STUDIES ON PYRETHROID EAR TAGS AND PYRETHROID RESISTANCE IN HORN FLY POPULATIONS IN MANITOBA

BY

FELIX SIMASIKU MWANGALA

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ABSTRACT

Studies on Pyrethroid Ear Tags and Pyrethroid Resistance in Horn Fly Populations in Manitoba.

By

Felix Simasiku Mwangala

Major Advisor: Dr. Terry D. Galloway.

This study was undertaken from 1987 to 1990, in Manitoba. A producer survey was conducted in 1987 to determine the extent of insecticidal ear tag usage in Manitoba. More than 80% of the 200 cattle producers who responded to the questionnaire applied tags to control flies. Ear tags were more rapidly adopted by beef producers than by dairy producers. Most of the producers applied one tag per animal and were satisfied with the control afforded by ear tags. Fenvalerate tags were used extensively followed by permethrin tags.

Field horn fly populations were evaluated for resistance to fenvalerate and permethrin using the impregnated filter paper petri-dish method in 1987 to 1989. Resistance factors were calculated by comparison to a susceptible laboratory strain from Kerrville, Texas. The number of resistant populations and intensity of resistance increased during the study. Resistance factors ranged from 0.11- to 5.5-fold and 0.6- to 14-fold in 1987, 0.03- to 38-fold and 0.1 to over 100-fold in 1988, and 1.0- to 62-fold and 0.8- to over 100-fold in 1989, for fenvalerate and

permethrin, respectively. Resistant flies were sampled on 3 herds in 1987, 6 herds in 1988, and 10 herds in 1989.

Fenvalerate and permethrin residues on hair of cattle at Glenlea Research Station were determined, using gas chromatography, over a 3 month period following application of two tags per animal or one tag for every other animal. Cattle with two tags had significantly higher residues on the head and neck region for one month and on the body and rump for 2 wk than cattle with one tag or without a tag in the same herd. Residues on cattle with or without a tag in the same herd were similar. Residues declined by 80 to 86% on the head, 73 to 78% on the body and 36 to 84% on the rump. The isomeric composition varied from 51-61% SR,RS:39-49%SS,RR for fenvalerate and 61-67% *trans*:33-39% *cis* for permethrin.

Fly numbers on cattle with two tags per animal and one tag for every animal were similar in 1987 and 1988. Fly numbers increased towards the end of the season and were higher in 1988 than in 1987. The LC_{50}'s of these flies increased during each season but the LC_{50}'s declined between fall and spring. Susceptible flies were eliminated from the population upon application of tags.

Stability of resistance to pyrethroids was assessed in two resistant horn fly populations at Glenlea and Libau Community Pasture in 1989. The response of these populations to fenvalerate and permethrin was similar during the season in the absence of tags. Tag formulations containing 20% diazinon, 4% cypermethrin + 18% diazinon, 10% λ-cyhalothrin, and 10 λ-cyhalothrin + 13% piperonyl butoxide were effective against pyrethroid resistant horn flies; and combination tags were as effective as single formulation tags.

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CHAPTER I

INTRODUCTION

The Problem

The horn fly, *Haematobia irritans* (L.), is an obligate blood sucking ectoparasite of cattle. It was introduced into the United States (U.S.) from Europe about 1885 (Riley 1889). In Canada, the fly was first reported in Oshawa, Ontario in 1892 (Fletcher 1892) and established itself as a major cattle pest in all provinces of Canada by 1900 (Hearle 1938). Horn flies cause over US $730 million (Drummond 1987) and Canadian $30 million (Skaptason 1950) losses to cattle production in the U.S.A. and Canada, respectively.

The traditional and most effective method of controlling horn flies has been the application of insecticides on cattle. This strategy has been effective because horn flies rest on cattle most of the time. Various delivery methods have been used to deposit insecticides on cattle hair. These methods include spraying, dusting and self-treatment devices, including backrubbers, dust bags, oilers and, more recently, insecticide-impregnated ear tags.

Insecticidal ear tags were introduced in the late 1970's and gained widespread and rapid acceptance by producers. Unlike other insecticide application methods that required regular handling of cattle and/or maintenance of equipment, insecticidal ear tags provided a simple, easy and effective season long control method for susceptible flies. Because of these properties, ear tags became very popular with producers.

However, within 2 to 4 yr of widespread ear tag usage, horn flies developed resistance to insecticides in the ear tags in the U.S. (Kunz and Schmidt 1985a; Quisenberry *et al*. 1984; Schmidt *et al*. 1985; Sheppard 1984). In Canada, ear tags were registered in 1981 (S. Van Walleghem, Ag. Canada, pers. comm.) but prior to the start of this research, there were no confirmed reports of horn fly resistance to insecticides in ear tags.

Objectives of the Research

The objectives of this research were to determine:

a) the extent of insecticidal ear tag usage in Manitoba,

b) the susceptibility of horn flies in Manitoba to pyrethroids,

c) the levels of pyrethroid residues deposited on hair over various regions of cattle following application of ear tags,

d) the changes in susceptibility of horn flies from cattle treated with fenvalerate and permethrin tags during the season,

e) the stability of pyrethroid resistance in field populations of horn flies in the absence of selection pressure, and

f) the efficacy of alternative control strategies against pyrethroid-resistant strains.

Thesis Organization

The results reported in this thesis are from experiments carried out from September, 1986 to April, 1990. Extent of insecticidal ear tag usage in Manitoba was determined through a questionnaire sent to producers in April, 1987. The questionnaire was also used to identify potential producer co-operators for future studies. Horn flies used in the susceptibility studies were collected from producers' cattle in various regions of the province during the summers of 1987, 1988 and 1989. Collection of hair samples for pyrethroid residue analysis and changes in the susceptibility of horn flies from cattle tagged with permethrin and fenvalerate tags were carried out at the University of Manitoba's Glenlea Research Station in the summers of 1987 and 1988. Studies on the stability of pyrethroid resistance in horn flies were conducted at the Glenlea Research Station and Libau Community Pasture in the summer of 1989. Efficacy of alternative control strategies against pyrethroid-resistant horn flies was evaluated on cattle at Libau Community Pasture, Narcisse Community Pasture, Gunton Bull Test Station, and cattle of producers near Libau and Lundar.

This thesis is divided into Chapters, each covering a separate aspect of the research. The problem and objectives of the research are outlined in Chapter I. Literature pertinent to the research is reviewed in Chapter II. Results of the experimental studies are described in Chapter III, and are prepared in sections in a style suitable for publication as a series of scientific papers. Section I covers the extent of ear tag usage in Manitoba. Susceptibility levels of horn flies to pyrethroids in Manitoba are reported in Section II. Distribution of pyrethroid residues on hair of cattle following application of ear tags are reported in Section III. Section IV covers studies on the dynamics of horn fly resistance to pyrethroids on tagged cattle during the season. Studies on the stability of pyrethroid resistance in horn flies in the absence of selection pressure are reported in Section V, while the studies on the efficacy of other control strategies against resistant strains are covered in section VI. A general discussion and conclusions from the research are presented in Chapters IV and V, respectively.

CHAPTER II

PERTINENT LITERATURE

Introduction

The horn fly, *Haematobia irritans* (L.), is an obligate blood sucking ectoparasite of cattle and is distributed throughout most of Europe, North Africa, Asia Minor, and the Americas (McLintock and Depner 1954). It was introduced into the United States from Southern Europe in about 1885, probably through shipments of cattle from Europe (Riley 1889). The fly became established in the New World and is now distributed from Venezuela in the south to about latitude 53° 33' North (McLintock and Depner 1954). In Canada, the fly was first reported in Oshawa, Ontario in 1892 (Fletcher 1892) and was established as a major cattle pest in all the provinces by 1900 (Hearle 1938).

Biology of Horn flies

The horn fly appears on cattle in spring with the onset of warm weather. On emergence, the flies seek their hosts and are attracted by carbon dioxide, heat, colour, and odour (Dalton *et al.* 1978). The latter seems to be the major attractant, at least over short distances (Dalton *et al.* 1978). The flies are also more attracted to dark coloured animals than to light coloured ones (Burns *et al.* 1962) and seem to prefer a temperature of about 37.8 °C (Dalton *et al.*

1978). Horn flies can disperse long distance over short periods (Beadles *et al*. 1975; Byford *et al*. 1987a; Eddy *et al*. 1962; Kinzer and Reeves 1974; Kunz *et al*. 1983; Skoda *et al*. 1987; Tugwell *et al*. 1966). Flies can disperse 12 km in 10 hr (Kinzer and Reeves 1974) and up to 26 km (Beadles *et al*. 1975). Newly emerged flies seeking their first hosts are the primary dispersers (Chamberlain 1982; Guillot *et al*. 1988; Tugwell *et al*. 1966). Once hosts are located, there appears to be little propensity for dispersal (Chamberlain 1981, 1982; McLintock and Depner 1954).

The flies spend most of their time resting on the host. They are intermittent feeders and take 24 to 36 blood meals per day (Harris *et al*. 1974). The flies rest on parts of the host that cannot be reached by the head or tail, slightly behind the shoulders, at the base of the horns, on the middle of the belly and low on the hind legs (McLintock and Depner 1954). Horn flies are sensitive to changes in temperature and move to the most favourable locations (Hammer 1942). When the weather is cloudy or cool, the flies always rest on the back of cattle, but when the weather is bright and sunny, their resting sites depend on air temperature. At temperatures up to 19 °C, flies tend to congregate on the back, but at temperatures of 26 to 29 °C, flies congregate on the shaded regions underneath the belly, on lower parts of the hind legs and on the scrotum or the udder (McLintock and Depner 1954).

Female flies leave the host for short periods to oviposit in fresh dung pats. The flies lay their eggs chiefly, if not exclusively, in the dung (McLintock and Depner 1954). The dung is most attractive to the flies during the first 2 minutes after defecation (Sanders and Dobson 1969). The eggs are deposited in groups of four to six on the pat surface, along the sides or in close proximity to the pat. Oviposition occurs during the day and night, but more adults are produced in the dung pats deposited at night than those deposited during the day (Kunz *et al*. 1970). This may be due to slow drying of the dung pats at night which increases egg survival. The number of eggs laid by a single female at each laying depends on temperature and humidity, and can be up to 24 (Bruce 1940). Each female is capable of laying 375 to 400 eggs over her life span (Bruce 1942), with maximum egg production on the third day after maturity (Palmer and Bay 1982).

Eggs hatch within 24 hr and viability depends on the temperature and humidity. The optimum temperature for egg development is about 20 °C. Above this temperature, survival of eggs decreases (Melvin 1934). The eggs also require high humidity to avoid desiccation.

Upon hatching the larvae burrow into the dung, where they feed. The larvae go through three instars and developmental time depends on temperature. Pupation occurs in the lower part of the dung or in the ground immediately beneath it and may take 3 to 12 days (McLintock and Depner 1954). At 29 °C, adults emerge in three to four days (McLintock and Depner 1954). Adult flies can survive for seven weeks in the field (Bruce 1942). In the laboratory, horn flies have been kept on artificial diets or on a calf for as long as 28 days (McLintock and Depner 1954). Under hot, humid conditions, one generation from egg to adult may take only 8 to 14 days and up to 30 days during spring and fall (Depner 1961). In warmer regions, the generation time of horn flies is about 8 to 10 days (Kunz *et al*. 1970), and the season may be 8 to 12 months (Kunz and Cunningham 1977; Thomas and Kunz 1986; Thomas *et al*. 1987). In Manitoba and most of Canada, the generation time is more than 14 days and the season is less than 5 months (Depner 1961; McLintock and Depner 1954).

Diapause occurs mainly in the pupal stage (Bruce 1940; Hammer 1942) and the intrapuparial pharate stage (Thomas 1985), though McLintock and Depner (1954) reported overwintering third instar larvae. Diapause is mainly triggered when adults are exposed to short photoperiod and the larvae are exposed to cool temperatures during fall (Thomas and Kunz 1986; Wright 1970).

Economic Impact of Horn Flies

Horn flies cause an estimated $730 million (U.S.) and $30 million (Canadian) loss annually to beef cattle and dairy industries of the United States and Canada respectively (Drummond *et al.* 1981; Skaptason 1950). These losses arise more from morbidity than mortality. Morbidity losses are principally from irritation and annoyance. Cattle under attack from horn flies are restless, nervous and difficult to handle. They lash their tails, swing their heads from side to side, and kick at their bellies; this results in unnecessary expenditure of energy and reduced grazing time.

The effects of horn control on beef and milk production have been reviewed by Palmer and Bay (1981), Drummond *et al.* (1981), and Drummond (1987). A number of studies have been conducted to quantify the effect of horn flies on the performance of cattle. The results of these studies have varied, probably due to the influence of other factors, such as nutrition and pasture quality, breed differences, presence of other insects, and horn fly infestation. Kinzer *et al.* (1984) reported a reduced average daily weight gain of 0.045 kg to 0.162 kg in steers exposed to horn flies in screened pens. They also observed a reduction in feed efficiency; fly-infested steers required 9.1 to 24.3% more feed to achieve weight gain equal to the screened ones. Yearling steers that were protected from horn flies on pasture gained an average of 8 kg more than the unprotected steers over the season (Harvey and Brethour 1979). An increase in live weight gain of 17.7% was also reported by

Haufe (1982) in steers protected by fenvalerate ear tags over a 115-day grazing period on range. However, in a 3 yr study, Schreiber *et al.* (1987) reported no significant cow, calf or cow/calf weight gains when cows were tagged with one fenvalerate tag per head. Brethour *et al.* (1987) did not observe any significant returns in using flucythrinate tags on Brahman x Hereford yearling heifers and very little on Angus x Hereford heifers.

Loss in milk production attributed to horn flies has been estimated at $59 million (U.S.) per year (Anonymous 1976). Morgan and Bailie (1980) found a mean increase of 0.8 to 1.0 kg in milk yield per cow per day from horn fly free cows. An increase of 20% to 25% in milk production was also reported by Skaptason (1948). Reduction in milk yield has been measured indirectly using the weaning weights of calves. Calves weaned from cows that were protected from horn flies had an average weaning weight of 5.8 kg/calf more than those weaned from untreated cows (Campbell 1976). Kunz *et al.* (1984) demonstrated that calves from fenvalerate-treated cows outweighed calves from untreated cows by 7.4 kg per head at weaning which gave an increase of up to $8.38 per $1 spent on fly control. Similar results have been reported by Kopp *et al.* (1984) and Quisenberry and Strohbehn (1984) in North Dakota and Iowa, respectively. In a study by Cocke *et al.* (1990a), male and female calves gained 6.7 and 11.3 kg, more than males and females from an untreated herd, representing a \$5.00 to \$ 7.44 return for each \$1.00 spent on ear tags. However, when the data were analyzed by breed, some breeds did not show any significant gains. Fly control did not affect calf weight gain in a study by Essing and Pund (1965).

Horn flies also cause blood loss in their hosts. A cow carrying 500 flies loses about 7 mL of blood per day (Harris and Frazar 1970). In addition, cattle attacked by horn flies have higher heart rates, respiration rates and rectal temperatures than the horn fly free ones (Schwinghammer *et al*. 1986).

Horn flies feed intermittently and move frequently from one animal to another. They are potential vectors of disease agents e.g. the parasitic filarial worm (*Stephanofilaria stilesi* Chitwood), which causes dermatitis (Hibler 1966). Butler *et al*. (1977) demonstrated the capacity of horn flies to transmit disease agents mechanically by using radioisotope ^{32}P. The flies transferred ^{32}P to a new food source in their first and second feeding, and the saliva was labelled for about two hours.

Attempts have been made to relate horn fly populations to reductions in potential production in order to establish economic threshold levels. Different economic thresholds have been determined for different localities. Haufe (1981) estimated the economic threshold at 12 flies per animal. In

Texas, the economic threshold is 250 flies per animal (Patrick *et al.* 1989, cited in Cocke *et al.* 1990a).

Control Methods

Horn flies spend most of the time on the host, and are therefore highly susceptible to insecticides applied to the host using a variety of methods. The methods include dipping, spraying, dusting, ultra low volume aerial spraying, and self-application devices.

The commonly used early methods were dipping and spraying, and to a lesser extent dusting. These methods had certain disadvantages. Dipping involved rounding up the cattle from pastures to dipping vats containing insecticide wash. Dipping required a fairly large labour input to round up cattle, to force them into the dip vat and attend to them as they swim through the vat. Spraying also involves rounding up cattle from pastures and herding them into chutes where they are confined and sprayed. Cattle can also be sprayed on pasture using vehicle-mounted sprayers. Dusts may also be applied to confined cattle either with hand dusters or with power dusters. Most of the insecticides that were used with these methods were not persistent and protected animals for less than two weeks. Therefore, insecticides had to be applied fortnightly to achieve good control. In addition to the labour required to round up cattle, spraying and dipping resulted in physical stress and interrupted grazing. As the cost of labour increased, spraying and dipping fell out of favour and producers started to use self-application devices.

Ultra low volume aerial spraying was used for horn fly control; low volumes of insecticides were sprayed on cattle on pastures by low flying aircraft. Ultra low volume spraying did not require gathering of animals and utilized low volumes of insecticides which resulted in lower residues. However, the noise from the aircraft excited cattle and more applications were required per season because the insecticides were not persistent. This made U.L.V. aerial spraying expensive and impractical under range conditions (Kinzer 1969).

Self-application devices include backrubbers, oilers, dust bags and, more recently, insecticide-impregnated ear tags. With these methods, there is no need to round up cattle regularly, therefore, less labour is required. Backrubbers are made of burlap or canvas wrapped around barbed wire or chains which are strung between posts. The burlap or canvas is saturated with an insecticide. The backrubbers and oilers are based on the principle that cattle like to rub themselves against posts and other objects. Cattle treat themselves when they rub against backrubbers and oilers. Backrubbers have the disadvantage that they have to be re-saturated regularly for effective control because insecticide formulations are subject to evaporation. In addition, the effectiveness of backrubbers and oilers is reduced when there are trees in pastures that can be used as alternatives. Dust bags are made of burlap and contain inner liners that regulate dust flow and prevent wetting of the dust by rain. The bags are suspended at about the height of the withers in either free choice or forced use situations where cattle are forced to use them to get to water or minerals or pass from one pasture to another. Dust bags require less attention than backrubbers once they are established (Lancaster and Simco 1967). The major problems with dust bags are compaction of the dust within the bag and wetting by rain. Therefore, a dust with good flowability should be used, and dust bags should be protected from rain.

The major disadvantage with backrubbers, oilers and dust bags is that they have to be placed at points where cattle congregate. When rotational grazing is practised, backrubbers, oilers and dust bag stations must be established in each pasture or forced use systems have to be established.

Most ear tags are made from polyvinyl chloride mixed with a plasticizer, and impregnated with an insecticide. Ear tags are designed to release the pesticide slowly over a prolonged period. The earlier ear tags were impregnated with organophosphorus insecticides but these fell out of favour because they were effective for only a short period

(Ahrens 1977; Harvey and Brethour 1970). They were replaced by pyrethroid-impregnated ear tags which provided season-long control of horn flies (Ahrens and Cocke 1979). Ahrens and Cocke (1979) obtained a 100% reduction in horn flies within 24 hr. Control was maintained for 20 weeks with two fenvalerate tags per head. Ninety-five per cent control of horn flies was achieved with one permethrin tag per head over a period of 17 weeks (Williams and Westby 1982). Good control of horn flies can also be achieved by partial herd treatment. Untagged animals kept in the same pasture with cattle treated with two fenvalerate tags per head were completely free from horn flies for 20 weeks (Ahrens and Cocke 1979). Fenvalerate-impregnated ear tags provided complete horn fly control in a herd when their nursing calves were tagged in one ear only (Harvey and Brethour 1983). In addition, Knapp (1982) obtained complete horn fly control for two seasons when the tags were left on cattle.

Pyrethroid-impregnated ear tags have been rapidly accepted by producers and widely used because of their effectiveness. Tagging does not require additional specialized application equipment and labour. Tags can be applied when animals are being dewormed or vaccinated, before going to the pasture.