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Farmer-led protected zero-grazed dairy cattle initiative in tsetse-infested areas of Southeast Uganda

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Abstract
A farmer-led protected zero-grazed dairy cattle initiative, involving pyrethroid treated netting around zero-grazing cowsheds, was implemented over a four-year period in tsetse-infested areas of Southeast Uganda. The pyrethroid treated netting was intended to prevent dairy cattle against tsetse bites and consequently transmission of trypanosomosis, while boosting milk production as an economic venture. A longitudinal study was conducted in six districts, including Budaka, Busia, Iganga, Manafwa, Mayuge and Tororo, during which a total of 184 protected zero-grazing units holding 289 dairy cattle were visited five times. The prevalence of trypanosomosis, mortality, mean packed cell volume (PCV), the status of netting, spraying practices, and pasture and legume feed status, cowshed hygiene status, and milk yield were monitored. The findings revealed low prevalence of trypanosomosis among dairy cattle (1.0-5.5%), due to *Trypanosoma brucei* (0.0-0.4%), *Trypanosoma congolense* (0.0-0.7%) and *Trypanosoma vivax* (0.4-3.4%) infections. Only 25 adult cattle and 40 calves were reported dead. Dairy cattle had good health, given high mean PCV values (27.7 - 30.6). 99.2% and 100.0% of the zero-grazing units had lost netting by visit IV and V, respectively. By the second to the fourth year, prevention of dairy cattle from tsetse or tick bites hugely relied on spraying because all zero-grazing units had lost netting. Dual tsetse and tick control was practised by 66.9% of the 184 zero-grazing units, while only 33.1% of the units applied tick-selective control. Correct spraying intervals were observed by 57.8% of the zero-grazing units. Most zero-grazing units (range 67.9-97.5%) had sufficient pasture, while few units (range 17.9-34.8%) had sufficient legumes. Poorest cowshed hygiene was observed in zero-grazing units in Budaka district (93.1%), followed by Busia district (33.3%), Iganga district (31.1%), Mayuge district (12.1%), Tororo district (10.0%) and Manafwa district (6.3%). The best average milk yield per cow per day was registered in Iganga district (6.2 L-8.7 L), followed by Mayuge district (4.5 L- 8.2 L), Manafwa district (4.5 L-6.2 L), Busia district (4.0 L-6.3 L), Tororo district (3.3 L-6.7 L), and Budaka district (3.7 L-6.0 L). Overall average milk yield per cow per day of 5.0 L to 6.4 L across visits with a minimum of 0.5 L and maximum of 19.0 L per cow per day were achieved. In conclusion, pyrethroid treated netting around zero-grazing units supplemented with spraying of cattle effectively protected dairy cattle against trypanosomosis and maintained their good health. However, farmers' observation indicated that as netting became older, it became more fragile. Larger nets of 1.5 m high had a longer duration of 6 to 8 months than smaller nets of 1.0 m high (shorter duration of 3 to 4 months). Replacement of netting for all zero-grazing units was desirable after the first year of installation, however, farmers could not afford the cost of 100,000 Uganda shillings (approx. USD 30) per zero-grazing unit.

Keywords: Farmer-led, protected zero-grazed dairy cattle, tsetse-infested region, southeast Uganda

Introduction

As tsetse invaded new areas of Uganda during the 20th Century, numerous control campaigns have been conducted in various areas of Uganda, but none have been sustainable in the long-term (Okoth, 1999; Meyer *et al.*, 2016) [1, 2]. The Farming in Tsetse-Controlled Areas (FITCA) programme was implemented from 1997 to 2004 in East Africa (Meyer *et al.*, 2016) [2]. Funded by the European Development Fund, it operated in Kenya, Uganda, Ethiopia and Tanzania. Initially it made use of impregnated targets and traps set up by government officials and then followed-up with insecticide treatment of cattle (Meyer *et al.*, 2016) [2]. The project also encouraged the use of zero-grazing dairy units protected by insecticide-treated nets (Bauer *et al.*, 2006) [3]. During FITCA project, attempts were made to control tsetse through tsetse-trapping and pour-on application, and trypanosomosis by means of block treatment of cattle in high-risk sub-counties (5% prevalence) with isometamidium chloride and diminazene aceturate in 12 districts in Uganda (Magona *et al.*, 2017) [4]. But was not effective due to insufficient coverage and unsustained control efforts. FITCA faced sustainability issues, such as management and financial challenges often associated with community-based projects, attributed to a lack of engagement of project recipients (Meyer *et al.*, 2016) [2].

Most previous tsetse and trypanosomosis control campaigns implemented in Southeast Uganda had a One Health focus, combining the control of African Animal Trypanosomosis (AAT) with Human African Trypanosomosis (HAT) through treatment of animal reservoirs for *Trypanosoma rhodesiense* (Magona *et al.*, 1998; Févre *et al.*, 2001; Kabasa, 2007; Magona and Walubengo, 2011) [5, 6, 7, 8]. Uniquely, the pyrethroid treated netting intervention supplemented with periodic spraying of cattle and other animal management strategies applied by smallholder farmers was intended to prevent dairy cattle from tsetse bites and transmission of trypanosomosis, while boosting milk production as an economic venture. In the aftermath of tsetse and trypanosomosis control programme, such a campaign advocated for creating a milk value-chain for economic empowerment of rural communities living in tsetse-infested areas. Pyrethroid treated netting (zero fly livestock fence) have been used elsewhere to combat fly challenges affecting smallholder cattle kept under zero-grazing (Bauer *et al.*, 2011; Maia *et al.*, 2012; Megersa *et al.*, 2017) [9, 10, 11]. However, little has been documented about the effectiveness of such a tsetse and trypanosomosis control intervention that was implemented in Uganda over a four-year period in the aftermath of the FITCA project. We report on the prevalence of trypanosomosis and PCV values of dairy cattle, milk yield, status of pyrethroid netting, farmer spraying practices, and status of pasture and legume feed monitored in a longitudinal study conducted among protected zero-grazing units in six districts in Southeast Uganda.

Materials and Methods

Study area

The longitudinal study was conducted among protected zero-grazing units in six districts, including Budaka, Busia, Iganga, Manafwa, Mayuge and Tororo in Southeast Uganda, an area largely infested with *Glossina f. fuscipes* and a limited extent with *G. pallidipes* (Magona *et al*., 2008) [18]. The main vegetation type in Southeast Uganda is savannah grassland. The area receives an annual rainfall of 1,200-1500 mm that is bimodally distributed. There are two wet seasons (March to June and September to November) and two dry seasons (December to February and July to August). The daily mean minimum and mean maximum temperatures are 15 °C and 27 °C, respectively.

Protected zero-grazing cattle initiative

Upon completion of the FITCA tsetse and trypanosomosis campaign in Southeast Uganda in 2005, the protected zero-grazing dairy initiative was established. Amongst 14 farmers from Budaka subcounty, Chali parish in Budaka district; 14 farmers from Busitema subcounty, Tira, Ajuket, Buchicha and Sikunda parishes in Busia district; 14 farmers from Bulamagi subcounty, Bulamagi parish in Iganga district; 14 farmers from Sibanga subcounty, Butta parish and Bugobero subcounty, Bugobero parish in Manafwa district; and 15 farmers from Imanyiro subcounty, Mbale parish in Mayuge district. The basis for selection of specific subcounties and parishes in the districts was areas being high-risk for trypanosomosis and having felt the highest negative impact from tsetse and trypanosomosis as per earlier baseline data. Selected farmers were largely women from rural communities.

FITCA project procured crossbred Friesian in-calf heifers and distributed to selected farmers. In addition, constructed zero-grazing units covered with pyrethroid treated netting. Furthermore, assorted acaricides, spray pumps and veterinary drugs were provided as well. Farmers were also supplied with pasture and legume seed for cultivation. Full veterinary attention was provided for the dairy groups. Veterinary advisory services and milk marketing guidance were provided as well. Recruitment of new farmer group members was through pass-on of female calves. The project then constructed zero-grazing units protected with pyrethroid treated netting for new members. This approach ran for four-years until project funding expired. A farmer group in each district selected a chairperson that guided regular group meetings and mobilized members for regular veterinary extension training.

Cattle were periodically sprayed using Knapsack spray pumps with either dual acaricides for tsetse and tick control or for tick-selective control. Farmers were advised to use dilutions and spraying intervals as per Manufacturers' recommendations.

Cattle were stall-fed largely pasture-Elephant grass and legumes-Lablab using a cut and carry method. Additional supplementary feeding with maize bran was practised by a few farmers.

Monitoring visits of the longitudinal study

A total of 184 protected zero-grazing units holding 289 dairy cattle were visited five times. Visit I constituted the baseline in May 2005. Visit II was a follow-up in November 2005. Visit III was a follow-up in April 2006. Visit IV was another follow-up in October 2006, while Visit V was the closing visit in June 2009. The visits were conducted by a monitoring team from National Livestock Resources Research Institute in Tororo, Uganda. Data on prevalence of trypanosomosis and PCV values of dairy cattle was extracted through testing of blood samples. Data on milk yield, livestock deaths and farmer spraying practices was extracted from farm records and farmer interviews. Data on the status of pyrethroid treated netting, status of cowshed hygiene and status of pasture and legume feed was collected through direct farm inspection.

Detection of trypanosomes and measurement of PCV values

During each visit, all dairy cattle in the protected zero-grazing units in the districts were bled from the jugular vein and blood examined for trypanosomes using both the Haematocrit Centrifugation Technique (HCT) (Woo, 1969) [12] and Buffy Coat Technique (BCT) (Murray *et al.*, 1977) [13]. The PCV value for a blood sample for each dairy animal was determined using the micro-haematocrit reader (Hawksley, England).

Statistical Analysis

Descriptive statistics on the data were generated using the frequency functions of Excel. Statistical analysis was performed using GENSTAT (GENSTAT®, Version 13). P-values < 0.05 were considered significant.

Results

A summary of the number of dairy farmers, protected zero-grazing units and number of dairy cattle per district is presented in Table 1. Overall, the dairy farmers visited ranged from 84 in visit I to 184 in visit V. While dairy cattle ranged from 145 in visit I to 289 in visit V. Most of the dairy cattle were lactating cows (61-109) with few dry cows (7-88), bulls (21-49) and calves (63-117). Females ranged from 124 in visit I to 239 in visit V, while males ranged from 21 in visit I to 49 in visit V. Protected zero-grazing registered low death, only 25 adult cattle and 40 calves were reported.

Table 1: Distribution of dairy farmers, protected zero-grazing units and cattle as per districts visited in the tsetse-infested areas of Southeast Uganda

District	Visits*	No. of dairy farmers visited			No. of protected zero-grazing units visited	No. of cattle in protected zero-grazing units visited							Cattle deaths in the protected zero-grazing units	
		All	New	Old		All	Dry cows	Lactating cows	Bulls	Calves	Female	Male	Adults	Calves
Budaka	Visit 1	14	0	14	14	24	3	11	2	10	22	2	0	0
	Visit II	14	0	14	14	27	7	7	4	13	20	7	0	0
	Visit III	22	8	14	22	34	6	11	5	17	29	5	0	2
	Visit IV	33	12	21	33	37	6	13	3	18	34	3	1	5
	Visit V	29	24	5	29	43	17	9	10	17	33	10	0	0
Busia	Visit 1	14	0	14	14	26	1	12	3	13	23	3	0	0
	Visit II	15	1	14	15	27	1	11	6	14	21	6	1	2
	Visit III	29	14	15	29	33	13	11	4	9	29	4	3	6
	Visit IV	29	0	29	29	42	11	11	7	20	36	7	4	6
	Visit V	15	12	3	15	27	14	6	2	7	25	2	0	0
Iganga	Visit 1	14	0	14	14	24	1	14	2	9	22	2	0	0
	Visit II	16	2	14	16	26	1	13	3	12	23	3	0	0
	Visit III	16	1	15	16	26	6	7	3	13	23	3	0	1
	Visit IV	30	14	16	30	50	3	22	6	25	44	6	1	4
	Visit V	45	15	30	45	72	15	34	12	23	60	12	0	0
Manafwa	Visit 1	14	0	14	14	24	0	14	6	10	18	6	0	0
	Visit II	14	0	14	14	28	0	14	9	14	19	9	0	1
	Visit III	14	0	14	14	26	4	8	7	14	19	7	1	2
	Visit IV	23	9	14	23	47	9	17	11	21	36	11	2	2
	Visit V	32	16	16	32	56	14	24	18	18	38	18	0	0
Mayuge	Visit 1	14	0	14	14	24	1	12	5	11	19	5	0	0
	Visit II	19	5	14	19	20	2	10	2	8	18	2	0	0
	Visit III	18	0	18	18	33	6	14	3	13	30	3	0	0
	Visit IV	35	17	18	35	42	2	20	13	20	29	13	3	1
	Visit V	33	7	26	33	52	11	21	5	20	46	5	0	0
Tororo	Visit 1	14	0	14	14	23	1	12	3	10	20	3	0	0
	Visit II	13	0	13	13	21	5	6	2	10	19	2	2	1
	Visit III	23	9	14	23	37	5	15	4	13	33	4	3	3
	Visit IV	18	4	14	18	40	6	16	7	18	33	7	4	4
	Visit V	30	12	18	30	39	17	15	2	7	37	2	0	0
Overall	Visit 1	84	0	84	84	145	7	75	21	63	124	21	0	0
	Visit II	91	8	83	91	149	16	61	26	71	120	29	3	4
	Visit III	122	31	91	122	189	40	66	26	79	163	26	7	14
	Visit IV	168	46	122	168	258	37	99	47	117	212	47	15	22
	Visit V	184	16	168	184	289	88	109	49	92	239	49	0	0

*Visit I (Baseline, May 2005), Visit II (Follow-up, November 2006), Visit III (Follow-up, April 2006), Visit IV (Follow-up, October 2006) and Visit V (Closing visit, June 2009)

The prevalence of trypanosomosis disaggregated according to dairy cattle categories and gender per district is shown in Table 2. Generally, the prevalence of trypanosomosis among dairy cattle under protected zero-grazing was extremely low, suggesting the pyrethroid treated netting intervention supplemented by spraying of cattle was effective. The prevalence of trypanosomosis declined from 5.5% in visit I to 1.0% in visit V. Iganga district registered no prevalence of trypanosomosis in dairy cattle. Mayuge district registered a prevalence of trypanosomosis of 25% in dairy cattle during visit I but remained free from visit II to visit V. Meanwhile, Budaka district registered a prevalence of trypanosomosis in dairy cattle ranging from 4.1% to 7.4%, with Busia district ranging from 2.4% to 7.4%, Tororo district ranging from 2.7% to 5.1% and Manafwa district ranging from 3.9% to 4.2%. Regarding dairy cattle categories, dry cows registered a prevalence of trypanosomosis ranging from 0.0% to 6.2%, with lactating cows ranging from 1.0% to 5.3% and calves ranging from 0.0% to 5.6%. Bulls were free from trypanosomosis. Regarding gender, females registered a prevalence of trypanosomosis ranging from 0.0% to 6.7%, but males registered a prevalence of trypanosomosis of 9.5% during visit I and remained free from visit II to V.

Table 2: Prevalence of trypanosomosis in dairy cattle in protected zero-grazing units during the visits

District	Visit	Dairy Cattle Categories Tested in the Zero-grazing units Prevalence of Trypanosomosis (%)						
		All	Dry cows	Lactating cows	Bulls	Calves	Female	Male
Budaka	Visit I	4.1	0.0	0.0	0.0	10.0	0.0	50.0
	Visit II	7.4	14.3	0.0	0.0	7.7	10.0	0.0
	Visit III	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit IV	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit V	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iganga	Visit I	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit II	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit III	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit IV	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit V	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mayuge	Visit I	25.0	0.0	33.3	0.0	18.2	26.3	20.0
	Visit II	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit III	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit IV	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit V	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Busia	Visit I	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit II	7.4	0.0	18.2	0.0	0.0	9.5	0.0
	Visit III	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit IV	2.4	9.1	0.0	0.0	0.0	2.8	0.0
	Visit V	3.7	0.0	0.0	0.0	0.0	4.0	0.0
Tororo	Visit I	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit II	4.8	0.0	0.0	0.0	10.0	5.3	0.0
	Visit III	2.7	20.0	0.0	0.0	0.0	3.0	0.0
	Visit IV	5.0	16.7	6.3	0.0	0.0	6.1	0.0
	Visit V	5.1	0.0	6.7	0.0	14.3	5.4	0.0
Manafwa	Visit I	4.2	0.0	0.0	0.0	10.0	0.0	16.7
	Visit II	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit III	3.9	25.0	0.0	0.0	7.2	5.3	0.0
	Visit IV	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Visit V	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Overall	Visit I	5.5	0.0	5.3	0.0	3.2	0.0	9.5
	Visit II	3.4	6.3	3.3	0.0	5.6	6.7	0.0
	Visit III	1.1	5.0	0.0	0.0	1.3	1.2	0.0
	Visit IV	1.2	5.4	1.0	0.0	0.0	1.4	0.0
	Visit V	1.0	0.0	0.9	0.0	1.1	1.3	0.0

The prevalence of trypanomosis in dairy cattle in protected zero-grazing units visited as per trypanosome species is presented in Table 3. The overall prevalence of *T. brucei* ranged from 0.0% to 0.4%, *T. congolense* ranged from 0.0% to 0.7%, *T. vivax* ranged from 0.4% to 3.4%, while the prevalence of *T congolense* and *T. vivax* mixed infection ranged from 0.0% to 2.7%. The prevalence of the different trypanosome species i.e *Trypanosoma brucei*, *Trypanosoma congolense* and *Trypanosoma vivax,* in general, were too low to have a pathogenic effect on the health of the dairy cattle. Suggesting the protected zero-grazing intervention was effective against both biological and mechanical vector transmission of trypanosomosis to dairy cattle.

Table 3: Prevalence of trypanosomosis in dairy cattle in the protected zero-grazing units during the visits by trypanosome species

District	Visit	No. of dairy cattle sampled	Trypanosome species prevalence				Overall prevalence
			T.b*	T.c*	T.v*	T.c/T.v*	
Budaka	Visit I	24	0.0	0.0	4.2	0.0	4.2
	Visit II	27	0.0	3.7	3.7	0.0	7.4
	Visit III	34	0.0	0.0	0.0	0.0	0.0
	Visit IV	37	0.0	0.0	0.0	0.0	0.0
	Visit V	43	0.0	0.0	0.0	0.0	0.0
Iganga	Visit I	24	0.0	0.0	0.0	0.0	0.0
	Visit II	26	0.0	0.0	0.0	0.0	0.0
	Visit III	26	0.0	0.0	0.0	0.0	0.0
	Visit IV	50	0.0	0.0	0.0	0.0	0.0
	Visit V	72	0.0	0.0	0.0	0.0	0.0
Mayuge	Visit I	24	0.0	0.0	16.7	8.3	25.0
	Visit II	20	0.0	0.0	0.0	0.0	0.0
	Visit III	33	0.0	0.0	0.0	0.0	0.0
	Visit IV	42	0.0	0.0	0.0	0.0	0.0
	Visit V	52	0.0	0.0	0.0	0.0	0.0
Busia	Visit I	26	0.0	0.0	0.0	0.0	0.0

	Visit II	27	0.0	0.0	3.7	3.7	7.4
	Visit III	33	0.0	0.0	0.0	0.0	0.0
	Visit IV	42	0.0	0.0	2.4	0.0	2.4
	Visit V	27	3.7	0.0	0.0	0.0	3.7
Tororo	Visit I	23	0.0	0.0	0.0	0.0	0.0
	Visit II	21	0.0	0.0	4.8	0.0	4.8
	Visit III	37	0.0	0.0	3.7	0.0	3.7
	Visit IV	40	0.0	0.0	0.0	0.0	0.0
	Visit V	39	0.0	0.0	0.0	5.1	5.1
Manafwa	Visit I	24	0.0	0.0	4.2	0.0	4.2
	Visit II	28	0.0	0.0	0.0	0.0	0.0
	Visit III	26	0.0	0.0	0.0	0.0	0.0
	Visit IV	47	0.0	0.0	0.0	0.0	0.0
	Visit V	56	0.0	0.0	0.0	0.0	0.0
Overall	Visit I	145	0.0	0.0	3.4	2.1	5.5
	Visit II	149	0.0	0.7	2.0	0.7	3.4
	Visit III	189	0.0	0.0	0.5	0.0	0.5
	Visit IV	258	0.0	0.0	0.4	0.0	0.4
	Visit V	289	0.4	0.0	0.7	1.0	2.1

*T. b - *Trypanosoma brucei*, T. c - *Trypanosoma congolense*, T. v - *Trypanosoma vivax*, T. c/T. v -*Trypanosoma congolense*//*Trypanosoma vivax*

Mean PCV values for dairy cattle in protected zero-grazing units visited are presented in Table 4. Generally, dairy cattle under protected zero-grazing had good health, given mean PCV values ranging 27.7 to 30.6. However, there was variation between districts. Dairy cattle in Mayuge district had the best mean PCV values (range 30.4-34.1), followed by Iganga district (range 28.8-31.8), Tororo district (range 27.7-30.0), Budaka district (range 24.4-34.7), Manafwa district (range 26.1-31.7) and Busia district (range 26.1-29.8).
Mean PCV values of dairy cattle in Mayuge district during visits II and III were significantly higher ($p<0.05$) than of those from Manafwa district. As well, mean PCV of dairy cattle in Tororo district during visits II and III were significantly higher ($p<0.05$) than those from Busia district.
Regarding dairy cattle categories, dry cows had the best PCV values (range 29.9 to 33.6), followed by bulls (range 28.3-32.1), calves (range 27.6-32.0) and lactating cows (range 26.3 to 30.3).
As regards gender, females and males equally had good PCV values, ranging from 28.3 to 31.2 for females and ranging from 28.3 to 32.1 for males. Low PCV values of 15 and below, denoting cattle experiencing anaemia because of either trypanosomosis or tick-borne diseases that were endemic in the area, were not observed among dairy cattle under protected zero-grazing across all districts. These findings suggest that the pyrethroid treated netting around zero-grazing units supplemented by periodic spraying of cattle effectively protected dairy cattle against tsetse-transmitted trypanosomosis and tick-transmitted diseases-theileriosis, anaplasmosis and babesiosis. Diseases often causing anaemia in cattle in areas visited.

Table 4: Packed Cell Volume (PCV) for the dairy cattle in the protected zero-grazing units during the visits

District	Visit	Mean PCV of different categories of dairy cattle in protected zero-grazing units visited						
		All	Dry cows	Lactating cows	Bulls	Calves	Female	Male
Budaka	Visit I	29.5	38.0	29.3	28.0	27.2	28.7	25.9
	Visit II	27.3	29.3	28.3	30.0	26.8	27.0	30.0
	Visit III	24.4	25.7	24.2	23.3	22.7	24.5	23.3
	Visit IV	34.7	34.6	32.2	39.7	36.0	34.9	39.7
	Visit V	28.8	27.9	25.6	25.9	29.1	29.7	25.9
Iganga	Visit I	29.5	27.0	32.1	32.5	29.7	30.9	32.5
	Visit II	28.8	32.0	29.8	30.0	27.5	28.2	30.0
	Visit III	30.6	31.2	29.4	34.0	30.9	30.3	34.0
	Visit IV	31.8	33.0	34.3	34.7	31.3	26.7	34.7
	Visit V	30.8	31.4	31.0	26.8	30.4	31.5	26.8
Mayuge	Visit I	30.4	38.0	31.8	29.2	28.3	30.8	29.2
	Visit II	31.6	35.0	33.3	28.0	28.5	32.0	28.0
	Visit III	34.1	34.9	33.6	30.5	30.6	32.5	30.5
	Visit IV	34.1	33.5	34.9	33.9	33.7	33.8	33.9
	Visit V	33.1	32.9	29.6	31.4	33.1	35.3	31.4
Busia	Visit I	26.1	34.0	24.2	23.0	27.3	26.4	23.0
	Visit II	26.9	28.0	26.2	31.4	27.5	25.9	31.4
	Visit III	28.9	31.8	25.0	30.3	27.0	28.8	30.3
	Visit IV	29.3	27.0	26.6	27.0	30.3	29.6	27.0
	Visit V	29.8	30.1	27.5	32.5	31.0	29.6	32.5
Tororo	Visit I	29.4	31.0	28.9	29.7	28.6	28.9	29.7
	Visit II	30.7	32.8	29.5	31.5	30.3	30.6	31.5
	Visit III	27.7	29.8	26.8	26.3	27.4	27.8	26.3
	Visit IV	29.9	30.7	31.1	26.4	28.7	30.7	26.4
	Visit V	30.0	28.6	29.0	30.0	31.9	30.0	23.0

Manafwa	Visit I	27.7	-	27.5	26.2	27.4	30.8	26.2
	Visit II	28.0	-	27.4	27.4	28.6	28.3	27.4
	Visit III	26.1	24.7	19.0	25.0	26.9	25.4	25.0
	Visit IV	31.7	32.3	30.9	30.7	32.0	31.2	30.7
	Visit V	27.3	28.8	27.2	30.0	31.9	30.2	30.0
Overall	Visit I	28.9	33.6	28.9	28.3	28.1	29.4	28.9
	Visit II	28.9	31.4	29.1	29.7	28.2	28.7	30.3
	Visit III	27.7	29.7	26.3	28.2	27.6	28.2	28.3
	Visit IV	30.6	31.9	30.3	32.1	32.0	31.2	32.1
	Visit V	29.9	29.9	28.3	29.4	31.2	31.1	28.8

The status of the pyrethroid treated netting around zero-grazing sheds is described in Table 5. Netting status varied from district to district. 50% of the zero-grazing units had intact netting in Budaka district during visit I, while 50% had damaged netting. However, only 7.1% of the zero-grazing units had intact netting by visit II, while 92.9% of the units had damaged netting. All units had lost netting by visit III to V. All zero-grazing units had damaged netting by visit I and 86.7% of the units had damaged netting by visit II with a few (13.3%) replaced in Iganga district. However, all zero-grazing units had lost netting by visit III to V. Similarly, all zero-grazing units had damaged netting by visit I and II with all units having lost netting by visit III to V in Mayuge district.

Likewise, 14.3% of the zero-grazing units had intact netting while 85.7% of the units had damaged netting by visit I in Busia district. However, all units had damaged netting by visit II and 7.1% of the units had damaged netting by visit III and 92.9% of the units had lost the netting. All units had lost netting by visit IV to V.

In Tororo district, all zero-grazing units had damaged netting by visit I and II. However, from visit III to V, all units had lost netting. Similarly, 21.4% of the zero-grazing units in Manafwa district had intact netting while 78.6% of the units had damaged netting by visit I. All zero-grazing units had damaged netting by visit II and all had lost netting by visit III to V.

Generally, only 14.3% and 2.2% of the 184 zero-grazing units had intact netting by visit I and II, respectively. 85.7%, 97.8% and 1.8% of the units had damaged netting by visit I, II and III, respectively. 99.2% of the units had lost netting in visit III, while all (100%) zero-grazing units had lost netting by visit IV and V.

Table 5: Status of pyrethroid impregnated netting around zero-grazing sheds during the visits

District	Visit	No. of protected zero-grazing unit visited	Status of netting around zero-grazing sheds (Number/%)		
			Intact netting	Damaged netting	No netting
Budaka	Visit I	14	7 (50.0)	7 (50.0)	0 (0.0)
	Visit II	14	1 (7.1)	13 (92.9)	0 (0.0)
	Visit III	22	0 (0.0)	0 (0.0)	22 (100.0)
	Visit IV	33	0 (0.0)	0 (0.0)	33 (100.0)
	Visit V	29	0 (0.0)	0 (0.0)	29 (100.0)
Iganga	Visit I	14	0 (0.0)	14 (100.0)	0 (0.0)
	Visit II	15	2 (13.3)	13 (86.7)	0 (0.0)
	Visit III	29	0 (0.0)	0 (0.0)	29 (100.0)
	Visit IV	29	0 (0.0)	0 (0.0)	29 (100.0)
	Visit V	15	0 (0.0)	0 (0.0)	15 (100.0)
Mayuge	Visit I	14	0 (0.0)	14 (100.0)	0 (0.0)
	Visit II	16	0 (0.0)	16 (100.0)	0 (0.0)
	Visit III	16	0 (0.0)	0 (0.0)	16 (100.0)
	Visit IV	30	0 (0.0)	0 (0.0)	30 (100.0)
	Visit V	45	0 (0.0)	0 (0.0)	45 (100.0)
Busia	Visit I	14	2 (14.3)	12 (85.7)	0 (0.0)
	Visit II	14	0 (0.0)	14 (100.0)	0 (0.0)
	Visit III	14	0 (0.0)	1 (7.1)	13 (92.9)
	Visit IV	23	0 (0.0)	0 (0.0)	23 (100.0)
	Visit V	32	0 (0.0)	0 (0.0)	32 (100.0)
Tororo	Visit I	14	0 (0.0)	14 (100.0)	0 (0.0)
	Visit II	19	0 (0.0)	19 (100.0)	0 (0.0)
	Visit III	18	0 (0.0)	0 (0.0)	18 (100.0)
	Visit IV	35	0 (0.0)	0 (0.0)	35 (100.0)
	Visit V	33	0 (0.0)	0 (0.0)	33 (100.0)
Manafwa	Visit I	14	3 (21.4)	11 (78.6)	0 (0.0)
	Visit II	13	0 (0.0)	13 (100.0)	0 (0.0)
	Visit III	23	0 (0.0)	0 (0.0)	23 (100.0)
	Visit IV	18	0 (0.0)	0 (0.0)	18 (100.0)
	Visit V	30	0 (0.0)	0 (0.0)	30 (100.0)
Overall	Visit I	84	12 (14.3)	72 (85.7)	0 (0.0)
	Visit II	91	2 (2.2)	89 (97.8)	0 (0.0)
	Visit III	122	0 (0.0)	1 (0.8)	121 (99.2)
	Visit IV	168	0 (0.0)	0 (0.0)	168 (100.0)
	Visit V	184	0 (0.0)	0 (0.0)	184 (100.0)

Farmer spraying practices for supplementary dual tsetse-tick control amongst protected zero-grazing units visited are described in Table 6. Spraying practices differed from district to district. Tsetse-Tick®, Decatix® and Spot-on® were acaricides largely used for dual control of tsetse and ticks in Budaka district, with Supona® being the main tick-selective acaricide used. Most zero-grazing units focussed on tick control during visit I (78.7%), II (78.7%) and III (95.5%). The routine, however, shifted to dual control of tsetse and tick control during visit IV (96.9%) and V (100%). Unfortunately, 85.8%, 78.7% and 100% of farmers applied wrong spraying intervals during visit I, II and III, respectively. Supona®, an acaricide whose recommended spraying interval is 7 days was applied by farmers every 14 days.

Tsetse-Tick®, Decatix® and Alpha Cypermethrin® were acaricides for dual tsetse and tick control, largely used in Iganga district, with Supona®, Amitraz® and Alfapor® being the main tick selective acaricides used. Most zero-grazing units focussed on tick control during visit I (57.1%) and II (75.0%). However, the trend shifted to dual tsetse and tick control during visit III (56.3%), IV (100.0%) and V (86.7%). Unfortunately, 60% of the zero-grazing units did not follow correct spraying intervals during visit V. Tsetse-Tick®, Alpha Cypermethrin® and Decatix® were applied every 7 days rather than every 14 days as recommended.

Decatix® and Tsetse-Tick® were the acaricides for dual tsetse and tick control largely used in Mayuge district, with Supona® and Amitraz® being the main tick-selective acaricides used. Most zero-grazing units focussed on tick control during visit I (78.6%), II (68.4%) and III (66.7%). However, 100% of the zero-grazing units shifted to dual tsetse and tick control during visit IV and V. Correct spraying intervals were not observed by 57.2% and 75.8% of the units during visit I and V, respectively. Supona® was applied every 14 days rather than every 7 days as recommended. In addition, Decatix® was applied every 7 days rather than every 14 days as recommended.

Decatix®, Spot-on® and Tsetse-Tick® were the acaricides for dual tsetse and tick control largely used in Busia district, with Supona®, Amitraz®, Triatix® and Steladone® being the main tick selective acaricides used. Most zero-grazing units focussed on tick control during visit I (64.3%), II (60.0%) and III (75.9%). The focus however shifted to dual tsetse and tick control during visit IV (93.1%) and V (93.3%). However, 69.0%, 51.7% and 53.3% of the zero-grazing units did not follow correct spraying intervals during visit III, IV and V, respectively. Supona® and Amitraz® were applied every 14 days rather than every 7 days as recommended. In addition, Decatix® was applied 7 days rather than every 14 days as recommended.

Decatix®, Spot-on®, Tsetse-Tick®, Alpha Cypermethrin® were the acaricides for dual tsetse and tick control used in Tororo district, with Supona®, Renegede® and Amitraz® being the main tick-selective acaricides used. Most zero-grazing units focussed on tick control during visit I (64.3%) and II (100%). The trend shifted to dual tsetse and tick control during visit III (78.3%), IV (94.4%) and V (86.7%). However, 53.8%, 65.2%, 72.7% and 70.0% of the zero-grazing units did not follow correct spraying interval during visit II, III, IV and V, respectively. Supona® and Amitraz® were applied every 14 days rather than every 7 days as recommended. In addition, Decatix®, Tsetse-Tick® and Spot-on® were applied every 7 days rather than every 14 days as recommended. Worse still, Alpha Cypermethrin was applied every 4 days rather than every 14 days as recommended.

Decatix® and Tsetse-Tick® were the acaricides for dual tsetse and tick control largely applied in Manafwa district, with Supona® and Taktic® as the main tick-selective acaricides used. Most zero-grazing units focussed on tick control during visit I (64.3%) and III (100.0%). However, 57.2%, 95.7% and 96.8% of the units shifted focus to dual tsetse and tick control during visit II, IV and V, respectively. Unfortunately, all (100%) zero-grazing units did not observe the correct spraying interval during visit III. Supona® and Taktic® were applied every 14 days rather than every 7 days as recommended. In addition, Decatix® was applied every 7 days rather than every 14 days as recommended.

Overall, 66.9% of the 184 zero-grazing units largely used acaricides for dual tsetse and tick control and only 33.1% of the units largely used tick-selective acaricides. Of all zero-grazing units, 57.8% observed correct acaricide spraying intervals while 42.2% of the units applied wrong spraying intervals.

Table 6: Farmer spraying practices for supplementary dual tsetse-tick control amongst protected zero-grazing units visited

District	Visit	No. of protected zero-grazing unit visited	Acaricide products used	Spraying Intervals applied (days)	Percentage farmers applying different acaricides	Percentage farmers applying dual tsetse/tick control acaricides	Percentage farmers applying selective tick control acaricides	Percentage farmers applying right spraying intervals	Percentage farmers applying wrong spraying intervals
Budaka	Visit I	14	Tsetse-Tick®	28	1 (7.1)	3 (21.3)	11 (78.7)	2 (14.2)	12 (85.8)
			Tsetse-Tick®	14	1 (7.1)				
			Supona®	14	11 (78.7)				
			Spot-on®	14	1 (7.1)				
	Visit II	14	Spot-on®	14	1(7.1)	2 (14.2)	12 (85.8)	3 (21.3)	11 (78.7)
			Supona®	14	11(78.7)				
			Supona®	7	2(14.2)				
	Visit III	22	Supona®	14	21 (95.5)	0 (0.0)	21 (95.5)	0 (0.0)	22 (100.0)
			No spraying	-	1 (4.5)				
	Visit IV	33	Decatix®	14	32 (96.9)	32 (96.9)	0 (0.0)	32 (96.9)	1 (3.1)
			No spraying	-	1 (3.1)				
	Visit V	29	Decatix®	14	29 (100.0)	29 (100.0)	0 (0.0)	29 (100.0)	0 (0.0)
Iganga	Visit I	14	Supona®	7	7 (50.0)	6 (42.9)	8 (57.1)	13 (92.9)	1 (7.1)
			Alpha Cypermethrin®	7	2 (14.3)				
			Tsetse-Tick®	14	2 (14.3)				

			Decatix®	14	2 (14.3)				
			Amitraz®	7	1 (7.1)				
	Visit II	16	Supona®	7	13 (81.3)	4 (25.0)	12 (75.0)	15 (93.8)	1 (6.2)
			Alpha Cypermethrin®	7	1 (6.3)				
			Tsetse-Tick®	14	3 (18.8)	9 (56.3)	7 (43.7)	11 (68.7)	5 (31.3)
	Visit III	16	Supona®	7	5 (31.3)				
			Supona®	14	2 (12.5)				
			Tsetse-Tick®	7	3 (18.7)				
			Tsetse-Tick®	14	5 (31.3)				
			Decatix®	14	1 (6.2)				
	Visit IV	30	Decatix®	14	17 (56.7)	30 (100.0)	0 (0.0)	17 (56.7)	13 (43.3)
			Decatix®	7	10 (33.3)				
			Decatix®	21	1 (3.3)				
			Tsetse-Tick®	14	1 (3.3)				
			Tsetse-Tick®	7	1 (3.3)				
	Visit V	45	Tsetse-Tick®	7	12 (26.8)	39 (86.7)	6 (13.3)	18 (40.0)	27 (60.0)
			Tsetse-Tick®	14	6 (13.3)				
			Alpha Cypermethrin®	14	5 (11.1)				
			Alpha Cypermethrin®	7	9 (20.0)				
			Alfapor®	7	3 (6.7)				
			Decatix®	14	2 (4.4)				
			Decatix®	7	6 (13.3)				
			Supona®	7	2 (4.4)				
Mayuge	Visit I	14	Supona®	7	4 (28.7)	3 (21.4)	11 (78.6)	6 (42.8)	8 (57.2)
			Supona®	14	5 (35.8)				
			Decatix®	7	1 (7.1)				
			Decatix®	14	1 (7.1)				
			Decatix®	21	1 (7.1)				
			Amitraz®	7	1 (7.1)				
			Amitraz®	14	1 (7.1)				
	Visit II	19	Supona®	7	13 (68.4)	6 (31.6)	13 (68.4)	18 (94.7)	1 (5.3)
			Decatix®	7	1 (5.3)				
			Decatix®	14	5 (26.3)				
	Visit III	18	Supona®	7	12 (66.7)	6 (33.3)	12 (66.7)	17 (94.4)	1 (5.6)
			Decatix®	7	1 (5.6)				
			Decatix®	14	5 (27.7)				
	Visit IV	35	Decatix®	7	6 (17.1)	35 (100.0)	0 (0.0)	27 (77.1)	8 (22.9)
			Decatix®	14	27 (77.1)				
			Tsetse-Tick®	7	2 (5.8)				
	Visit V	33	Decatix®	7	22 (66.7)	33 (100.0)	0 (0.0)	8 (24.2)	25 (75.8)
			Decatix®	14	11 (33.3)				
Busia	Visit I	14	Decatix®	14	2 (14.3)	5 (35.7)	9 (64.3)	11 (78.6)	3 (21.4)
			Spot-on®	14	1 (7.1)				
			Tsetse-Tick®	14	2 (14.3)				
			Supona®	7	2 (14.3)				
			Supona®	14	2 (14.3)	4 (26.7)	9 (60.0)	8 (53.3)	7 (46.7)
			Amitraz®	14	1 (7.1)				
			Steladone®	7	2 (14.3)				
			Triatix®	7	2 (14.3)				
	Visit II	15	Decatix®	14	4 (26.7)				
			Supona®	7	4 (26.7)				
			Supona®	14	3 (20.0)				
			Amitraz®	7	1 (6.7)				
			Amitraz®	14	1 (6.7)				
			No spraying		2 (13.2)				
	Visit III	29	Supona®	7	2 (6.9)	7 (24.1)	22 (75.9)	9 (31.0)	20 (69.0)
			Supona®	14	20 (68.9)				
			Decatix®	14	2 (6.9)				
			Tsetse-Tick®	14	5 (17.3)				
	Visit IV	29	Decatix®	7	13 (44.8)	27 (93.1)	0 (0.0)	12 (41.4)	15 (51.7)
			Decatix®	14	12 (41.4)				
			Decatix®	21	2 (6.9)				
			Not spraying		2 (6.9)				
	Visit V	15	Decatix®	7	7 (46.7)	14 (93.3)	0 (0.0)	7 (46.7)	8 (53.3)
			Decatix®	14	7 (46.7)				
			No spraying		1 (6.6)				

Tororo	Visit I	14	Decatix®	14	1 (7.1)	5 (35.7)	9 (64.3)	11 (78.6)	3 (21.4)
			Spot-on®	14	1 (7.1)				
			Tsetse-Tick®	14	3 (21.5)				
			Supona®	7	5 (35.7)				
			Supona®	14	3 (21.5)				
			Renegede®	7	1 (7.1)				
	Visit II	13	Supona®	7	6 (46.2)	0 (0.0)	13 (100)	6 (46.2)	7 (53.8)
			Supona®	14	7 (53.8)				
	Visit III	23	Decatix®	14	1 (4.3)	18 (78.3)	5 (21.7)	8 (34.8)	15(65.2)
			Tsetse-Tick®	7	15 (65.2)				
			Tsetse-Tick®	14	2 (8.8)				
			Supona®	7	5 (21.7)				
	Visit IV	18	Decatix®	7	12 (66.6)	17 (94.4)	1 (5.6)	5 (27.8)	13 (72.2)
			Decatix®	14	4 (22.2)				
			Tsetse-Tick®	7	1 (5.6)				
			Supona®	7	1 (5.6)				
	Visit V	30	Decatix®	7	11 (36.7)	26 (86.7)	4 (13.3)	9 (30.0)	21 (70.0)
			Decatix®	14	6 (20.0)				
			Decatix®	21	1 (3.3)				
			Spot-on®	7	6 (20.0)				
			Alpha Cypermethrin®	4	2 (6.7)				
			Amitraz®	7	3 (10.0)				
			Amitraz®	14	1 (3.3)				
Manafwa	Visit I	14	Decatix®	14	1 (7.2)	5 (35.7)	9 (64.3)	11 (78.6)	3 (21.4)
			Tsetse-Tick®	14	1 (7.2)				
			Supona®	7	3 (21.6)				
			Supona®	14	7 (50.0)				
			Supona®	28	1 (7.2)				
			Taktic®	14	1 (7.2)				
	Visit II	14	Decatix®	14	8 (57.2)	8 (57.2)	6 (42.8)	10 (71.4)	4 (28.6)
			Supona®	7	2 (14.2)				
			Supona®	14	4 (28.6)	0 (0.0)	14 (100.0)	0 (0.0)	14 (100.0)
	Visit III	14	Supona®	14	13 (92.9)				
			No spraying		1 (7.1)				
	Visit IV	23	Decatix®	14	21 (91.4)	22 (95.7)	1 (4.3)	21 (91.4)	2 (8.6)
			Decatix®	7	1 (4.3)				
			Supona®	14	1 (4.3)				
	Visit V	32	Decatix®	14	31 (96.8)	31 (96.8)	1 (3.2)	31 (96.8)	1 (3.2)
			Supona®	14	1 (3.2)				
Overall		649				434 (66.9)	215 (33.1)	375 (57.8)	275 (42.2)

The status of pasture and legume feed produced by zero-grazing units in terms of sufficiency in different districts visited is presented in Table 7. The proportion of zero-grazing dairy farmers with sufficient pasture varied from district to district. Iganga (range 90-100%), Busia (range 80-100%) and Manafwa (range 78.3-100%) districts had impressively high proportions of farmers with sufficient pasture feed. While Budaka (range 42.4-92.9%), Mayuge (range 63.6-94.4%) and Tororo (range 66.7-100%) districts had a good proportion of farmers with sufficient pasture feed. Overall, a high proportion of zero-grazing dairy farmers (range 67.9-97.5%) had sufficient pasture feed.

Regarding legume production by zero-grazing units, Busia (range 3.4-50%), Mayuge (range 0.0-55.6%) and Tororo (range 7.7-64.3%) districts had a fair proportion of farmers with sufficient legume feed. While Budaka (range 9.1-34.5%), Iganga (range 8.9-37.5%) and Manafwa (range 6.3-35.6%) districts had a low proportion of farmers with sufficient legume feed. Overall, only 17.9% to 34.8% of the farmers had sufficient legume feed.

Table 7: Pasture and legume feed status of the protected zero-grazing units during the visits

District	Visit	No. of protected zero-grazing units visited	Percentage farmers with sufficient pasture	Percentage farmers with sufficient legumes
Budaka	Visit 1	14	13 (92.9)	2 (14.3)
	Visit II	14	12 (85.7)	3 (21.4)
	Visit III	22	20 (90.9)	2 (9.1)
	Visit IV	33	14 (42.4)	4 (12.1)
	Visit V	29	19 (65.5)	10 (34.5)
Iganga	Visit 1	14	13 (92.9)	4 (25.6)
	Visit II	16	16 (100.0)	6 (37.5)
	Visit III	16	16 (100.0)	6 (37.5)
	Visit IV	30	27 (90.0)	4 (13.3)
	Visit V	45	45 (100.0)	4 (8.9)
Mayuge	Visit 1	14	12 (85.7)	0 (0.0)
	Visit II	19	17 (89.5)	5 (26.3)

	Visit III	18	17 (94.4)	10 (55.6)
	Visit IV	23	17 (73.9)	12 (52.2)
	Visit V	33	21 (63.6)	15 (45.5)
Busia	Visit 1	14	13 (92.9)	7 (50.0)
	Visit II	15	15 (100.0)	3 (20.0)
	Visit III	29	29 (100.0)	1 (3.4)
	Visit IV	29	24 (82.8)	1 (3.4)
	Visit V	15	12 (80.0)	6 (40.0)
Tororo	Visit 1	14	10 (71.4)	9 (64.3)
	Visit II	13	11 (84.6)	1 (7.7)
	Visit III	23	23 (100.0)	1 (4.3)
	Visit IV	18	14 (77.8)	2 (11.1)
	Visit V	30	20 (66.7)	6 (20.0)
Manafwa	Visit 1	14	13 (92.9)	2 (14.3)
	Visit II	14	12 (85.7)	5 (35.7)
	Visit III	14	14 (100.0)	4 (28.6)
	Visit IV	23	18 (78.3)	7 (30.4)
	Visit V	32	31 (96.9)	2 (6.3)
Overall	Visit 1	84	74 (88.1)	24 (28.6)
	Visit II	91	83 (91.2)	23 (25.3)
	Visit III	122	119 (97.5)	24 (19.7)
	Visit IV	168	114 (67.9)	30 (17.9)
	Visit V	184	148 (80.4)	64 (34.8)

The status of cowshed hygiene amongst zero-grazing units in different districts visited is presented in Table 8. Budaka district had the highest percentage of poorly managed cowsheds (93.1%), followed by Busia district (33.3%), then Iganga district (31.1%), Mayuge district 12.1%), Tororo district (10.0%) and lastly Manafwa district (6.3%).

Table 8: Status of cowshed hygiene amongst protected zero-grazing unit during the final visit (Visit V)

District	No. of protected zero-grazing units visited	Percentage zero-grazing units with poor cowshed hygiene
Budaka	29	27 (93.1)
Iganga	45	14 (31.1)
Busia	15	5 (33.3)
Tororo	30	3 (10.0)
Mayuge	33	4 (12.1)
Manafwa	32	2 (6.3)

The status of milk yield in the zero-grazing dairy units in different districts visited is elaborated in Table 9. The best average milk yield per cow per day was registered by zero-grazing units in Iganga district, ranging from 6.2 Litres to 8.7 Litres per cow per day, with a minimum of 1.0 litres per cow per day and maximum of 18.0 Litres per cow per day. Likewise, good average milk yield per cow per day, ranging from 4.5 Litres to 8.2 litres, with a minimum of 1.0 Litres per cow per day and a maximum of 19.0 Litres per cow per day were registered in Mayuge district. The average milk yield per cow per day registered in Manafwa district was fair, ranging from 4.5 Litres to 6.2 Litres, with a minimum of 1.0 Litres per cow per day and a maximum of 17.0 litres per cow per day.

On the contrary, low average milk yield per cow per day, ranging from 4.0 Litres to 6.3 Litres, with a minimum of 1.0 Litres per cow per day and a maximum of 14.0 Litres per cow per day were registered in Busia district. Likewise, zero-grazing units in Tororo district registered low average milk yield per cow per day, ranging from 3.3 Litres to 6.7 Litres, with a minimum of 0.5 Litres and maximum of 16.0 Litres per cow per day. Worse still, low average milk yield per cow per day, ranging from 3.7 Litres to 6.0 litres, with a minimum of 0.5 Litres per cow per day and a maximum of 15.0 litres per cow per day were registered in Budaka district. Overall, fair average milk yield per cow per day, ranging from 5.0 Litres to 6.4 Litres, with a minimum of 0.5 Litres per cow per day and maximum of 19.0 Litres per cow per day were achieved by the entire dairy cattle initiative.

Table 9: Milk yield in the protected zero-grazing dairy units during the study

District	Visits*	No. of protected zero-grazing units visited	No. of Dairy cows				Daily Milk Yield (L)	
			Total cattle	Dry cows	Lactating cows	Average milk yield (L) per cow per day	Min (L) per cow per day	Max (L) per cow per day
Budaka	Visit 1	14	24	3	11	6.0	1.5	12.0
	Visit II	14	27	7	7	3.7	0.5	8.0
	Visit III	22	34	6	11	4.0	1.0	7.5
	Visit IV	33	37	6	13	3.7	1.0	15.0
	Visit V	29	43	17	9	5.5	2.0	10.0
Busia	Visit 1	14	26	1	12	4.8	1.0	10.0
	Visit II	15	27	1	11	4.0	1.5	12.0
	Visit III	29	33	13	11	6.3	2.0	12.0
	Visit IV	29	42	11	11	6.0	3.0	14.0
	Visit V	15	27	14	6	4.7	2.0	10.0
Iganga	Visit 1	14	24	1	14	6.2	2.0	13.0

	Visit II	16	26	1	13	8.7	3.0	15.0
	Visit III	16	26	6	7	8.0	3.0	15.0
	Visit IV	30	50	3	22	7.9	1.0	16.0
	Visit V	45	72	15	34	6.8	1.0	18.0
Manafwa	Visit 1	14	24	0	14	4.9	1.0	14.0
	Visit II	14	28	0	14	4.9	1.0	10.0
	Visit III	14	26	4	8	5.7	1.0	7.0
	Visit IV	23	47	9	17	6.2	1.0	12.0
	Visit V	32	56	14	24	4.5	3.0	17.0
Mayuge	Visit 1	15	24	1	12	4.5	1.0	14.0
	Visit II	19	20	2	10	5.2	1.0	14.0
	Visit III	18	33	6	14	7.5	3.0	14.0
	Visit IV	35	42	2	20	7.4	1.0	13.0
	Visit V	33	52	11	21	8.2	2.0	19.0
Tororo	Visit 1	14	23	1	12	3.7	0.5	6.0
	Visit II	13	21	5	6	5.2	1.0	15.0
	Visit III	23	37	5	15	6.7	2.5	10.0
	Visit IV	18	40	6	16	6.3	3.0	16.0
	Visit V	30	39	17	15	3.3	2.0	15.0
Overall	Visit 1	84	145	7	75	5.0	0.5	14.0
	Visit II	91	149	16	61	5.3	0.5	14.0
	Visit III	122	189	40	66	6.4	1.0	15.0
	Visit IV	168	258	37	99	6.3	1.0	16.0
	Visit V	184	289	88	109	5.5	1.0	19.0

Discussion

We report on the longitudinal study that was conducted on a protected zero-grazing dairy cattle initiative implemented in tsetse-infested areas of Southeast Uganda, an area infested with *G. f. fuscipes* and *G. pallidipes* (Magona *et al*., 2008) [18]. Over a period of four years, a sizeable number (184) of protected zero-grazing units holding a substantial number of dairy cattle (289) were visited five times. Dairy cattle consisted largely of lactating cows with few dry cows, bulls and calves. Females were more than males. The herd structure was largely dictated by the milk production function. Females, especially lactating cows rather than dry cows were preferred to attain the required milk production. Males, especially bulls were disposed of as soon as they were ready for the market. Protected zero-grazing units registered low deaths, suggesting that the pyrethroid treated netting intervention was effective against tsetse bites and transmission of trypanosomosis in conformity with earlier reports (Bauer *et al*., 2011; Maia *et al*., 2012; Megersa *et al*., 2017) [9, 10, 11].

Generally, the prevalence of trypanosomosis among dairy cattle under protected zero-grazing was extremely low, with Iganga district registering no prevalence of trypanosomosis in dairy cattle, while Mayuge, Budaka, Busia, Tororo and Manafwa districts registering very low prevalence of trypanosomosis. Regarding dairy cattle categories, dry cows, lactating cows and calves registered low prevalence of trypanosomosis but bulls were free from trypanosomosis. Females and males registered equally low prevalence of trypanosomosis. These findings suggest that the pyrethroid treated netting intervention supplemented by spraying of cattle was effective. Bauer *et al*. (2011) [9] similarly reported low trypanosome infection due to zero fly fences.

The prevalence of the different trypanosome species i.e *Trypanosoma brucei*, *Trypanosoma congolense* and *Trypanosoma vivax* were too low to have a pathogenic effect on the health of the dairy cattle. Suggesting the protected zero-grazing intervention was effective against both biological and mechanical vector transmission of trypanosomosis to dairy cattle. Given that *T. brucei* and *T. congolense* are transmitted by tsetse as a biological vector, while *T vivax* is transmitted by tsetse and biting flies as mechanical vectors (Magona *et al*, 2008) [18].

Generally, dairy cattle under protected zero-grazing had good health, given high mean PCV values. This was in line with previous reports (Bauer *et al*., 2011; Maia *et al*., 2012; Megersa *et al*., 2017, Lejebo *et al*, 2019) [9, 10, 11, 17]. However, there was variation between districts. Dairy cattle in Mayuge district had the best mean PCV values, followed by Iganga, Tororo, Budaka, Manafwa and Busia districts. Regarding dairy cattle categories, dry cows had the best PCV values, followed by bulls, calves and lactating cows. As regards gender, females and males equally had good PCV values. Low PCV values of 15 and below, denoting cattle experiencing anaemia because of either trypanosomosis or tick-borne diseases that were endemic in the area, were not observed among dairy cattle under protected zero-grazing across all districts visited. These findings suggest that the pyrethroid treated netting around zero-grazing units supplemented by periodic spraying of cattle effectively protected dairy cattle against tsetse-transmitted trypanosomosis and tick-transmitted diseases-theileriosis, anaplasmosis and babesiosis. Diseases often causing anaemia in cattle in areas visited.

All zero-grazing units across the districts had lost netting from visit III to V. Ideally, zero-grazing units had intact netting, only within the first six months of installation. By the first year after installation, most zero-grazing units had damaged netting. By the second year to the fourth year, all zero-grazing units had lost netting. At which time prevention of dairy cattle from bites by either tsetse flies or ticks and nuisance flies hugely relied on supplementary periodic spraying of dairy cattle by owners. Destruction of netting was attributed to confined calves and aggressive cows on heat that either bit or kicked and tore the netting. In conformity with earlier reports (Bauer *et al*., 2006) [3], farmers' observation indicated that as netting became older, it became more fragile. It was also observed that larger nets of 1.5 m high had a longer duration of 6 to 8 months than smaller nets of 1.0 m high, whose duration was 3 to 4 months. While replacement of netting for all zero-grazing units was desirable after the first year of installation, farmers could not afford the cost of netting replacement of 100,000 Uganda shillings (approx. USD 30) per zero-grazing unit.

Tsetse-Tick®, Decatix®, Spot-on® and Alpha Cypermethrin® were acaricides for dual tsetse and tick control and Supona®, Amitraz®, Alfapor®, Triatix®, Steladone®. Renegede® and Taktiz® were tick-selective acaricides used in all districts. This was dictated by the range of acaricide products available on the market.

Initially, most zero-grazing units in Budaka, Busia and Mayuge districts focussed mainly on tick control during visit I, II and III. The spraying routine, however, shifted to dual tsetse and tick control during visit IV and visit V. This coincided with loss of netting by all zero-grazing units. On the contrary, most zero-grazing units in Iganga and Tororo districts focussed on tick control during visit I and visit II. However, the trend shifted to dual tsetse and tick control by during visit III, IV and V. For Manafwa district, most zero-grazing units focussed on tick control during visit I and III and shifted to dual tsetse and tick control during visit II, IV and V. Use of acaricides for dual tsetse and tick control was dominant among the 184 zero-grazing units, while tick selective acaricides were less preferred. Farmers have been reported to prefer an insecticide-treatment interventions for cattle that controls both tsetse and ticks (Torr *et al.*, (2007) [14].

Generally, most zero-grazing units applied correct spraying intervals while fewer units applied incorrect spraying intervals. However, the spraying practices differed from district to district. Incorrect spraying intervals were largely applied during visit I, II and III in Budaka district but the reverse did occur during visit IV and V. In Mayuge district, incorrect spraying intervals were largely applied during visit I and V and correct spraying intervals were applied during visit II, III and IV. On the contrary in Busia district, incorrect spraying intervals were applied during visit III, IV and V, while correct spraying intervals were applied during visit I and II. For Tororo district, incorrect spraying intervals were applied during visit II, III, IV and V, while correct spraying intervals were applied only during visit I. In Iganga district, incorrect spraying intervals were applied during visit V, while correct spraying intervals were applied during visit I, II, III and IV. For Manafwa district, incorrect spraying intervals were applied during visit III, while correct spraying intervals were applied during visit I, II, IV and V. Irregular spraying intervals by farmers have been reported in Uganda previously (Angwech *et al.*, 2011) [15]. Such irregular spraying practices have a danger of pyrethroids leading to acaricide resistance in tick populations (Bruce and Wilson, 1998; Torr *et al*., 2007) [16, 14].

Incorrect spraying intervals in Budaka, Mayuge, Busia, Tororo and Manafwa districts, involved Supona®, Amitraz® and Taktic® being applied every 14 days rather than every 7 days as recommended. For Iganga, Mayuge, Busia, Tororo and Manafwa districts, Tsetse-Tick®, Alpha Cypermethrin®, Spot-on® and Decatix® were applied every 7 days rather than every 14 days as recommended. Worse still, Alpha Cypermethrin® in Tororo district was applied every 4 days rather than every 14 days as recommended. Incorrect spraying intervals were attributed to (1) Lack of familiarity among farmers of correct usage and understanding of new acaricide products; (2) Lack of training while changing over to new acaricide products; (3) Availability of a wide range of acaricide products within the project contributing to the mix-up of acaricide spraying intervals; and (4) Farmers' limited awareness on the acaricides. Experience in Zimbabwe has shown that some farmers treat their cattle at preferably longer spraying intervals rather than at the recommended intervals to reduce costs (Torr *et al.*, 2007) [14].

Sufficient pasture varied from district to district, with Iganga, Busia and Manafwa districts being the most pasture feed sufficient, while Budaka, Mayuge and Tororo districts were less pasture feed sufficient. Unfortunately, all districts were not legume feed sufficient. This was attributed to clear understanding of the need for sufficient pasture for the dairy cattle to meet the required milk production, while underestimating the importance of sufficient legume feed. Legume seed was scarce as well.

Budaka district had the highest percentage of poorly managed cowsheds, followed by Busia, Iganga, Mayuge Tororo and Manafwa district. This was attributed to farmers being over-whelmed with too much work during the cultivation season and hence had limited time to properly manage the cowsheds. Incidentally, all dairy farmers visited did not recognize the fact that unhygienic cowshed would lead to increased cases of mastitis and as a result reduce milk production. Indeed, zero-grazing units in Budaka district registered the lowest average milk yield per cow per day.

The best average milk yield per cow per day was registered by zero-grazing units in Iganga district, followed by Mayuge, Manafwa, Busia, Tororo and Budaka districts. A milk yield increment of 56% in cows protected by zero fly fences has been reported previously in Ethiopia (Megersa *et al.*, 2017) [11].

Conclusion

In conclusion, pyrethroid treated netting around zero-grazing units supplemented with periodic spraying of cattle effectively protected dairy cattle against trypanosomosis and maintained their good health. Farmers' observation indicated that as netting became older, they became more fragile. Larger nets of 1.5m high had a longer duration of 6 to 8 months than smaller nets of 1.0 m high, whose duration was 3 to 4 months. While replacement of netting for all zero-grazing units was desirable after the first year of installation, farmers could not afford the cost of netting replacement of 100,000 Uganda shillings (approx. USD 30) per zero-grazing unit.

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