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Evidence-based tick acaricide resistance intervention strategy in Uganda: concept and feedback of farmers and stakeholders

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Abstract

The emergence of multi-acaricide resistant ticks has led to unprecedented level of acaricide failure in central and western Uganda. In the absence of a national acaricide resistance management strategy, the country's dairy sector is threatened by upsurge of ticks and tick-borne diseases. In this study, we developed a short-to-medium-term intervention approach called Evidence-Based Acaricide Tick Control (EBATIC): Identify, Test, Intervene and Eradicate (IT-IE). Furthermore, the perception of 199 farmers and extension workers, 12 key informants in four districts and 47 stakeholders in the animal industry in Uganda were assessed using semi-structured questionnaires. We report that the establishment of a specialized laboratory is pivotal in identifying and testing (IT) acaricide resistant ticks for prompt intervention and eradication (IE). The laboratory test results and the farm tick control gaps identified are very important in guiding acaricide resistance management strategies such as evidence-based acaricide rotation, development and dissemination of extension materials, training of farmers and extension workers, and stakeholders' engagement towards finding sustainable solutions. All the 47 stakeholders and 91.0% (181/199) of farmers and extension workers reported that the EBATIC

approach will help in solving the tick acaricide resistance crisis in Uganda. Similarly, all the 12 key informants and 92.5 % (184/199) of the farmers and extension workers suggested that the EBATIC approach should be sustained and rolled out to other districts. The EBATIC stakeholders' dialogue generated both short-to-medium and long-term strategies for sustainable management of tick acaricide resistance in the country. Overall, the positive feedback from farmers, district veterinarians and stakeholders in the animal industry suggest that the EBATIC approach is a useful proof-of-concept on scalable intervention pathway against tick acaricide resistance in Uganda with possibility of adoption in other African countries.

Key words

Acaricide resistance, evidence-based, *R. appendiculatus*, *R. decoloratus*, tick control

1. Introduction

The use of pesticides in crop and animal production has greatly increased agricultural production through suppression of pest populations below the economic threshold (Sparks and Nauen, 2015). Ticks and other arthropods vector pathogens and cause physical damage to animals, hence the need for routine control using acaricides and insecticides (Graf et al., 2004). The most economically important tick species that parasitize domestic animals in Africa include *Rhipicephalus* spp., *Boophilus* spp., and *Amblyomma* spp. These ticks vector parasites that cause fatal diseases such as theileriosis, babesiosis, anaplasmosis and cowdriosis (De Castro, 1997). Several classes of acaricides have evolved and marketed globally to combat ticks (Abbas et al., 2014). In Africa, the history of chemical tick control has been traced back to arsenic and organochlorines (Keating, 1983) before the introduction of organophosphates, synthetic

pyrethroids and amidine. However, persistent use of chemicals for control of ticks often leads to the selection of resistant strains (Abbas et al., 2014; Guerrero et al., 2012).

In Uganda, acaricide failure due to tick resistance against organochlorine was first reported in 1970 (Kitaka et al., 1970). In the 1960's, Uganda had a streamlined mechanism for control of acaricide supply chain through zonation, implemented by the Ministry of Animal Industry. However, the structural adjustment programs in 1990's led to a merger of the Ministry of Animal Industry with Ministry of Agriculture, leading to the collateral loss of some of the structures and functions that supported effective tick control (Ociba et al., 2002). Subsequently, lack of national policy on ticks and tick-borne diseases control and widespread irrational acaricide use has led to the emergence of multiple acaricide resistance in especially western and central Uganda (Vudriko et al., 2016; Vudriko et al., 2017).

The future of chemical tick control is under serious threat due to reports of emergence of multiple acaricide resistance (Mendes et al., 2011; Vudriko et al., 2016). Recent findings that revealed the emergence of tick resistance against ivermectin, fipronil (Castro-Janer et al., 2011; Mendes et al., 2011) and fluazuron (Reck et al., 2014) suggest that care must be taken to preserve the efficacy of the existing chemicals, lest there would be no options. Whenever acaricides fail, there is an exponential increase in tick population leading to tick worries, increase in the incidence and costs associated with treatment of tick-borne diseases (Foil et al., 2004).

Tick acaricide resistance management strategies are therefore an essential component of chemical tick control. However, lack of tick acaricide resistance surveillance data in Uganda for the last one decade meant that the country lacked the relevant information to inform strategy. This may be partly attributed to lack of a specialized laboratory for diagnosis of acaricide resistance and pragmatic monitoring of the efficacy of licensed acaricide molecules in the country. Since farmers are likely not to have knowledge on acaricide resistance, whenever chemicals fail, they are tempted to think that the acaricide in use is fake and weak. Thus, cases of

increasing concentration of acaricide beyond the manufacturers' recommendation and shortening acaricide application interval from 1 week to 3 days have been practiced as a means of overcoming acaricide failure due to the perceived "fake and weak" acaricides. We previously reported that such practices would potentially worsen acaricide resistance with possible adverse effect on public health (Vudriko et al., 2016). This study, therefore, sought to develop a simple and sustainable intervention approach that can be adopted for prudent chemical tick control following emergence of tick acaricide resistance in Uganda. We also report the perception of farmers, extension workers and selected stakeholders in Uganda's animal industry on whether the proposed EBATIC intervention approach will improve rational chemical tick control and management of acaricide failure and resistance in Uganda.

2. Materials and methods

2.1. The study area

We previously investigated tick control practices in Adjumani, Mbarara, Mitooma and Rukungiri districts in Uganda as shown in Fig. 1 (Vudriko and Suzuki, Unpublished). The same districts were used to extend an intervention approach aimed at creating awareness on acaricide resistance, enhancing farmers' knowledge on prudent chemical use and building a technical support system for diagnosis of acaricide resistance towards prompt intervention. The three districts in southwest included Mbarara, Mitooma, and Rukungiri while Adjumani district is located in northwestern Uganda. Southwestern Uganda is the backbone of the country's dairy industry and contributes up to 25% of the total milk production (Balikowa, 2011). The population of cattle in Mbarara and Rukungiri district were estimated as 149,992 and 60,061, respectively (MAAIF and UBOS, 2008). In Mitooma district, it was estimated that 19.5% of the household own cattle as part of mixed (crop-livestock) farming (UBOS, 2011). Adjumani district, on the other hand was reported to have 105,229 heads of cattle in the 2008 livestock census (MAAIF and UBOS, 2008). The three districts in southwestern Uganda have been confirmed in our previous study to have acaricide resistant ticks (Vudriko et al., 2016) and threats of possible spread were feared. Livestock production is considered as an integral part of the household food and income security in the study areas and any surge in ticks and tick-borne diseases, especially in the southwest would not only cause worries but affect livelihoods.

2.2. Study design

This was a community action research in which an intervention approach against tick acaricide failure was developed and transferred to the community. The intervention approach

included conceptualization of evidence-based tick control approach, development of knowledge enhancement tools for farmers and animal health workers, conducting training seminars on rational chemical tick control, stakeholder workshop for creating awareness on acaricide resistance and the establishment of a specialized laboratory for tick susceptibility testing to enhance rational acaricide prescription. Knowledge transfer training seminars were implemented at community level in the respective districts and the perception of 199 participants was assessed using semi-structured questionnaires. The category of respondents who participated in the training included farmers, district extension staff (veterinary and agricultural service providers) and district administrators. A stakeholders' workshop was organized to foster dialogue on tick acaricide resistance, towards identifying actor specific solutions. The workshop was attended by participants from the four study districts, National Drug Authority (NDA), the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), National Livestock Resources Research Institute (NaLIRRI) and academic institutions. The perception of the stakeholders and key informants from the four districts on EBATIC approach were also assessed using questionnaires. The development of the intervention approach is detailed below.

2.3. Designing the intervention approach

2.3.1 Conceptualizing the approach

A conceptual framework for intervention was developed based on critical gaps in chemical tick control identified in our earlier baseline survey (Vudriko and Suzuki, Unpublished). The approaches were categorized as; i) development of knowledge enhancement kit for farmers and extension workers; ii) establishment of technical capacity for acaricide susceptibility and resistance diagnosis; iii) Community and stakeholders' engagement. The knowledge enhancement kit consisted mainly of posters, guide/manual on appropriate chemical

tick control, farm assessment report that identified gaps in tick control and laboratory findings and recommendations. Technical capacity building involved the establishment of the Research Center for Ticks and Tick-borne disease Control (RTC), training of laboratory personnel on tick taxonomy, rearing, bionomics and *in vitro* tick-acaricide resistance assays. Blending technical capacity and knowledge enhancement was used to deliver a unified intervention approach referred to as evidence-based acaricide tick control (EBATIC), which aimed at taking the laboratory findings to the community for improved tick control outcomes.

2.3.2. Intervention

The farmers were mobilized by the veterinary departments in the four districts. Each farmer whose farm was profiled in our earlier baseline study on chemical tick control practices received their farm report and recommendations on appropriate tick control. The training workshop was organized to train participating farmers on appropriate acaricide use practices to minimize acaricide failure and prolong the effectiveness of acaricides. The major areas of training included ticks and their importance, farm structures for appropriate acaricide application, understanding instructions on acaricide bottles, proper acaricide dilution and application, acaricide safety tips, detection of acaricide failure or resistance, and procedures for collection of ticks and submission for testing. After the training, the farmers whose farms were baselined were each given a manual on appropriate chemical tick control.

2.3.3. District extension (Veterinary) staff

Technical staff under the district production (Veterinary department) participated in a separate training seminar on appropriate tick control. The Agriculture staff and district

administrators from southwestern region requested to participate in the training because they also owned cattle and were concerned about the widespread tick acaricide failure in their community. Like the farmers, each of training participant received a guide/manual on appropriate chemical tick control for strengthening their technical capacity.

2.4. Assessing perception of the participants on EBATIC approach in solving tick acaricide failure and resistance

A semi-structured questionnaire was used to assess the perception of 199 training participants (farmers, extension workers, and district administrators) who attended the training on the effectiveness of EBATIC approach in solving tick acaricide resistance. The key variables assessed included challenges with acaricide failure or presence of ticks on cattle, the usefulness of the training session in enhancing their knowledge on appropriate chemical tick control and whether they would recommend EBATIC intervention to other farmers. The participants also reflected on their own irrational acaricide application practices in relation to the knowledge acquired during the training and proposed areas they will improve. In addition, 12 district technical staff were randomly selected after the training to rank their level of satisfaction with the performance of EBATIC intervention approach and whether they would integrate it into the district extension system.

2.5. Engagement of stakeholders in the animal industry and their perception

A one-day feedback workshop on EBATIC intervention was organized and actor specific solutions were proposed through group discussions. Separate groups included; i) Local government (district) veterinarians and farmers' representatives; ii) Veterinary pharmaceutical

drug suppliers; iii) Regulatory bodies (NDA and MAAIF); iv) National research and training institutions (NaLIRRI and Makerere University). Each category of groups was tasked to discuss and propose short-to-medium (2-3 years) and long-term (over 4 years) intervention strategies against tick acaricide resistance. In addition, a semi-structured questionnaire was used to assess the perception of 47 participants on the effectiveness of the EBATIC approach in addressing acaricide resistance in Uganda.

2.6. Data analysis

The responses from the questionnaire data were coded, entered in Microsoft excel and analyzed in SPSS version 21 (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). The resultant statistical outputs were presented as frequency tables. Data generated in the focused group discussion were synthesized, categorized and presented as stakeholder specific recommendations in tabular format.

2.7. Ethical considerations

The study was approved by the College of Veterinary Medicine, Animal Resources and Biosecurity, Makerere University (Approval number: VAB/REC/15/104). Ticks were handled under strict internal procedure involving restriction of access to tick incubation room, autoclaving all materials used for larval packet test (LPT) or immersing them in hot water at 99 ^{o}C for 30 minutes. Questionnaires were administered to only those participants who consented to the study and the identity of the respondents were kept confidential. Each farmer whose farm was used for baseline data collection received a report and recommendations for improvement of tick control practices.

3. Results

3.1. Description of the EBATIC approach

The EBATIC intervention approach is illustrated in Fig.2. The EBATIC approach involved integrated activities aimed at generating evidence to inform appropriate farm intervention and also foster multi stakeholder dialogue for generating ideas and solutions against tick acaricide failure and resistance in Uganda. The approach recognizes the multiplicity of actors who play a key role in ticks and tick-borne disease control and have responsibilities in ensuring that licensed chemicals are not only used prudently but their efficacy is monitored through an organized system. In the EBATIC approach, a specialized laboratory such as RTC is not only central in generating evidence for informing farm intervention but also basis for stakeholder dialogue. The framework and mechanism through which tick control service providers, regulators and researchers can effectively work together to detect and intervene against acaricide resistance is shown in Fig. 2. The core components of the EBATIC approach are described below.

3.1.1. Identify farms with tick acaricide failure

Both government (district extension staff) and private service providers (animal health workers and drug suppliers) were recognized as pivotal in identifying acaricide failure hotspots in livestock farms or communities. Regulatory bodies (ministry responsible for animals and drug regulatory authority) also received complaint from farms on acaricide infectiveness and referred the farmers to the RTC laboratory. It was therefore evident that the above entities formed a key intermediary between farmers and tick testing laboratory. The EBATIC approach therefore emphasizes the importance of fostering relationship between RTC laboratory and farm service

providers to guarantee a sustainable information loop, tick submission and referral. However, the laboratory also initiated community outreach to identify farms with tick acaricide failure based either on the request by a concerned farmer or farmer groups.

3.1.2. Testing and diagnosis of acaricide resistance

Central to the EBATIC intervention approach was the establishment of a dedicated Tick Acaricide Resistance Testing Service Center referred to as RTC. Upon sample reception, ticks were identified to species level based on morphology. The engorged ticks were incubated so that first generation larvae were produced for carrying out various panels of acaricide tests by larval packet test to identify chemicals which were effective. Comprehensive farm reports containing farm specific recommendations were compiled based on both laboratory evidence and farm tick control gaps identified. Where few engorged ticks have been collected, farmers were given reports containing recommendations based on farm tick control gaps identified during farm appraisal.

3.1.3. Intervention

Evidence of inappropriate farm tick control practices and where possible laboratory tick tests were key in the intervention. Three approaches were used;

Farm level: During the EBATIC pilot study, a feedback sensitization and training seminar was organized at the time of delivery of results. This approach allowed farmers to learn about appropriate tick control but also reflect on their previous mistakes regarding tick control, and relate those errors to why acaricides fail and ticks become resistant. Hence, the farmers were able to envision and propose what they needed to fix to improve tick control and prevent future

acaricide failure. The intervention farmers were also given the knowledge enhancement kit which mainly included the RTC guide on appropriate chemical tick control, EBATIC brochure and poster.

Government and private extension service providers: Since acaricide resistance was a relatively new phenomenon to some extension service providers, it was prudent that the knowledge of service providers was enhanced. A separate training seminar was conducted for technical and administrative staff on tick acaricide resistance, causes and predisposing factors for its occurrence and management strategy. They were also trained on appraisal of tick control gaps, tick collection and submission to RTC and interpretation of RTC reports. Like the farmers, each extension staff and drug shop owners were given the knowledge enhancement kit.

Stakeholders' engagement and collective dialogue: The EBATIC intervention approach and its findings were shared with the stakeholders in the animal industry such as the drug regulatory authority, Directorate of Animal Resources, Veterinary pharmaceutical distributors, District Veterinarians, researchers and farmers' representatives. This helped to create awareness on acaricide resistance, EBATIC intervention approach and collective dialogue on what each actor can do to contribute towards preventing and solving tick acaricide resistance in the country.

3.1.4. Eradicate

The implementation of EBATIC recommendations at farm level such as improvement of tick control practices, evidence-based acaricide rotation or both were crucial to successful management of acaricide failure. Further submission of samples for testing in the laboratory allows active and passive monitoring of performance of chemicals recommended for intervention. However, the EBATIC intervention approach may be futile for farms that had ticks

that were resistant to all the acaricides on the market (multiple acaricide resistance). This implied that regulatory oversight and restricted release of acaricide molecules at a time to create reserve is essential in sustainable acaricide rotation and long-term acaricide resistance eradication program.

3.2. Feedback from participants after training on EBATIC intervention approach

The sensitization and training seminar attracted more farmers and district extension and administrative staff as shown in Table 1. A total of 199 participants attended the training, 77.9% (155/199) and 22.1% (44/199) were from the southwestern region and northwestern district of Adjumani, respectively. At the time of the seminar, 89.0% (138/155) of the participants from southwestern Uganda reported that they had acaricide failure in the last 6 months. On the other hand, 37 out of 44 farmers in Adjumani district also had ticks on their cattle. After the training, 80.9% (161/199) of the farmers reported that they gained valuable knowledge and their expectations were met. Only 6.5% (13/199) of the participants were not satisfied with the seminar. Furthermore, 98.1% (152/155) of the participants in the southwest noted that EBATIC training impacted knowledge that is useful in fighting tick acaricide failure or resistance in their areas, 95.5% (42/44) of the participants from Adjumani also agreed that their knowledge on controlling ticks was improved. As such, 95.5% (190/199) of participants from both southwest and Adjumani district reported that they would recommend the training to other farmers. Also, 91.6% (142/155) of the respondents in southwest acknowledged that the EBATIC approach will reduce tick acaricide failure or resistance in their farms. Similarly, 88.6% (39/44) of the participants in Adjumani district noted that the knowledge acquired will help them reduce tick burden on their animals. Overall, 92.5% (184/199) of the training participants noted that they would like to see the EBATIC intervention approach sustained.

3.3. Reflection of the participants on why acaricides failed and what they will change on their farms after the training

Of the 199 participants who were asked to give their opinion about the factors that might have led to acaricide failure in their area (southwest) or presence of ticks on cattle (northwest), 119 (59.8%) participants responded while 80 (40.2%) participants declined to respond (Table 2). Of the 97 participants from southwestern Uganda who disclosed the reasons for acaricide failure in their area, lack of knowledge due to poor extension (24/97), wrong acaricide mixing due to inappropriate measuring equipments (24/97) and using double or triple concentrations (15/97) were mentioned as the main drivers of acaricide failure. Moreover, 67.1% (104/155) of the participants from the southwest pledged to take immediate action to improve gaps in tick control they have identified after the training. These actions included proper acaricide rotation and seeking advice from veterinarians (26/155), adherence to manufactures' instruction (14/155), improving fence and crush (13/155) and synchronizing tick control with the neighbor (10/155). Overall, 35.7% (71/199) of the participants proposed that more sensitization of farmers and improved extension and teamwork were important considerations towards finding lasting solutions against tick acaricide failure and resistance.

3.4. Feedback of key informants from district veterinary department

The feedback of 12 key informants (district veterinary and agriculture staff) who participated in the EBATIC activities such as farm appraisal and training is shown in Table 3. All the key informants (100%) reported that the tick control manual, farm reports and training seminar were the key benefit of the EBATIC intervention approach. They further considered

EBATIC approach relevant (100%) in solving tick acaricide resistance and recommended that it should be rolled out (100%) to other districts.

3.5. Stakeholders feedback

The stakeholders' feedback on EBATIC approach and proposed short-to-medium and long-term intervention strategies against tick acaricide resistance is shown in Tables 4 and 5. The short-to-medium-term solutions proposed by all the actors can be categorized as increased farmer access to extension services, sensitization and training on appropriate chemical tick control, increasing access to acaricide strength (concentration) and tick susceptibility testing services at regional level, promotion of integrated tick control (Fig. 3), instituting local by-laws to enforce proper tick control practices, strengthening veterinary drug regulation, supporting research on ticks and tick-borne diseases (TBD) and increased financial allocation for ticks and TBD control. The long-term strategies proposed included enacting a law to govern ticks and TBD control, introduction of new acaricide molecules and vaccines against ticks and TBD, close partnership between local researchers and veterinary drug manufactures in identifying and trial of novel products against ticks and TBD.

The feedback of the 47 stakeholders who participated in the workshop is shown in Table 4. The EBATIC intervention approach was rated by 83.0% (39/47) of the stakeholders as either very good (24/47) or excellent (15/47) in solving tick acaricide resistance challenge in Uganda. The stakeholders were mostly satisfied with the useful research findings on factors that predispose to acaricide failure or resistance and the EBATIC intervention approach (36.2%, n=47); as well as fostering inclusive dialogue on actor specific discussions (46.8%, n=47) aimed at finding short-to-medium and long-term solutions against tick acaricide resistance in Uganda.

All the 47 stakeholders reported that the EBATIC approach will help in solving tick acaricide resistance. However, strengthening stakeholder alliance and upscaling the EBATIC approach to more farmers across the country was recommended by 66.0% (21/47) of the stakeholders.

4. Discussion

Tick acaricide resistance management is an integral part of chemical tick control. The widespread acaricide failure in Uganda is an indication that there has been lapse in strategic use of chemicals for tick control in the past one decade. One of the strategies employed in acaricide resistance management in 1960's was zonal distribution of acaricide by the central government. This essentially meant that there was regional zonation and rotation of acaricide that allowed some molecules to be reserved for the future. Thus, the initial episode of tick acaricide resistance reported in 1970's by Kitaka et al. (1970) was swiftly managed by switching from the organochlorine –Toxaphene to organophosphate Supona® (chlorfenvinphos) and Steladone® (chlorfenvinphos) in 1980 (Otim, 2000). However, the central control of acaricide supply by the Ministry of Animal Industry was lost following structural reforms and liberalization of the economy in 1990's. Divesting tick control to the local governments (1997) and designation of ticks and tick-borne diseases (TBD) as private good further created a vacuum in centralized institutional arrangements for effective monitoring of acaricide resistance. The consequence of the above vacuum has now manifested as unprecedented level of acaricide resistance in western and central Uganda, amidst lack of national acaricide resistance management strategy.

Given the challenges stated above, the EBATIC intervention approach (Fig. 2) was developed to enhance the knowledge of farmers and extension workers on prudent acaricide use. The approach was also intended to create an opportunity for collective dialogue among stakeholders towards finding solutions against tick acaricide failure and resistance in Uganda (Tables 4 and 5). Based on the feedback post training (Tables 1 and 2), it was clear that the participants (mainly farmers) lacked enough information on appropriate use of chemicals for tick control. Sharing practical evidence of wrong tick control practices identified in their area enabled the farmers to reflect, realize and commit to making positive changes in both facilities and tick

control practices as showed in Table 2. We expect that the knowledge enhancement tools like the guide on appropriate tick control and brochures will positively re-enforce the commitment of farmers towards use of recommended practices for chemical tick control. Availing the same tools to area animal health workers would help them to sustain dissemination of the content during their routine farm visits and community training. The importance of information in promoting rational chemical tick control was also reported by George et al. (2004).

The establishment of a dedicated RTC laboratory was a very important step towards sustainability of the EBATIC approach and tick acaricide resistance surveillance in Uganda (Fig. 2). The information generated from continuous testing of ticks can also be used as surveillance tool for monitoring performance of existing and newly introduced molecules, as well as informing future acaricide rotation and zonation. The importance of laboratory testing in efficacy of tick control outcomes has also been highlighted by Moyo and Masika (2009). Since its establishment, RTC has received exponential number of tick submissions by both farmers and veterinarians. This has helped farmers to know the status of acaricide performance in their farms and to institute evidence-based acaricide rotation. The veterinarians who submitted samples also used the RTC results for evidence-based acaricide prescription, where possible. The benefit of evidence-based acaricide application includes increased success rate of tick control outcome and reducing losses resulting from purchase of non-effective classes of acaricides. It is also hypothesized that prescription of effective acaricide may lead to reduction in the incidence of TBD infection and losses associated with treatment of the clinical disease.

Stakeholders' dialogue aimed at fostering collective alliance and synergy against ticks and TBD was one of the key pillars of the EBATIC approach. The stakeholders' dialogue generated very important proposals for sustainable control of ticks and TBD in Uganda (Tables 5A and 5B). The actor specific short-to-medium and long-term solutions proposed by the

stakeholders can be used by the line ministry to institute strategic interventions against ticks and TBD in Uganda. The short-to-medium-term interventions proposed are aimed at addressing farmers' knowledge gap in appropriate tick control and strengthening access to quality technical services (extension) as shown in Table 5A. Based on the feedback of the respondents (Tables 1 and 2), farmers' knowledge on proper use of acaricides can be achieved through mass sensitization, training and demonstration of appropriate techniques for tick control. This has to be simultaneously carried out with continuous professional development (CPD) for animal health service providers so that they are equipped with the knowledge on acaricide resistance management. It is worth noting that the deficiencies in veterinary extension services has been widely reported as one of the major constraints to animal production in Uganda (Bugeza et al., 2017; Kabunga et al., 2016; Mbolanyi et al., 2017; UBOS, 2016). A survey by International Food Policy Research Institute (IFPRI) on the state of public service delivery in Uganda reported glaring gap in both the level of access and quality of livestock extension services. The study found that a mere 11.0% of the rural households received one visit by livestock professional within a year and only 8.0% claimed to have received knowledge and expertise from visiting an extension officer (Kabunga et al., 2016). The researchers at the Economic Policy Research Center (EPRC) in Uganda further argued that the country's agricultural extension human resource level has reached a crisis level following the ban in the recruitment of public extension officers at district level (Barungi et al, 2016). This ban has created an estimated 86.0% extension human resource deficit at sub-county level (Barungi et al, 2016). Therefore, employing more veterinarians at lower administrative units such as sub-counties will help to bridge the current gap in animal health extension service delivery in areas experiencing acaricide resistance crisis. Increased routine farm visits by area veterinarians is critical in early identification of farms with acaricide failure, inspection of animals on transit, submission of tick samples for testing and using the result to intervene early before the resistant ticks spread to neighboring areas.

Strengthening regulation of veterinary drugs and acaricides to ensure professionalism in drug dispensing and promotions, pharmacovigilance and ensuring only effective molecules are in circulation was suggested as an action for the drug regulator and MAAIF (Table 5). However, sustainable regulation of veterinary drugs under the current unified veterinary drug regulation requires close collaboration between the drug regulator and MAAIF, as well as implementation of the National Veterinary Drug Policy (2002) which strongly emphasizes promotion of rational veterinary drug use at farm level. Furthermore, farmers in Uganda use drug shops as an alternative extension service point, thus the technical capacity of human resources at the shop determines the quality of advice farmers get from the drug outlets. Regular inspection of veterinary drug outlets to weed out unqualified personnel is crucial. However, the most viable option for on-farm management of acaricide failure is to promote integrated tick control to reduce over dependence on acaricides (Fig. 3). The proposed integrated approaches include rotational pasture grazing and spelling for farms with paddocked pasture, intensification of dairy cattle management with alternative feeding technologies such as silage and hay to reduce contact between ticks and cattle, immunization against theileriosis (Ociba et al., 2002; Pegram et al., 1993), and rearing tick and TBD resistant breeds of cattle (Kaiser et al., 1982). Integrated tick control will substantially reduce the over dependence on acaricides and lessen selection pressure by ticks, thus preserving the efficacy of chemicals and reducing incidence of acaricide resistance (Jongejan, 1999; Mondal et al., 2013; Young et al., 1988).

The long-term strategy for control of ticks and TBD will ultimately depend on harnessing technologies like vaccines against both the ticks and TBD as suggested by stakeholders (Table 5B). Already, anti-tick vaccines have been reported to be effective in controlling acaricide resistant *R. microplus* ticks in Cuba and Venezuela (Suarez et al., 2016; Valle et al., 2004). Such existing anti-tick vaccines developed against *R. microplus* could be tested against *R. decoloratus* for possible adoption in Uganda. However, due to limited cross-protection (de la Fuente et al.,

2000), the long-term strategy should focus on establishing collaborative research between the local scientists and leading anti-tick research and development companies for identifying novel antigens from other economically important tick species such as *R. appendiculatous* and *A. variegatum* to produce a broad spectrum anti-tick vaccine. Furthermore, there is need to invest resources in research and development of vaccines against TBD, especially babesiosis and anaplasmosis based on the local strains. For example, Australia is among the countries that have used babesia and anaplasma cocktail vaccine successfully in cattle (Bock and de Vos, 2001). For Uganda to fast-track development of such vaccine, there is needs for a deliberate policy and financial resources to support research and technology development for control of the above diseases as part of an integrated and evidence-based ticks and TBD control initiative.

5. Conclusions

Overall, this study proposed evidence-based approach (EBATIC: IT-IE) as a short-to-medium-term intervention pathway for management of tick acaricide resistance in Uganda. Building national laboratory and technical human capacity is pivotal in prompt detection of acaricide resistant ticks, evidence-based acaricide rotation and monitoring the efficacy of acaricide resistance eradication interventions. Moreover, both laboratory and farm-based evidence can be used to support development of community sensitization and training packages for behavioral change and adoption of appropriate tick control practices. Such efforts should be complemented with a broader stakeholder dialogue aimed at identifying actor specific solutions that will constitute a foundation for national acaricide resistance management strategy.

Conflict of interest

Non to declare.

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Figure caption

Fig. 1. Map of Uganda showing the study.

Mbarara, Mitooma and Rukungiri districts are in southwestern Uganda. Farmers in southwest keep both local and exotic crossbreed cattle and generally acaricide pressure and acaricide failure are high. Adjumani district is located in northwestern Uganda and farmers rear indigenous cattle, thus low acaricide pressure and no acaricide resistance.

Fig. 2. Evidence-based acaricide tick control (EBATIC) intervention approach against tick acaricide resistance in Uganda.

EBATIC: IT-IE involves identifying farms with acaricide failure and gaps in tick control, collecting tick samples and testing in the laboratory and using the test and farm tick control gaps identified to intervene and eradicate acaricide resistance.

CPD, Continued Professional Development; DVO, District Veterinary Officer; NDA, National Drug Authority; MAAIF, Ministry of Agriculture, Animal Industry and Fisheries; RTC, Research Center for Ticks and Tick-borne diseases control; TBD, Tick-borne diseases

Fig. 3. Roadmap for integrated tick control approach for management of tick acaricide resistance in Uganda.

Roadmap generated during EBATIC stakeholders workshop as a pathway for management of tick acaricide resistance in Uganda.

Fig.1

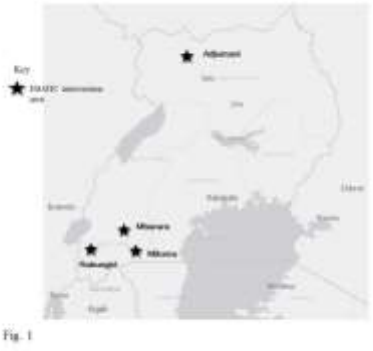

Fig. 1

Fig.2

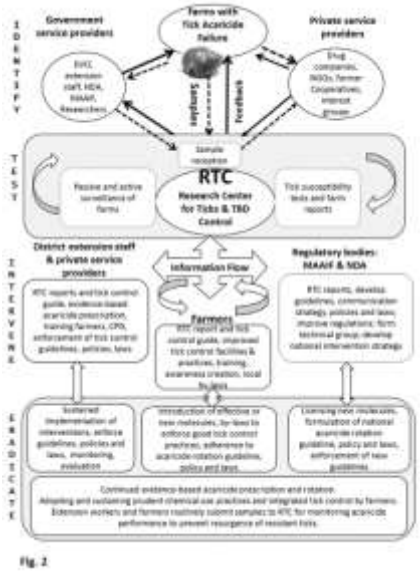

Fig.3

Table 1. Feedback from the EBATIC sensitization and training seminar on acaricide resistance and appropriate chemical tick control for farmers and district extension staff

Characteristics	Variables	Region		Total	Percentage
		Southwest	North		
Intervention district	Mitooma	88	0	88	44.2
	Adjumani	0	44	44	22.1
	Rukungiri	38	0	38	19.1
	Mbarara	29	0	29	14.6
	Total	155	44	199	100.0
Gender of participant	Male	123	40	163	81.9

	Female	32	4	36	18.1
Category of participants in the sensitization and training seminar	Farmer	100	23	123	61.8
	Animal husbandry officer	23	5	28	14.0
	No response	12	12	24	12.1
	District veterinarian	7	1	8	4.0
	District administrative officer	4	1	5	2.5
	Drug shop attendant	4	0	4	2.0
	Agriculturalist	5	2	7	3.5
Do you have challenge of acaricide failure on your farm or tick burden?	Yes	138	37*	175	87.9
	No	15	6	21	10.6
	No response	2	1	3	1.5
Were your expectations met in the sensitization/ training seminar	Yes	130	31	161	80.9
	No response	18	7	25	12.6
	No	7	6	13	6.5
Do you think this kind of seminar is useful for fighting tick in your area?	Yes	152	42	194	97.5
	No	2	1	3	1.5
	No response	1	1	2	1.0
Would you recommend other farmers for the same training?	Yes	149	41	190	95.5
	No response	4	1	5	2.5
	No	2	2	4	2.0
Do you think the EBATIC approach will reduce the tick acaricide resistance challenge in your area?	Yes	142	39	181	91.0
	No response	8	2	10	5.0
	No	5	3	8	4.0
Would you like to see the EBATIC approach sustained?	Yes	145	39	184	92.5
	No response	9	2	11	5.5
	No	1	3	4	0.6
	No response	88	19	107	53.8

Any suggestion regarding EBATIC approach?	Regular sensitization seminars at grassroot for farmers and extension officers	34	14	48	24.1
	Extend EBATIC model and research to other farmers and districts in Uganda	23	9	32	16.1
	Government should enact strict laws to govern acaricides use and tick control	7	0	7	3.5
	Providing extension material like the EBATIC manual to all farmers	3	2	5	2.5

* No acaricide failure but presence of ticks due to irregular acaricide application

Table 2. Reflection of participants on wrong practices on the farms that might have led to acaricide failure or tick challenge and what they will do to improve tick control

Question	Response	Region		Total	Percentage
		Southwest	North		
In your opinion, what are the factors that led to acaricide failure in your farm or area?	No response	58	22	80	40.2
	Wrong acaricide mixing and inappropriate measuring equipment	24	11	35	17.6
	Farmers lack of knowledge and poor extension services	24	5	29	14.6
	Irrational acaricide use (doubling or tripling concentration)	15	1	16	8.0
	Low pressure pumps use and not wetting the animal properly	8	0	8	4.0
	Improper farm structures and poor farm management	3	3	6	3.0
	Irregular spraying of animals	5	1	6	3.0
	Farmers failure to adhere to professional advice	5	0	5	2.5
	Poor acaricide regulation (all classes are on the market)	4	0	4	2.0
	Acaricide overuse for long time	4	0	4	2.0
	lack of consensus with neighbors on the type of acaricides to use	1	1	2	1.0
	Getting advice from wrong (unqualified) people	1	0	1	0.5
	Inadequate supervision by farm owners during spraying	1	0	1	0.5
	Other animals like goats and dogs are not sprayed	1	0	1	0.5
	Acaricide is washed off quickly in rainy season	1	0	1	0.5
	Total	155	44	199	99.9
After today's	No response	51	21	72	36.2
	Proper rotation of acaricide and seeking veterinary advice	26	0	26	13.1

seminar, which aspect of tick control will you improve on your farm?	Proper spraying to wet the animal with acaricide and reach all tick attachment sites	17	4	21	10.6
	Use right amount of acaricide and water for mixing as instructions and instructed by manufacturer	14	3	17	8.5
	Proper dilutions and change from hand spray to bucket/foot pump	7	8	15	7.5
	Fencing and improving crush and other farm structures	13	2	15	7.5
	Synchronizing day of spraying with neighbor	10	1	11	5.5
	Proper dip management and charging dip tank	7	2	9	4.5
	Proper record keeping for acaricides used	4	1	5	2.5
	paddocking and improves farm management	1	2	3	1.5
	Training my workers and those of neighboring farm on proper tick control	3	0	3	1.5
	Improve supervision of spraying on my farm	2	0	2	1.0
In your opinion, how best do you think the current problem tick acaricide failure can be solved?	Sensitization of farmers and improved extension service delivery	56	15	71	35.7
	No response	49	17	66	33.2
	Team work among stakeholders and the government	17	3	20	10.1
	Follow instructions from manufacturers and veterinary professionals regarding acaricide use	12	2	14	7.0
	Proper acaricide mixing, measurement and application	8	3	11	5.5
	New policies and regulations for acaricides and tick control	5	2	7	3.5
	Proper rotation within different classes of acaricides	7	0	7	3.5
	regular spraying of animals	1	2	3	1.5

Table 3. Feedback of key informants on performance of EBATIC approach in appropriate control of ticks and management of acaricide failure and resistance

Characteristics	Variable	Region		Total	Percent
		South west	North		
Characteristics of key informants at the intervention district	Veterinary officer	2	2	4	33.3
	AHO	3	1	4	33.3
	Agriculturalist	2	0	2	16.7
	Entomologist	1	0	1	8.3
	Lab technologist	1	0	1	8.3
How did you/ your district benefit from the project	EBATIC manual, sanitization/training seminar & Farm reports	9	3	12	100.0
Rate your level of satisfaction with the content and relevance of EBATIC Tick control manual	Highly satisfied	6	1	7	58.3
	Satisfied	3	2	5	41.7
Rate your level of satisfaction with relevance of EBATIC Farm reports and recommendations	Satisfied	5	2	7	58.3
	Highly satisfied	4	1	5	41.7
Rate your level of satisfaction on EBATIC farmers sensitization seminar on tick control and acaricide resistance	Highly satisfied	5	2	7	58.3
	Satisfied	3	1	4	33.3
	Moderately satisfied	1	0	1	8.3
Rate the performance and importance of EBATIC project activities in your district	Excellent	5	0	5	41.7
	Very good	4	1	5	41.7
	Good	0	2	2	16.7
Integration of EBATIC in extension	Very good	2	3	5	41.7
	Excellent	4	0	4	33.3
	Fair	2	0	2	16.7

Characteristics	Variable	Region		Total	Percent
		South west	North		
Characteristics of key informants at the intervention district	Veterinary officer	2	2	4	33.3
	AHO	3	1	4	33.3
	Agriculturalist	2	0	2	16.7
	Entomologist	1	0	1	8.3
	Lab technologist	1	0	1	8.3
	Good	1	0	1	8.3
Rate relevance of EBATIC in solving acaricide resistance	Highly relevant	7	0	7	58.3
	Relevant	2	3	5	41.7
Should EBATIC be rolled to other districts with tick challenge?	Yes	9	3	12	100.0

AHO, Assistant Animal Husbandry Officer; EBATIC, Evidence based tick acaricide control; Lab, Laboratory

Table 4. Perception of stakeholders' on the relevance of EBATIC intervention approach in solving tick acaricide resistance in Uganda

Characteristics	Variables	Frequency	Percent
Gender of respondents	Male	40	85.1
	Female	7	14.9
	Total	47	100.0
Category of stakeholders in the EBATIC dialogue workshop	Extension service provider	8	17.0
	Academia	7	14.9
	Regulatory body (NDA & MAAIF)	5	10.6
	Research institution	3	6.4
	Farmer representative	3	6.4
	Farmers' cooperative union	1	2.1
	Non-governmental organization	1	2.1
	Pharmaceutical representative	1	2.1
	Others	18	38.3
Rate relevance of EBATIC initiative solving the current tick acaricide resistance challenge in the country	Very good	24	51.1
	Excellent	15	31.9
	Good	7	14.9
	Fair	1	2.1
Which part of EBATIC approach satisfied you most	Stakeholders' focused group discussions and sharing	22	46.8
	EBATIC model , its research findings and suggested way forward	17	36.2
	Farmer representative presentation	6	12.8
	Understanding acaricide classes and rotation	1	2.1
	Collaboration with partners	1	2.1
Do you think EBATIC approach will help in solving acaricide resistance in Uganda?	Yes	47	100.0

If yes, how can it be fully operationalized and sustained?	Stakeholders alliance and synergy to solve tick resistance and TBDs	18	38.3
	Upscaling EBATIC approach to more farmers and other districts	13	27.7
	Regulatory bodies should be strict and enact the policies for tick control	8	17.0
	Multiple farmer sensitization seminars across districts affected by tick resistance	7	14.9
	No response	1	2.1

NDA-National Drug Authority; MAAIF- Ministry of Agriculture, Animal Industry and Fisheries

Table 5A. Short-to-medium-term intervention strategies against tick acaricide resistance proposed by stakeholders during EBATIC workshop

Stakeholders	Short-to-medium-term strategies for acaricide resistance management (2-3 years)
Local government and farmers' representatives	- Mobilization and sensitization of cattle farmers and leaders on acaricide resistance management. - Adequate staffing of extension staff at district and sub county level. - Supervision and inspection of veterinary drug shops by DVOs and NDA. - Regular feedback meeting with stakeholders on acaricide resistance interventions. - Put in place Bi-laws to ensure proper tick control at community level. - Clear channel of information sharing and dissemination on acaricide resistance management strategies. - Renovation and supervision of communal cattle dipping where possible. - Intensification of zero grazing practices where applicable.
Pharmaceutical actors	- Continue availing quality products to the market. - Sensitize farmers on proper application of the acaricides and the recommended equipment and structures required for tick control. - Submission of tick to and acaricide samples to relevant stakeholders (RTC, NaLIRRI, MAAIF, NDA) to enhance the EBATIC program. - Recommend the right acaricide to the farmers based on the proper analysis of the history of acaricide use on the farm and test results from the laboratory. - Discourage mixing of different molecules while spraying animals. - Uphold professionalism in promotion of acaricides and other pharmaceutical products. - Cost effective products in form of a range of volumes that are friendly to all farmers. - Provide calibrated measuring cups attached to each acaricide bottle.
The Regulators (Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and	- MAAIF and NDA should promote integrated tick control. - MAAIF should secure financial resources both locally (Ministry of Finance) and internationally (donors) for intervention program. - MAAIF to co-ordinate different stakeholders in tick and tick borne disease management to build on the EBATIC approach. - Conduct massive community sensitization and training together with all the actors. - Continued professional development to the extension workers on tick acaricide resistance management and EBATIC approach.

National Drug Authority (NDA))	- Strengthening the extension and regulatory services through increased recruitment of veterinarians in both MAAIF and NDA. - Re-instituting the Uganda Veterinary Board to regulate standard of personnel in Veterinary drug outlets so as to weed out quarks who misadvise farmers.
National Research and training institutions	- Collaborative mapping of tick acaricide resistance to identify acaricide resistance hotspots and the classes of chemicals resisted. - Assessing the economic losses associated with acaricide failure and resistance, as well as tick-borne diseases in the affected areas. - Sharing information and experience among researchers on ticks and tick-borne disease control research to avoid duplication of efforts. - Further building of the capacity of both NaLIRRI, RTC and regional laboratories to be able to offer acaricide susceptibility services at large scale towards sustaining the EBATIC approach. - Sensitization of key stakeholders in the country based on available findings. - Formation of acaricide resistance working group to advance research and information needed by stakeholders and inform policy.

DVO, District Veterinary Officer; EBATIC, Evidence-Based Acaricide Tick Control; MAAIF, Ministry of Agriculture, Animal Industry and Fisheries; NaLIRRI, National Livestock Resources Research Institute; RTC, Research Center for Ticks and Tick-borne Diseases Control; NDA, National Drug Authority.

Table 5B. Long-term intervention strategies against tick acaricide resistance proposed by stakeholders during EBATIC workshop

Stakeholders	**Long-term strategies for acaricide resistance management (> 4 years)**
Local government and farmers' representatives	- Decentralization of acaricide strength testing facilities at regional laboratories. - Establishment of demonstration farms (field schools) for training farmers on appropriate technologies for tick and tick-borne diseases control. - Sustaining integrated tick control.
Pharmaceutical actors	- Introduction of new molecules on the market with different mode of action from the ones available in Uganda. - Link experts in the manufacturing industry to the researchers in Uganda to enhance synergy in testing novel products.
The Regulators (Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and National Drug Authority (NDA))	- Advocating for tick and TBD control policy. - Strengthening regulations at importation, distribution and use of the acaricides. - Review of the Veterinary Surgeons Act 1958, to strengthen professional ethics in the practice. - Reviewing the Animal Disease Act, should consider issues of tick acaricide resistance management. - Lobbying for resources by the Ministry of Agriculture, Animal industry and fisheries to carryout mass tick acaricide resistance intervention program.
Research and training institutions	- Collaboration with international research groups with experience in tick acaricide resistance research. - Vaccine research against ticks and tick-borne diseases as part of integrated tick control. - Search on alternative chemicals and natural products against ticks.

	- Collaboration with Pharmaceutical industry to try new novel products against ticks and tick-borne diseases.