Proceedings, Applied Reproductive Strategies in Beef Cattle

August 29 – 30, 2018; Ruidoso, N.M.

IMPACT OF FLY CONTROL ON CATTLE PERFORMANCE

B. G. Smythe

Center for Animal Health & Food Safety
&
Department of Animal and Range Sciences
New Mexico State University

Introduction

Specific coping mechanisms to certain environmental stressors are critical to maintaining animal health while simultaneously increasing monetary returns for producers, as stress responses are often manifested through decreased animal performance. For instance, the stress imposed by various ectoparasites are implicated as a major source of economic loss through blood feeding, toxicosis, and disease transmission (Byford et al. 1999). More than 50 pestiferous ectoparasite species including mites, ticks, lice, and flies contribute to reduced cattle performance (Hardwood and James 1979). Often, economic losses due to ecotparasite infestations are manifested through decreases in animal weight gain and milk production. One pest in particular, the horn fly (*Haematobia irritans*), is responsible for an estimated $700 million in cattle production losses annually (Drummond et al. 1981, Kunz et al. 1990). When adjusted for inflation, more recent production loss estimates easily exceed $1 billion annually (Holderman et al. 2017). Furthermore, returns as high as $8.38 for each $1.00 spent on control products illustrate the economic benefits of successful horn fly control (Kunz et al. 1984, DeRouen et al. 2003).

Horn flies have long been considered one of the, if not the most important ectoparasitic pests affecting rangeland cattle in the United States (Byford et al. 1999). Adults, which are brownish gray in color, may take as much as 14.6 mg/fly of blood per day feeding, which may happen as many as 38 times per day (Harris et al. 1974; Harris and Frazar 1970). These estimates can be exponentially increased when considering that populations may easily exceed 1000 flies / cow in certain regions of the U.S. Furthermore, these pests rarely leave their host, usually only for oviposition, ultimately accounting for a constant source of irritation for the animal.

Oviposition is predictable and continuous throughout the course of the day and into the night (Sanders and Dobson 1969). Horn fly eggs are initially white and continually darken in color leading to larval eclosion. Eclosed larvae utilize nutrients provided by manure pats throughout larval development (Schmidt et al. 1967). Horn fly maggots migrate to nearby sandy locations or other sites within and around the manure pat to initiate pupation (Mendes and Linhares 1999). Eclosed adults return to the host and immediately initiate blood-feeding until

sexual maturity is reached. Blood meal acquisition is considered a requirement as sexual organ development in the horn fly is dependent upon proteins acquired from these feeding activities (Kuramochi 2000). Adult horn flies initiate diapause with the onset of cooler environmental temperatures to avoid harsh winter months. With the onset of warmer temperatures marking spring and summer months, diapause ceases and horn flies finalize pupal development emerging as host-seeking adults (Hoelscher and Combs 1970).

Horn fly populations may rapidly exceed levels in which economic burdens may be expected. This is undoubtedly due to the reproductive potential maintained by this pest. Reproductively active females can produce an average of 14.93 viable horn fly eggs daily (Thomas and Kunz 1986). Considerable population growth during favorable environmental conditions can be expected. Of course, in uncontrolled scenarios horn fly infestations will result in economic loss for producers. Therefore, recommendations for managerial interventions are largely based on population densities associated with horn fly infested cattle. In general, to alleviate host burdens from horn fly infestations, control measures are recommended when population levels exceed an average of 200 flies/animal (Schreiber et al. 1987).

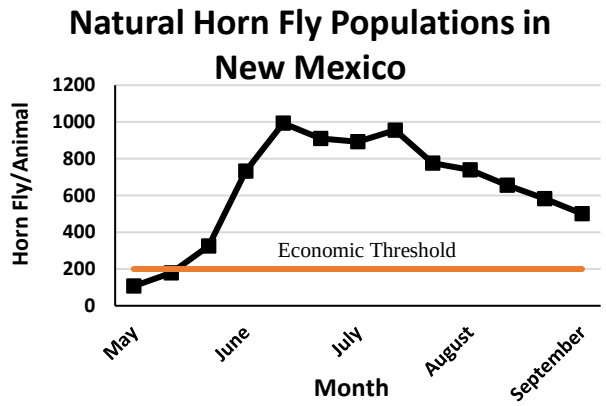

Figure 1. *Four year average of naturally occurring horn fly populations occurring at CRLRC in New Mexico*

New Mexico Field Trial

A four-year study was conducted at the Corona Range and Livestock Research Center (CRLRC) to evaluate the effect of horn flies on rangeland cattle performance. General horn fly population data is reported in Figure 1. Characteristic seasonal peaks were observed mostly throughout June and July. However, intra and inter-seasonal variation in control populations was present. Regardless, untreated control populations were consistently maintained well above the recommended economic threshold throughout each yearly trial.

To assess cattle performance, initial (May) and final (October) weights of cows along with weaning weights (October) of calves were gathered each year. In general, cows receiving insecticidal products throughout the study gained on average 15.44 ± 6.51 kg more ($F_{1,3}$ = 5.63; P = 0.0492) each year in comparison to untreated counter parts. Furthermore, calves paired with insecticide treated cows tended to wean 16.28 ± 8.04 kg heavier ($F_{1,3}$ = 5.63; P = 0.0492) than calves paired with cows infested with natural populations of horn flies.

In addition to growth performance, weekly blood samples were assayed to determine postpartum responses of horn fly infested cattle. Despite weight gain effects, no differences were detected between horn fly infested and insecticide treated cattle with regard to postpartum interval, days to pregnancy postpartum, or calving interval (Table 1).

Table 1. *Initial and final body weights (kg) for cows and weaning weights of calves averaged within untreated control and insecticide-treated animal herds.*

	Average (SEM)[a]		
Variable[b]	UTC	TRT	*P* - value
WG (kg)	62.40 (4.72)	77.83 (4.73)	0.0492
WW (kg)	228.99 (5.66)	245.27 (5.78)	0.0680
PPI (d)	69.13 (3.57)	66.41 (3.57)	0.3425
DP (d)	76.20 (1.63)	74.16 (1.61)	0.2635
CI (d)	352.37 (2.92)	354.80 (2.95)	0.3070

[a] Data are presented as model based means and respective SEMs within treatment groups

[b] Multiple variables were assessed; WG = weight gain, calculated as final body weight – initial body weight; WW = weaning weight; PPI = postpartum interval; DP = days to pregnancy; CI = calving interval.

Horn Fly Control and Insecticide Resistance

One of the most effective horn fly interventions is that of larval control, specifically through manure management. Such methods can be implemented in most confined animal production systems, where fecal waste is readily accessible and easily removed. As such, horn flies are rarely considered a serious pest in dairy or feedlot operations. However, in pastured cattle production manure management is not practical, leaving few non-insecticidal options aimed at controlling horn fly populations.

Currently, most insecticides are delivered using impregnated cattle ear tags, liquid pour-ons, or sprays, with early application methods including forced walk-through back applicators and human-operated sprayers. More recent delivery methods have been developed to be less labor intensive and formulated to provide continual control throughout most of the horn fly season. It is perhaps, for these reasons that many producers now heavily rely on the use of insecticides for horn fly control in pastured systems. Unfortunately, overreliance has in turn, led to the development of insecticide resistance in many field populations. Field trials throughout the world have reported horn fly insecticide resistance to commonly used active ingredients such as pyrethroids (Quisenberry and Strohbehn 1984, Cilek et al. 1991, Jamroz et al. 1998, Oyarzun et al. 2011). High levels of resistance from heavy insecticide use have stimulated research towards alternative control options including biological control and natural product repellency (Thomas and Morgan 1972, Blume et al. 1973, Mullens et al. 2017). Nevertheless, these control options have yielded limited success in rangeland settings, resulting in little interest or support from producers. The availability, ease of incorporation, and perceived effectiveness of insecticides from a producer's prospective will likely be key in maintaining the popularity of this approach.

Rapid and accurate identification of insecticide resistance is critical for successful management of horn flies. Often, reports of resistance arrive in the form of concerns of product failure expressed by producers. Late identification and continuous over exposure to similar active ingredients (AI) can lead to fixed genetic mutation expression in those field populations (Guerrero et al. 2002, Oremus et al. 2006). Various methods have been developed to determine insecticide resistance in insect populations. Arguably, one the most common methods to evaluate horn fly population resistance is that of dose-dependent bioassays (Sheppard and Hinkle, 1987). In summary, known amounts of AIs are serial diluted, typically utilizing acetone as a solvent, and applied to filter papers prior to horn fly exposure. Based on the binomial (alive or dead) response of the insects, probit based regression equations can be used to estimate lethal concentrations (LC) estimates within a tested population. In an attempt to maintain consistency between dose-based population responses, these assays are often conducted in the field.

Consequently, environmental factors such as, heat and humidity may affect procedures and horn fly fitness during assays. Furthermore, dose-based responses are typically evaluated over a number of hours allowing horn fly responses at lower AI exposures to manifest. The time associated with conducting these evaluations ultimately limits researcher's ability to evaluate multiple populations within a single day restricting the range in which data based inferences on resistance transmission across populations can be made.

New Mexico Laboratory Trial

Recently, our laboratory has developed a single dose lethal time (LT) based field assay procedure that can be used to collect information regarding insecticide resistance in multiple populations with a given area throughout a single season. Two colonized horn fly strains, a susceptible (SS) and permethrin resistant (PR) were used to establish baseline susceptibility to multiple pyrethroid and organophosphate AIs (Table 2). As expected, resistance ratios (RR) between the two fly colonies varied dramatically between insecticide class. Furthermore, variation within pyrethroid AIs fluctuated as well.

Table 2. *Baseline susceptibility of horn fly colonies exposed to multiple active ingredients.*

Active Ingredient[a]	LC_{50} (FL)[b]	Slope (SEM)	RR[c]
Permethrin			
SS	1.24 (1.13 – 1.40)	4.54 (0.38)	356.77
PR	442.39 (321.14 – 690.52)	1.33 (0.14)	
4S-Zetacypermethrin			
SS	0.22 (0.20 – 0.25)	2.96 (0.20)	679.36
PR	149.46 (123.44 – 186.36)	1.52 (0.12)	
Lambda-Cyhalothrin			
SS	0.34 (0.30 – 0.39)	2.30 (0.14)	55.79
PR	18.97 (16.64 – 21.62)	2.23 (0.13)	
Diazinon			
SS	0.60 (0.44 – 0.85)	4.20 (0.80)	0.55
PR	0.33 (0.27 – 0.41)	1.29 (0.15)	
Chlorpyriphos			
SS	1.32 (0.95 – 1.83)	2.17 (0.26)	0.73
PR	0.97 (0.82 – 1.19)	1.56 (0.11)	

[a]Each active ingredient was evaluated against two fly strains; SS = permethrin susceptible and PR = permethrin resistant.
[b]Estimates for LT_{50} and LT_{90} were developed using PROC PROBIT procedure of SAS 9.4 (SAS 2014, Cary NC) are reported in µg/cm^2 followed by the respective fiducial limits (FL).
[c]RR = Resistance ratio; RR calculated as LT_{50} of PR divided by LT_{50} of SS for each parent compound and compound mixture.

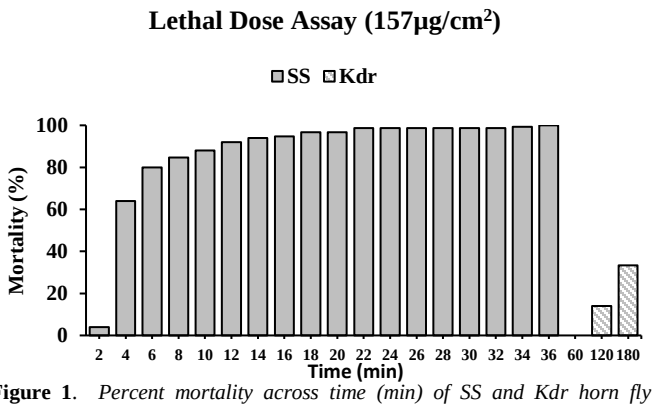

Figure 1. *Percent mortality across time (min) of SS and Kdr horn fly populations exposed to single dose of permethrin (10,000 ppm).*

To establish high dose concentrations for use in a field diagnostic kit, multiple high dose exposures were conducted using time as a gradient. For illustration purposes, results specific to permethrin are discussed. Lethal time (LT_{90}) estimates were used to establish RR with regard to time between the two horn fly colonies. At the highest and lowest concentrations evaluated, PR flies took 646.25 and 287.42 times as long to respond to the exposure, respectively. In fact, SS horn flies reach 100% mortality with the first hour of exposure while PR flies failed to reach 100% in the full 8-hour exposure window at this concentration. In general, as concentration increased, LT estimates decreased for both SS and PR indicating an ability to adjust exposure ranges for field diagnostics. Progress is on-going for this research.

References

Blume, R. R., Matter, J. J., and Eschle, J. L. 1973. *Onthophagus gazella*: effect on survival of horn flies in the laboratory. Environ.Entomol. 2(5), 811-814.

Byford, R. L., Craig, M. E., DeRouen, S. M., Kimball, M. D., Morrison, D. G., Wyatt, W. E., and Foil, L. D. 1999. Influence of permethrin, diazinon and ivermectin treatments on insecticide resistance in the horn fly (Diptera: Muscidae). International journal for parasitology, 29(1), 125-135.

Cilek, J. E., Steelman, C. D., and Knapp, F. W. 1991. Horn fly (Diptera: Muscidae) insecticide resistance in Kentucky and Arkansas. J. Econ. Entomol. 84(3), 756-762.

DeRouen, S. M., Foil, L. D., MacKay, A. J., Franke, D. E., Sanson, D. W., and Wyatt, W. E. 2003. Effect of horn fly (*Haematobia irritans*) control on growth and reproduction of beef heifers. J. Econ. Entomol, 96(5), 1612-1616.

Drummond, R.O., G. Lambert, H. E. Smalley, and S. E. Terrill. 1981. Estimated losses of livestock to pests. In D. Pimentel (Ed.) CRC Handbook of Pest Management in Agriculture. CRC Press, Boca Raton, FL.

Guerrero, F. D., M. W. Alison, D. M. Kammlah, & L. D. Foil. 2002. Use of the polymerase chain reaction to investigate the dynamics of pyrethroid resistance in *Haematobia irritans irritans* (Diptera: Muscidae). J. Med. Ento., 39(5), 747-754.

Hardwood, R.F., and M.R. James. 1979. Entomology in Human and Animal Health. MacMillan Publishing Co., New York.

Harris, R. L., and Frazar, E. D. 1970. Intake of blood by adult horn flies reared in the laboratory. Annals of the Entomological Society of America, 63(5), 1475-1476.

Harris, R. L., Miller, J. A., and Frazar, E. D. 1974. Horn flies and stable flies: feeding activity. Annals of the Entomological Society of America, 67(6), 891-894.

Hoelscher, C. E., and Combs, R. L. 1970. The horn fly. II. Comparative physiological studies of reproductive and diapaused pupae. Physiological Zoology, 43(4), 241-248.

Holderman, C. J., L. A. Wood, C. J. Geden, P. E. Kaufman. 2017. Discovery, development, and evaluation of a horn fly-isolated (Diptera: Muscidae) *Beauveria bassiana* (Hypocreales: Cordyciptaceae) strain from Florida, USA. J. Insect Sci. 17(2) 1-6.

Jamroz, R. C., Guerrero, F. D., Kammlah, D. M., and Kunz, S. E. 1998. Role of the *kdr* and *super-kdr* sodium channel mutations in pyrethroid resistance: correlation of allelic frequency to resistance level in wild and laboratory populations of horn flies (*Haematobia irritans*). Insect Biochem. Mol. Biol., 28(12), 1031-1037.

Kunz, S. E., Miller, A. J., Sims, P. L., and Meyerhoeffer, D. C. 1984. Economics of controlling horn flies (Diptera: Muscidae) in range cattle management. J. Econ. Entomol. 77(3), 657-660.

Kunz, S.E., K.D. Murrell, G. Lambert, L.F. James, and C.E. Terrill. 1990. Estimated losses of livestock to pests. CRC Handbook of Pest Management in Agriculture. 1:69.

Kuramochi, K. 2000. Ovipositional behavior of the horn fly (Diptera: Muscidae) in the field. Journal of medical entomology, 37(3), 461-466.

Mendes, J., and Linhares, A. X. 1999. Diapause, pupation sites and parasitism of the horn fly, *Haematobia irritans*, in south-eastern Brazil. Medical and Veterinary Entomology, 13(2), 185-190.

Mullens, B.A., D. W. Watson, A.C. Gerry, B.A. Sandelin, D. Soto, D. Rawls, S. Denning, L. Guisewite, and J. Cammack. 2017. Field trials of fatty acids and geraniol applied to cattle for suppression of horn flies, Haematobia irritans (Diptera: Muscidae), with observations on fly defensive behaviors. Vet. Parasitol. 245, 14-28.

Oremus, G., Guerrero, F. D., Alison, M. W., Kimball, M. M., Kim, J. H., & Foil, L. D. (2006). Effects of mid-season avermectin treatments on pyrethroid resistance in horn fly (Diptera: Muscidae) populations at three locations in Louisiana. Vet. Parasitol. 141(1), 156-164.

Oyarzún, M. P., Li, A. Y., and Figueroa, C. C. 2011. High levels of insecticide resistance in introduced horn fly (Diptera: Muscidae) populations and implications for management. J. Econ. Entomol, 104(1), 258-265.

Quisenberry, S. S., and Strohbehn, D. R. 1984. Horn fly (Diptera: Muscidae) control on beef cows with permethrin-impregnated ear tags and effect on subsequent calf weight gains. J.Econ. Entomol., 77(2), 422-424.

Sanders, D. P., and Dobson, R. C. 1969. Contributions to the Biology of the Horn Fly. J. Econ. Entomol, 62(6), 1362-1366.

Schmidt, C. D., Harris, R. L., and Hoffman, R. A. 1967. Mass rearing of the horn fly, *Haematobia irritans* (Diptera: Muscidae), in the laboratory. Annals of the Entomological Society of America, 60(3), 508-510.

Schreiber, E. T., Cambpell, J. B., Kunz, S. E., Clanton, D. C., and Hudson, D. B. 1987. Effects of horn fly (Diptera: Muscidae) control on cows and gastrointestinal worm (Nematode: Trichostrongylidae) treatment for calves on cow and calf weight gains. J. Econ. Entomol, 80(2), 451-454.

Sheppard, D. C., & N. C. Hinkle. 1987. A field procedure using disposable materials to evaluate horn fly insecticide resistance. J. Agric. Entomol. *(USA)*.

Thomas, D.B., and Kunz, S. E. 1986. Diapause survival of overwintering populations of the horn fly, *Haematobia irritans* (Diptera: Muscidae), in south-central Texas. Environmental entomology, 15(1), 44-48.

Thomas, G. D., and Morgan, C. E. 1972. Field-mortality studies of the immature stages of the horn fly in Missouri. Environmental Entomology, 1(4), 453-459.