaricide has shown encouraging results (PACE 2013). Studies from Congo have also shown that mortality of 95% and 100% using 10 and 20 mg/ml of leaves of two varieties of *T. vogelii* against *R. appendiculatus* ticks has been observed by Kalume et al. (2012). The same observation was made when chloroformic, methanolic, aqueous and etheric extracts of leafy stems of *Tephrosia vogelii* were used on nymphs and adult ticks in Uganda (Matovu and Olila 2007). In Benin, similar studies have shown that extraction of leaf materials using ethanol from *T. vogelii* caused 98.51% mortality in *A. variegatum* (Dougnon et al. 2014). Generally, the results obtained in this study regarding the effectiveness of the extracts agree with that has been observed.

The overall reduction pattern in tick counts after treatment suggests that there was a significant reduction in tick loads on cattle within 24 h after treatment and remained steadily low for close to a week before reinfection began to show on day six (Fig. 3). Tick numbers reduced from day 1 to day 6. The general impression showed that the acaricidal effects of the leaf extracts on ticks were significant and should be recommended for use by small-scale farmers and those venturing in organic farming.

From these results, the protection period was 5–6 days post-treatment which suggests that under high tick challenge in the field, dipping should be repeated weekly. Interestingly, weekly dipping is also recommended when using commercial acaricide during periods of high risk. Studies by Barnes and Freyre (1966), Gaskins et al. (1972) have shown that the rotenoid present in leaves of *T. vogelii* is effective in killing numerous pests, yet all toxicity is lost in 5–6 days. According to Koigi (2011), *T. vogelii* crude extracts usually remain for a week after which results appear. In another study, Gadzirayi et al. (2009) showed that there was no significant difference in performance by using *T. vogelii* and Triatix dip (a conventional dip chemical) for tick control. These findings show that it is easier to use *T. vogelii* leaf extracts by small-scale farmers which are cheaper to propagate for tick control. Similar observations by Dougnon et al. (2014) have supported the findings that the effects of *T. vogelii* and a (Alfapor—cypermethrin) synthetic acaricide are similar.

The drastic drop in tick mortalities suggests that the effectiveness of the leaf extract is high and can be observed within 24 h after its application (Fig. 4). The negative control showed an increase in the number of ticks after treatment with water which had no effect on the ticks on the cattle. The difference in tick counts before treatment to different concentrations were all lowered to zero on the sixth day of observation. The gradient of tick reduction rate was directly proportional to the increase in *T. vogelii* leaf extract concentrations. This is even evident when the slopes for all the concentrations are compared with the control with the lowest reduction seen on day 6 post-treatment. This observation is in agreement with that reported by Muyobela et al. (2016), who found that *T. vogelii* plant extracts have excellent acaricidal activity against ticks and persisted for 8 days with 100% mortality of *A. variegatum* ticks in 24 h. The knockout effect of *T. vogelii* leaf extract was evident and high at all concentration levels as seen with steep slope.

The results also showed that the lower concentration treatment group had the lower mean counts of ticks than the positive control, while in the negative group, the tick counts were higher. This may be related to few number of ticks prior to the application in the 0.05% treatment group. There was also a variation in the mean count between 0.05 and 0.40%.

The incidence rate ratio (IRR) calculated in Table 3 indicates the relationship between the negative control and treatment groups in action. Five percent w/v concentration of *T. vogelii* leaf extracts had the highest reduction rate of ticks of 88%, while 0.10, 0.20 and 0.40% w/v gave 71, 74 and 80% reduction in tick counts, respectively. This observation was not expected, a situation whereby the low concentration treatment group had higher mortalities effects on ticks than the higher concentration treatment group. This could probably be attributed to several factors including: the low number of ticks in this treatment group and inadequate hand spraying of the crude extract to the body sites, especially where ticks were observed on each animal in the group. The study has shown the incident rate ratio in other different groups compared with the negative control with a significant reduction of $p < 0001$. The associations between leaf extract concentrations used for tick mean count reduction were significant. It was further noted that, despite the different level of concentrations, the effectiveness was statistically similar at all concentration. This observation is useful in showing us that the effect of the lower and the higher concentrations are similar, and the usage of biomass in the preparation of the crude extract can be minimized in order to preserve the leaves for the next spray than using higher concentrations which may demand a lot of biomass of leaves.

There was a progressive increase in the efficacy of *T. vogelii* leaf extracts, resulting in reducing the number of ticks on sprayed animals. From day 1, the efficacy was above 50% of tick reduction from different concentrations. The summary of daily mean efficacy ranged from 85.6% on day 1 to 98% on day 5. It can be confirmed that from the day after application of the extract, there is likely to show increase in efficacy of the extract.

It was possible to achieve a significant efficacy of *T. vogelii* leaf extract use as bio-acaricide at 5% concentration w/v instead of the earlier prescribed 10% w/v (Kaposhi 1993). The implication of this finding will significantly reduce the required biomass needed in the preparation of the *T. vogelii* bio-acaricide by farmers, thus conserving their fields and reducing the cost of treatment using this method. There was no significant difference in the protection period against reinfection between high and low concentration.

Conclusion

The crude extracts were effective in reducing the number of ticks on cattle and could be used as an acaricide by resource-poor livestock farmers and also by those undertaking organic farming. Since the crude extract was effective even at low concentration, utilization of the biomass can be reduced in order to allow more leaves to grow on the plant.

Recommendation

From this study, it can be recommended that *T. vogelii* plant leaf extracts be considered for use as an acaricide because they are effective in the control of tick on cattle under field conditions. The utilization of biomass should be significantly reduced for improved sustainability in the long run. Further checking of the leaf performance at every growth stage must be evaluated for its effectiveness.

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Author contributions CPS, HC and EM conceived and designed the study; CPS and HC performed the field experiments; JBM, KC and CPS analyzed the data and wrote the paper.

Compliance with ethical standard

Conflict of interest The authors declare no conflict of interest in the study.

Ethical standard The research proposal was first approved by the Graduate Research Committee at the School of Veterinary Medicine at the University of Zambia. Ethical approval was granted by the Ethics Committee of the Ministry of Fisheries and Livestock in Zambia (Ref No. 2015/002). The district veterinary officers-in-charge of animals in the study areas were also informed of the study. Consent to use the animals was verbally obtained from individual farmers after explaining the objectives of the study.

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