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THE IMPACT OF STABLE FLIES (*Stomoxys calcitrans* L.) ON SMALL STOCK PRODUCTION IN BODIBENG, BOTHATOGO AND SEHITHWA IN THE NORTH WEST DISTRICT, BOTSWANA; A SURVEY STUDY

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ABSTRACT: Stable fly, *Stomoxys calcitrans* L. (Diptera: Muscidae) is a globally recognized livestock pest of economic importance, which also attacks wild animals, pets and humans. These flies frequently feed on the forelegs of animals and can cause significant production losses and severe animal health and welfare concerns. This study investigated the impact of stable flies on small stock (sheep and goats) production and documented control measures adopted by farmers in Sehithwa, Bodibeng and Bothatogo villages in the North West District of Botswana. Simple Random Sampling was used to select 90 respondents in the study area. Data on demographic characteristics (i.e., age, sex, marital and educational status of the respondents), control measures against stable flies, time stable flies appeared, factors contributing to abundance of stable flies, and the role of government and private sector in the control of stable flies were collected and analysed using SAS. The Chi-square test of goodness of fit was used to show the unequal distribution of the frequencies of respondents among the categories for each variable. Results showed that wood smoking (53.33%) was the common control measure against stable flies followed by migration to unaffected areas (35.55%) and dipping (11.11%). Feeding activity of stable flies reached its peak in the evening (58.89%) followed by morning (31.11%), afternoon (6.67%) and the least was night (3.33%). Eighty-seven percent of respondents mentioned that stable fly contributed to poverty, starvation (16.67%) and loss of income (13.33%). It is concluded that stable flies affect livestock productivity and people' livelihood; hence the need to adopt effective control measures. Control measures against these flies will be more effective when applied in the evening and morning.

Keywords: Control measures, Economic losses, Livestock pest, Small stock, Stable flies.

INTRODUCTION

Stable flies (*Stomoxys calcitrans* L.) are among the important livestock pests in most parts of the world (Showler and Osbrink, 2015; Taylor et al., 2020; Rochon et al., 2021). Kneeland et al. (2012) reported that stable flies are cosmopolitan pests of livestock, wild animals, pets and humans. They have been reported as pests of livestock and humans since the late 1800s to early 1900s (Cook, 2020). Stable flies are hematophagous insects that feed on fore legs of cattle (Erasmus, 2015). Stable fly is a cosmopolitan biting fly of both economic and welfare concern, mainly due to its painful bite, which can cause blood loss, discomfort and loss of livestock productivity (Parravani et al., 2019). According to Taylor et al. (2020), the painful bites from stable flies induce costly behavioral and physiological stress responses and reduce productivity. The flies ignore swatting, stamping and other tactics that the animals use to try to avoid the bites (Kaufman and Weeks, 2019). Stable fly is commonly known as *lethobo* in the North West district of Botswana where it causes economic losses on livestock following the rainy season. Stable fly parasitism has the greatest effect on the livestock industry where animals are confined to stables or pastures, providing suitable conditions for feeding and oviposition of the flies (Kneeland, 2011). Taylor et al. (2006) reported that the stress from *S. calcitrans* painful bites causes confined animals to bunch together or stand in water in an endeavour to escape the fly annoyance or perform avoidance behavior. This results in a significant decline in weight gain or milk production.

Stable fly is the primary pest of cattle that causes major economic losses estimated to over 1 billion USD in cattle feedlots, cattle dairies and in poultry farms in the United States (Kneeland, 2011). Both female and male flies feed on blood and are persistent feeders that cause significant irritation to their host. They can be distinguished with their distinct stiletto like proboscis that extend forward beyond the head. This sharp point beak is used to pierce the skin and draw blood (Kneeland, 2011). According to Showler and Osbrink (2015), stable flies mostly feed on the lower parts of animal

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front legs where hair is less and shorter. The study by Cruz-Vázquez et al. (2004) in Mexico reported that the population of *S. calcitrans* increases fast when the humidity is high due to seasonal rainfall. This explains why *S. calcitrans* occurs following heavy rains in the North West district of Botswana.

Arable and livestock production are practised in Ngamiland East Agricultural District, however, livestock production forms the main agricultural activity. The district comprises 17 extension areas including Bodibeng, Bothatogo and Chanoga (research sites). Statistics Botswana (2018) estimates the populations of cattle, sheep, goats, horses and donkeys in Ngamiland East to be 94300, 10352, 61332, 3169 and 9288, respectively. Although stable fly causes enormous significant livestock mortalities and decreased productivity in the North West District of Botswana resulting in economic losses, no studies have been conducted on this pest. Therefore, a survey study was conducted to investigate the impact of stable flies on small stock (sheep and goats) production and to document measures adopted by farmers to control this pest in Bodibeng, Bothatogo and Sehithwa villages of the North West district of Botswana.

MATERIALS AND METHODS

Study area

The study was conducted in accordance with ethical regulations (i.e., BUAN-AEC-2022-01) approved by the Animal Ethics Committee of Botswana University of Agriculture and Natural Resources. The North West District which comprises Ngamiland East and West has an estimated human population of 175 631. Ngamiland East and Ngamiland East have human populations of 90 334 and 59 421, respectively (Buthali, 2014). The study was conducted in Bodibeng, Sehithwa and Bothatogo of Ngamiland East in the North West District of Botswana in February 2021. The location coordinates for each village are as follows: Bodibeng 20 37'22.79"S and 22 36'6. 59"E; Sehithwa 20 28'00"S and 22 43'00 and Bothatogo -20 47'68.8"S and 22 71 '36.2"E (Statistics Botswana, 2015). The estimated human population for Sehithwa is 2748, 778 for Bodibeng and 555 for Bothatogo (Statistics Botswana, 2015). The distance of the villages from Maun (the district's capital) is as follows: Sehithwa 100 km, Bodibeng 136 km and 112 km for Bothatogo. The research sites (i.e., Bodibeng, Bothatogo and Sehithwa) are shown in Figure 1.

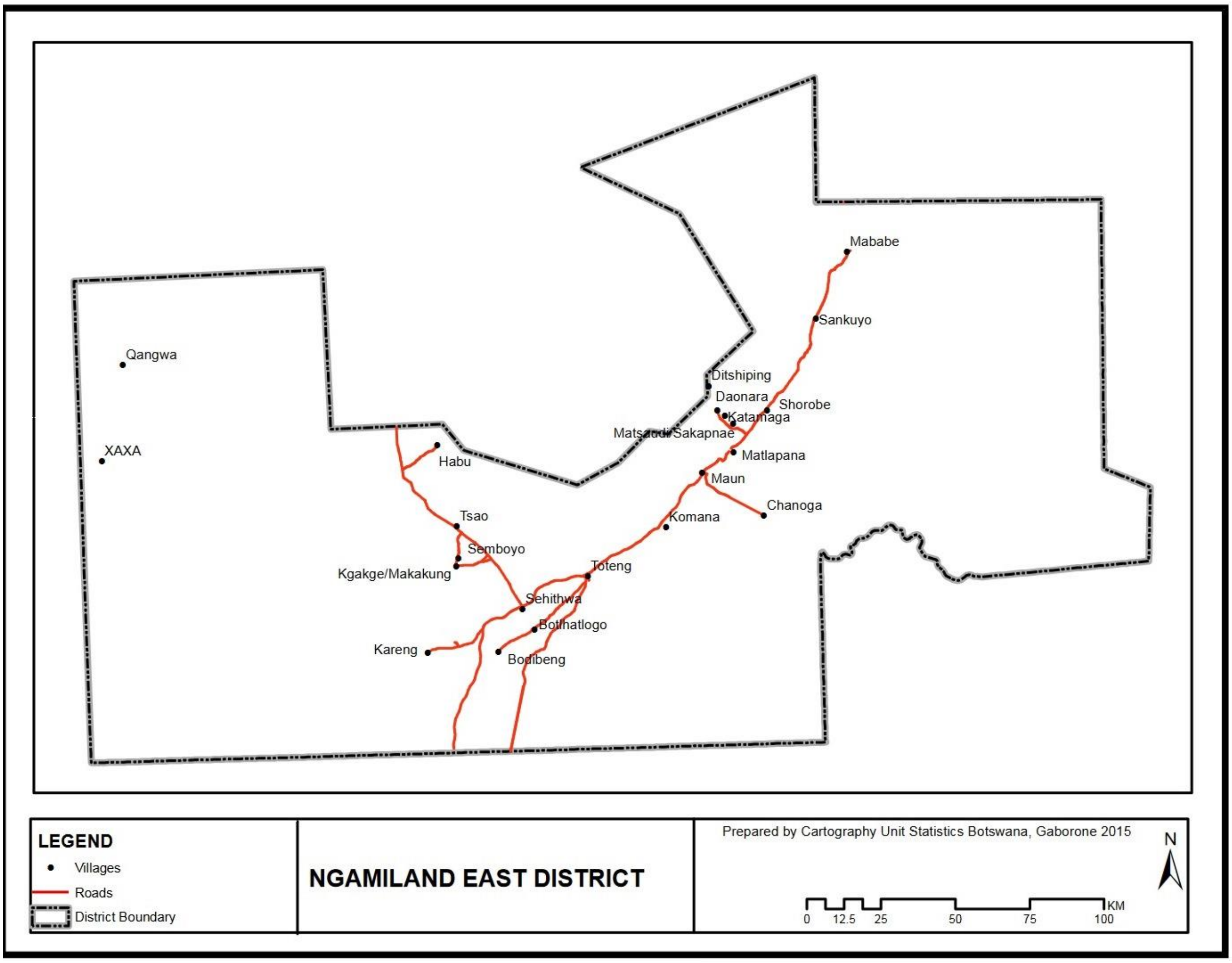

Figure 1 - Map of Ngamiland East District showing the research sites (Source link)

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Sample design

Simple Random Sampling technique was used to select 90 respondents in the study area (i.e., Bodibeng, Bothatogo and Sehithwa). Sample size was based on the population size of the research sites/villages (Table 1).

Table 1 - Sample size of research sites

Village	Estimated population	Sample size
Sehithwa	2748	40
Bodibeng	778	30
Bothatogo	555	20
Total	3581	90

Sources: Statistics Botswana (2015)

Data collection

Data were collected using a structured questionnaire that was administered to 90 respondents across the three villages to gather information on stable flies and their impact on small stock production. Data were also collected from secondary resources. Interviews were conducted in local languages (i.e., Setswana and Herero) and responses written in English. Respondents were asked to give information on sex, educational level, age, practices used to control stable flies, time stable flies appears, factors that contribute to the abundance of stable flies, as well as, role of Government and private sector in the control of stable flies in the study area.

Data analysis

Data derived from questionnaires were captured into a spread sheet and analysed using Statistical Analysis System (SAS, version 9.4) (SAS Institute, 2002-2012). Data were subjected to frequency analysis. Summary statistics are presented in tables and figures. The Chi-square test of goodness of fit was used to show the unequal distribution of the frequencies of respondents among the categories for each variable.

RESULTS AND DISCUSSION

Demographic characteristics of the respondents

Data on demographic characteristics of the respondents are presented in Table 2. The majority (54.44%) of the respondents were married followed by singles (38.89%) with the least being divorced (6.67%). About 51% of the respondents were females and the remainder males. In this study, majority of respondents were aged 36 years and above (53.33%) followed by 26 to 35 years (38.89%), 19 to 25 years (6.67%) and 18 years and below (1.11%). This shows that older people were involved in livestock production than young people probably because they are more experienced than the young generation. However, youth participation in livestock production in this study is high (46.67%). According to the Annual Agricultural Survey 2017, youth (15 to 35 years) participation in agriculture in Botswana is 5.6% (Statistics Botswana, 2019).

According to Table 2, 67.78% respondents had junior secondary education followed by non-formal education (13.33%), primary education (5.56%), never attended school (5.56%), senior secondary education (4.44%), and tertiary education (3.33%). The literacy level in this study was 94.44% which indicates that the respondents were likely to consume extension messages and/or try to adopt new technologies with ease. Opoku-Amankwah and Brew-Hammond (2009) stated that people who can read and write are able to keep records in trade and agriculture.

Animals affected by stable flies

Stable flies and other flies such as horn flies, horse flies, house flies and bow flies are considered troublesome to goats (Talley, 2015). Table 3 shows that sheep and goats are affected by stable flies (47.78%) more than other animals followed by cattle (34.44%), dogs (3.33%) and calves (2.22%). In consonance with this finding, the North West district First Sub-Council Meeting of 2021/2022 stated that high mortalities due to stable flies were recorded in small stock compared to other livestock such as cattle, donkeys and equines (North West District Council Report, 2021). Data from the Sub-Council revealed that 2282 small stock, 310 cattle and 7 donkeys were killed by stable flies. Sheep and goats appear to be vulnerable to stable flies probably because of their short tails which make it difficult for them to keep away stable flies. Compared to large stock (cattle and equines), small stock has thin coat layers which enable the stable flies' sharp proboscis to penetrate easily during feeding activity. Although stable flies feed mainly on large animals such as horses, donkeys and cattle for a blood meal, in the absence of these animals they will bite goats, sheep, pigs, pets and humans (Kaufman and Weeks, 2019). According to ElAshmawy et al. (2021), cattle react to biting stable flies with an aggregating behavior known as bunching, which reduces grazing or feed consumption leading to a decrease in cattle productivity and welfare.

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Table 2 - Demographic characteristics of respondents in the study area			
Category	**Frequency**	**Percentage**	**Chi-square test p-value***
Marital status			
Single	35	38.89	
Married	49	54.44	
Divorced	5	5.56	
Other	1	1.11	
Total	90	100	0.0001
Sex			
Female	46	51.11	
Male	44	48.89	
Total	90	100	0.8330
Age			
≤ 18 years	1	1.11	
19-25 years	6	6.67	
26-35 years	35	38.89	
≥ 36 years	48	53.33	
Total	90	100	0.0001
Education			
Primary school	5	5.56	
Junior secondary school	61	67.78	
Senior school	4	4.44	
Tertiary	3	3.33	
Non-formal education	12	13.33	
Never attended school	5	5.56	
Total	90	100	0.0001

*The categories of the respective variables have significantly different frequencies if the chi-square test p-value less than 0.05.

Table 3 - Animal mostly affected by stable flies in the study area

Animal	Frequency	Percentage
Small stock	43	47.78
Dogs	3	3.33
Calves	2	2.22
Cattle	31	34.44
Chi-square p-value	0.0001*	

*Animal categories have significantly different frequencies since the chi-square test p-value is less than 0.05.

Table 4 - Part of the day in which stable flies attack animals

Time	Frequency	Percentage
Morning	28	31.11
Afternoon	6	6.67
Evening	53	58.89
Night	3	3.33
Total	90	100
Chi-square p-value		0.0001*

*Time categories have significantly different frequencies since the chi-square test p-value is less than 0.05.

Time of stable flies occur

The frequency analysis output showed that 53% of the respondents mentioned that stable fly outbreak occurs in autumn (March and April) while the remainder said it occurs in summer (November to February). These frequencies were not statistically different (P>0.05) though it is expected that precipitation in summer favours the outbreak of stable flies. Actual measurement of the prevalence of the stable flies in the study area might prove otherwise compared to the respondents' perception. Kaufman and Weeks (2019) observed that stable fly abundance is closely linked to rainfall. Previous study by Evert (2014) at Karan Beef Feedlot in South Africa showed that high rainfall contributes to the abundance of stable flies. Furthermore, Gillies et al. (2008) and Erasmus (2015) reported that environmental factors such as temperature, humidity and rainfall are positively correlated to stable fly outbreaks. In Botswana, November to February is the rainy season and during this period temperatures are high in the North West district and the rest of the country. These factors (i.e., temperature and moisture) favor the outbreak of stable flies. A related study by Pitzer et al. (2011) on equines in Florida State in the United States reported that stable flies can be active throughout the year but feeding activity is greatest between January and April (fall) depending on the amount of rain. This indicates that rainfall is an important factor in stable fly outbreaks.

Approximately 59% of the respondents mentioned that stable flies attack animals in the evenings followed by mornings (31.11%) (Table 4). These findings are consistent with Semelbauer et al. (2018) and ElAshmawy et al. (2021) who stated that temperature and relative humidity are the most important factors that influence feeding activity of stable fly. The authors observed stable flies' seasonal activity to be large at the end of summer with a second smaller peak before the end of the flight season. Kaufman and Weeks (2019) reported that in warm weather, stable flies feed on their hosts during the early morning and late afternoon while in cooler weather feeding is in the middle of the day. Berry and Campbell (1985) demonstrated that stable fly feeding activity is at peak at 24-30 °C. In another study, Lendzele et al.

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(2019) reported that the pest's daily activity peak was between 14 hours and 16 hours with a mean temperature of 31 °C, a mean wind speed of 1.5 m/s, and a mean humidity of 50%. Showler and Osbrink (2015) reported that stable flies bask in the sun on the sunny side of animals when the temperatures are low, indicating that temperature positively correlates to stable fly feeding activity. In Thailand, Masmeatathip et al. (2006) found that stable flies' feeding activity was high between 08:00-10:00 hours. In disagreement with the current findings, Thomas et al. (1989) in southern Nebraska in the United States observed that stable fly feeding activity in feedlot animals was higher at 1400 hours.

Control measures against stable flies

Although many researches in different parts of the world have been carried out on the ways of eliminating stable flies, none of these measures have been reported to be successful. From Table 5, 53.33% of the respondents used wood smoking as a control measure against stable flies followed by migration (relocation of livestock) to unaffected areas (35.55%) and dips (11.11%). The 2021/2022 North West District Council First Session reported that 26 cattle crushes in Sehithwa, Tsau, Shorobe and Bodibeng extension areas were affected by stable flies and that 198 farmers were assisted with acaricides to dip their animals (North West District Report, 2021). The respondents reported that they experienced high mortalities due to late provision of acaricides. This indicates that farmers in the study area were not taking it upon themselves to buy dips but wait for government, international organizations such as United Nations Development Programme and the private sector to supply them with dips. During the 2018 stable fly outbreak some company in Maun (the capital of North West district) donated acaricides to farmers around Sehithwa extension area. It is therefore important that the extension services encourage farmers to purchase acaricides and dip their animals in time to reduce losses due to stable flies.

Table 5 - Common practices used by farmers to control stable flies in the study area

Animal	Frequency	Percentage
Dips	10	11.11
Migration to unaffected areas	32	35.55
Wood smoking	48	53.33
Total	90	100
Chi-square p-value	0.0001*	

*Practice categories have significantly different frequencies since the chi-square test p-value is less than 0.05.

As mentioned earlier, wood smoking was the most common control measure used against stable flies in the study area. Green grass, old tyres and cow dung were burnt to produce smoke to render pests inactive. Wood smoking is cheaper compared to dips but is unfriendly to the environment. According to Hogsette et al. (1987), burning repeatedly effectively kills stable fly larvae and pupae. In this study, only 11.11% of the respondents used dips possibly because majority of them did not know how to mix and apply dips. About 82% of the respondents mentioned that they could not afford to purchase acaricides to use against stable flies as they were expensive. Failure by majority of respondents to use dips might point to inadequacy of technical support from the extension services (government or private). Foil and Hogsette (1994) stated that treatment of animals with residual insecticides can help in controlling stable flies with thorough application of the chemical to the lower body parts of livestock being important.

Seventy-five percent of the respondents mentioned that they could not relocate their animals from the areas affected with stable flies to unaffected areas due to high labour costs required for migration. Relocating animals from areas affected with *S. calcitrans* to unaffected areas is likely to result in the spread of this pest and diseases to areas that were not affected before and hence lead to more animal deaths. Rochon et al. (2021) reported that stable flies are associated with the mechanical transmission of several pathogens that cause diseases in animals. According to Kaufman and Weeks (2019), stable flies can transmit the pathogens that cause diseases such as anthrax, equine infectious anemia, and anaplasmosis. Furthermore, wounds resulting from bites can also become secondarily infected by opportunistic pathogens. Again, some animals are likely to get astray during the relocation while others might die from thirst and stress due to being trekked long distances. In addition, relocation of animals to new areas could lead to increased incidences of stock theft and overgrazing, as well as, mortalities due to adaptation challenges. Kneeland (2011) stated that integrated pest management is the most recommended pest control measure as it involves a combination of different pest control measures. Other control measures that can be effective in reducing stable fly populations include the use of modified traps, and using either treated targets or solar-powered electrocution grids (Foil and Hogsette, 1994).

Role of extension in the control of stable flies

About 97% of the respondents said that support from Ministry of Agricultural Development and Food Security was inadequate. Seventy-nine percent of the respondents reported that Department of Veterinary Services (DVS) provided acaricides on time (*i.e.*, before the rainy season) to enable farmers prepare for the outbreak, whereas the remainder said support came late. In addition, the respondents said that the acaricides supplied to farmers by DVS were not enough for

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their herds as one liter of acaricides provided was shared by 2 to 3 households. Previous study by Seleka (2005) in Botswana reported that livestock management and husbandry practices are poor among smallholder livestock farmers who dominate the livestock subsector in Botswana. Moreover, Cook (2020) observed that acaricides such as larvicides and animal spray provide a quick knockdown to adult flies, indicating that dips are more effective than wood smoking. Recently, Barros et al. (2019) evaluated the susceptibility of *S. calcitrans* populations to cypermethrin in the state of Mato Grosso do Sul in Brazil and found that all the populations were resistant to cypermethrin, with resistance factors among field populations ranging from 6.8 to 38.6. The authors concluded that the intensive use of insecticides leads to the development of pyrethroid resistance in stable fly populations.

In this study, 97.77% of the respondents mentioned that they were not trained to use acaricides while a smaller percentage of respondents acknowledged receiving training on the use of acaricides. The training which was on livestock management was held in Nxaraga Rural Training Centre and lasted for 5 days. The fact that about 98% of the respondents did not receive training on the use of acaricides indicates that technical support to farmers is inadequate. This also indicates that extension service could be inadequate.

Impact of stable flies on the rural economy

Stable flies are pests of economic importance as they continue to cause great losses in animal production. The 2021/2022 North West District Council first session estimated small stock, cattle and donkey mortalities due to *S. calcitrans* to be 2282, 310 and 7, respectively (North West District Report, 2021). As the Government of Botswana buys a unit of small stock for beneficiaries of Government support programmes such as Livestock Management and Infrastructure Development and Poverty Eradication at 1000 BWP (100 USD), small stock losses due to stable flies is estimated to be 2 282 000 BWP (228200 USD). However, this value is underestimated as most farmers could not recall losses incurred or report losses to DVS. The cost of medication for the diseased animals is not known as the number of diseased animals could not be estimated.

As illustrated in Figure 2, the outbreak of stable flies has deleterious effect on the livelihoods of households in the study area. About 87% of the respondents mentioned that stable fly outbreaks contributed to poverty followed by starvation (16.67%) and loss of income (13.33%). The loss of animals due to stable flies render households which depend majorly on livestock production for a living more vulnerable to economic hardships, especially in the era of COVID-19 pandemic. The climate and soils in the North West district support livestock production than crop production. The respondents mentioned that they were no longer able to sell their animals due to their poor body conditions resulting from stable flies' bites.

Fifty-five percent of respondents said they lost nearly all their animals due to stable flies. This indicates that stable flies cause economic losses and hardships to livestock farmers in the study area; hence the need for intervention. Taylor et al. (2012) estimated economic national losses due to stable flies for each animal industry sector in the United States to be 358 million USD, 226 million USD, 360 million USD, 1.268 million USD for cow calf herds, cattle on feed, dairy cattle and pastured cattle, respectively. The authors estimated the median annual losses in animal production to be 139 kg of milk for dairy cows, 6 kg of body weight for pre-weanling calves, 26 kg body weight for pastured calves and 9 kg of body weight for feeder cattle of body weight. These values show that stable flies detrimentally affect animal performance, people' livelihoods and the economy in its entirety.

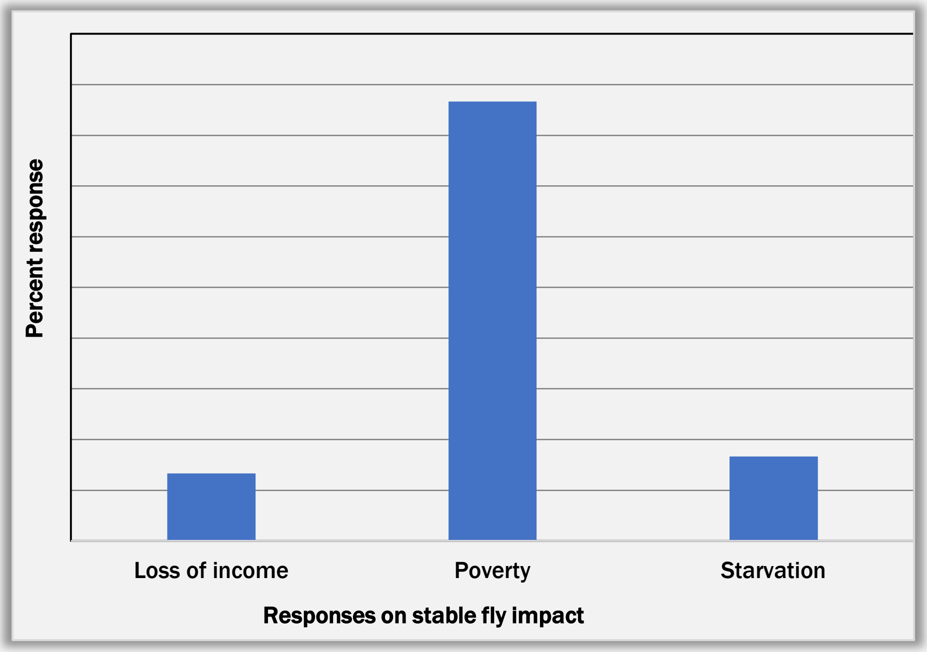

Figure 2 - Impact of stable flies on people's livelihood

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CONCLUSION

Stable flies cause economic losses in livestock production, thus affecting livelihoods of families in North West District and the rural economy in its entirety. Therefore, there is a need to come up with effective control measures against this pest. Although 53.33% of respondents said wood smoking was an effective control measure against stable flies, it is important that the respondents are encouraged to adopt other control measures such as integrated pest management to eliminate stable flies to avoid unnecessary losses.

Recommendations

1. Further research on stable fly ecology and biology in the North West district is required in order to come up with more effective control measures against this pest of economic importance.
2. Monitoring of stable fly for early detection of possible outbreaks using sticky traps must be carried out.

DECLARATIONS

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Authors' contributions

J.C. Moreki: Conceptualised the study, guided collection of data and wrote the manuscript.
K. Tjinyeka: Collected data and participated in the writing of the manuscript.
K. Tlotleng: Edited and critiqued the manuscript.
J. Makore: Assisted with statistical design and analysis and edited the manuscript.
M.I. Moseki: Edited the manuscript and provided some relevant literature.

Availability of data

Data can be made available to the journal upon request.

Conflict of interest

All the authors consented to the publication of this manuscript. The authors declare no conflict of interest.

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