COMBINATION ANTHELMINTICS TO CONTROL GASTROINTESTINAL NEMATODES IN FOALS

A Thesis

by

JOE LUKE LUKSOVSKY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Biomedical Sciences

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Approved by:

Chair of Committee,	Thomas M. Craig
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ABSTRACT

Combination Anthelmintics to Control Gastrointestinal Nematodes in Foals.

(December 2011)

Joe Luke Luksovsky, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Thomas M. Craig

A study was undertaken to evaluate and compare the effectiveness of three anthelmintics, ivermectin, fenbendazole, and a combination of ivermectin and pyrantel pamoate, on fecal egg count reductions of cyathostomes and *Parascaris equorum* in 30 foals at the Texas A&M Horse Center. The foals were reared under standard horse center practices and were naturally infected with both cyathostomes and *Parascaris.* The foals were randomized into three treatment groups with individuals being rerandomized after each eight week observation period. The treatments of ivermectin and fenbendazole were given at the manufacturer's recommended doses and the pyrantel treatment was given at two times the manufacturer's recommended dose. All doses were based on weights taken prior to treatment. Fecal egg counts were performed at the time of treatment and at two week intervals after treatment for a total of eight weeks. Each foal received a total of three treatments during the course of the study along with the most effective treatment at the conclusion of the study. Fecal egg counts were performed by a modified McMaster's test with a sensitivity of 25 eggs per gram of feces and by the modified Wisconsin double centrifugal floatation with a sensitivity of 0.2 eggs per gram

of feces. Fecal egg reduction percentages were calculated for each two week interval. Analysis of the results showed that ivermectin, either used alone or with pyrantel was a more effective anthelmintic for cyathostome (small strongyle) control than fenbendazole. Fenbendazole and pyrantel showed a higher initial reduction in *Parascasris* eggs when compared to the ivermectin only treated group, but ivermectin showed improved egg reduction over time. At the conclusion of this study, a primary treatment of ivermectin at the manufacturer's recommended dose and treatment of pyrantel at two times the manufacturer's recommended dose was recommended to control cyathostome egg production and severely reduce the initial number of *Parascaris* adults in the foals at this facility. Subsequent monthly does of ivermectin at the manufacturer's recommended dose was also recommended to continue to control both parasites. Follow up fecal examinations were also recommended to test the continued effectiveness of the recommended treatment protocol.

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1. INTRODUCTION

The purpose of this study is to determine the effect of specific anthelmintics, or a combination of anthelmintics on controlling gastrointestinal nematodes in foals, specifically *Parascaris equorum* and cyathostomes, (small strongyles) at a single farm. Through this study, insights into which drug or drugs have the most affect on the particular farm being treated will be observed. Both these parasites are commonly found in horses, though *Parascaris* is usually found in young or naïve animals, while cyathostomes are found in horses or all ages. Both are acquired when a horse ingests the infective stages of the parasite while grazing, the L3 larvae in the case of cyathostomes and the larvated eggs of *Parascaris*. Once inside the host, the parasites begin the process of maturing and taking up residence in the niche within the intestinal tract of the horse most suited for their needs. *Parascaris* adults are found in the small intestine and cyathostome adults live in the lumen of the large intestine. At this time, the two most important gastrointestinal nematodes of foals are *Parascaris equorum,* and cyathostomes (small strongyles). If uncontrolled, these parasites can adversely affect the foal's health.

This thesis follows the style of Veterinary Parasitology.

1.1 Disease and Life Cycle

Parascaris equorum can cause lung damage by focal hemorrhages from larval migration, catarrhal enteritis (intestinal inflammation), ill thrift, and even death (Urquhart et al., 1996). It can also lead to poor growth, colic, and intestinal impaction or perforation, and is considered the most pathogenic parasite of juvenile equids (Reinemeyer, 2009). *Parascaris equorum* is a large roundworm, 15-50 cm long, which inhabits the small intestine of immature horses throughout the world. Horses are infected when they ingest larvated eggs from the environment. Once ingested, the L2 larvae emerge from the eggs within the alimentary tract of the horse, penetrate the intestinal wall, and passively migrate to the liver. The larvae reach the liver in as little as two days post infection with most migrating through by seven days post ingestion (Clayton et al., 1978). From the liver, the larvae migrate to the lungs via the portal system of blood vessels. The majority of larvae reach the lungs between fourteen and twenty-three days post infection (Clayton et al., 1978). From here they are coughed up and swallowed, they molt to the final larval stage, then to adults in the small intestine. It takes between twenty-three and thirty-seven days for the larvae to migrate back to the small intestine post infection with some larvae being seen in as little as fourteen days (Clayton et al., 1978). Not all larvae that make it to the small intestine become adults, competition for resources and space limit numbers, one study found that of 4150 larvae that emerged into the small intestine, only 123 adults remain four months later (Clayton et al., 1978). Both the larval stage and adults found in the intestine feed on ingesta of the host. The

time from ingestion of the infective egg to establishment in the small intestine takes about one month with 75-80 days required from infection to reproduction by an adult worm. Adult females can produce thousands of eggs each day. In the environment, the eggs become infective in as short as 10 days, and can survive for as long as 10 years (Reinemeyer, 2009). *Parascaris* is unusual in that hosts can develop absolute immunity to this nematode, thus older horses that have been exposed previously to the helminth rarely show signs of disease.

Cyathostomes, small non-migratory strongyles, are a group of parasites that reside on the surface or in the luminal contents of the large intestine of equids (Ogbourne, 1976). At least forty separate species make up this group of parasites. The eggs and larvae of these parasites cannot be differentiated among species, but morphological features can be used to separate adults. Features such as buccal capsule shape, presence or absence of teeth or plates in the buccal capsule, and elements of the *corona radiata* are morphologic determinate of each cyathostome species. Different species also have preferred developing sites, *Cylicocyclus nassatus, Cylicostephanus minutes, C. calicatus* and *Cyathostomum catinatum* are usually found in the ventral colon. In the dorsal colon, *Cylicostephanus longiburastus, C. goldi,* and *C. insigne* predominate. *Coronocyclus coraonatum* and *Petrovinema poculatum* develop in the cecum, but other genera of cyathostomes may colonize the cecum after emergence from the mucosa (Ogbourne, 1978).

Infection occurs when an equine ingests the L3 larvae from the environment. Once in the body, the L3 exsheath and invade the mucosa of the large intestine through

the glands of Lieberkuhn (Ogbourne, 1978). Most cyathostomes only burrow into the mucosa, but a few species, such as *Cylicostephanus longibursatus* will penetrate into the submucosa (Ogbourne, 1978). Once embedded in the mucosa, the L3 larvae will either molt to the L4 stage or arrest development (hypobiosis) (Eysker et al., 1986). The L4 stage, larvae subsequently emerge into the lumen of the large intestine. The prepatent period (the time it takes from when larvae are ingested, to when adults shed eggs) varies on species, from a minimum of 35 days to as long as 10-13 weeks if hypobiosis does not occur (Poynter, 1969). Once in the lumen, the L4's develop into adults and reproduce, shedding eggs into the environment.

Within the egg, larvae (L1) are found in a matter of days at a minimum temperature of 10 C (Lucker, 1941). Once the L1 larva is fully developed, it hatches from the egg and feeds on bacteria in the fecal mass. After feeding, the L1 molts to an L2 larva. The L2 will then molt to the L3 infective stage, which is encased in a protective sheath, the cuticle from the L2 stage. This sheath is vital for prolonged survivability, as it protects the larva from desiccation in the environment. Once the parasite reaches its infective stage, it will ascend the surrounding vegetation in an effort to increase its chances for being ingested by a viable host. Egg and larval development and survivability are dependent on climate, with high temperatures causing more rapid development to L3 larvae (Ogbourne, 1973). In tropical and subtropical climates, infective larvae can be found on herbage throughout the year, with peak concentrations during the cooler month, mid-September thru March (Baudena et al, 2000). In Texas, the peak month of acquisition is November. Temperatures optimal for cyathostome larva

development are between 10-18 C, but can develop in temperatures between 5-33 C. Oddly enough, moisture has a negative effect on the survivability of infective L3 cyathostome larvae, but is essential for development up-to that stage (Baudena et al, 2000). The theory behind this occurrence is that increased moisture levels cause increased osmotic stress to the L3 larvae, especially if the moisture levels fluctuate rapidly, weakening the larvae's protective sheath (Mfitilodze, 1988).

Cyathostomes can affect foals in the following ways: ulceration of the mucosa of the large intestine, diarrhea, colitis, peritonitis, ill thrift, and weight loss (Urquhart et al., 1996). In animals six months to one year of age, heavy infections can cause catarrhal and hemorrhagic enteritis along with mucosal thickening and edema. Disease caused by cyathostomes is not limited to young animals, but can affect older horses as well. The larvae of cyathostomes encyst in the mucosa of the cecum and colon and cause disease during emergence, usually between late fall and early spring. The disease, known as cyathostomiasis, is characterized by sudden onset watery diarrhea and inflammation of the mucous membranes, emaciation, weight loss, hypoalbuminemia, possible anascara (extreme generalized edema), and even death. Cyathostome infection has been implicated as the cause of sudden-onset diarrhea syndrome which leads to emaciation and death in as little as two to three weeks (Love et al., 1999). During the winter and spring cyathostomiasis occurs as more larvae enter the intestinal lumen than the horse can support and many larvae and adult cyathostomes may appear in the feces (Bowman, 2009). A major reason for cyathostomiasis is hypobiosis due to competitive inhibition. If the horse already had a substantial cyathostome load at the time the larvae were ingested,

the larvae could arrest development and wait until adult populations in the lumen had fallen before completing their development. Since parasite acquisition naturally is lessened in the late fall and winter due to reduced grazing, and thus reduced larvae ingestion, the lack of adults in the lumen of the horse triggers a mass emergence of the larvae that were in hypobiosis. Cyathostomes can also be the cause of a recurrent diarrhea in ponies where the parasites cause rapid weight loss, severe peripheral edema and pyrexia without diarrhea. The first clinical sign of this disease is weight loss, which lasts for several months before the start of diarrhea (Love et al., 1999). Cyathostomes have been linked to various forms of equine colic including non-strangulation infarction and caecal tympany (colic with distension of the abdomen), as well as mild colics (Love et al., 1999).

1.2 Treatments

Three classes of anthelmintics have widely been used to control gastrointestinal nematodes in horses in the United States. These are the benzimidazoles: fenbendazole, oxfendazole, and oxifendazole; tetrahydropyrimidines, the pyrantel salts; and macrocyclic lactones or avermectin-milbemycins: ivermectin and moxydectin. The benzimidazoles work by inhibiting the nematode's energy metabolism. It starves the worm by inhibiting microtubular polymerization, which decreases nutrient absorption in the worm's intestine. The tetrahydropyrimidines cause continuous firing of neuro-muscular junctions by stimulating the acetylcholine agonists forcing all muscles to

constrict causing rigid paralysis. The macrocyclic lactones act on the worm by enhancing the effect of γ-aminobutyric acid, a neurotransmitter, causing permanent flaccid paralysis. This, in effect, makes it impossible for the parasite to maintain itself in the intestinal lumen of the host and it is eliminated (Austin et al., 1991). When first developed, these anthelmintics worked well against cyathostomes and *Parascaris*, but, like many drugs, resistance is increasing to these medications.

1.3 Anthelmintic Resistance

The first case of anthelmintic resistance in horses was reported over fifty years ago when phenothiazine failed to reduce Strongyle egg counts. Today, resistance to anthelmintics has been reported in virtually every drug in use throughout the world, especially in the Netherlands, Canada, the United States, Denmark, Germany, Brazil, and Italy (Reinemeyer, 2009). Today, drug resistance in cyathostomes has been reported from benzimidazoles (almost total insusceptibility), pyrantel salts, piperazine and macrocyclic lactones, the most commonly used anthelmintics on the market (Reinemeyer, 2009). This does not mean that no current drug on the market will kill helminths, but it does mean that horse owners and veterinarians must know which anthelmintics will work on each particular farm.

Kaplan et al., (2004) published a study of 1,274 horses from 44 farms in Georgia, South Carolina, Florida, Kentucky, and Louisiana to determine anthelmintic resistance to cyathostomes. The authors used four different anthelmintics: fenbendazole,

oxibendizole, pyrantel pamoate, and ivermectin. The data collected from 786 of the 1,274 horses in this study indicated fecal egg count reductions of 24.8% for fenbendazole, 73.8% for oxibedazole, 78.6% for pyrantel pamoate, and 99.9% for ivermectin for Strongyle type eggs (cyathostomes). Using the suggested <90% egg count reduction as a measure of resistance, Kaplan et al. (2004) determined that parasites on these farms had a 97.7% resistance to fenbendazole, a 53.5% resistance to oxibendazole, and a 40.5% resistance to pyrantel pamoate. No resistance was detected to ivermectin in this study.

Likewise, Lyons et al. (2006) had similar results in a study of seven farms in central Kentucky. The authors found that ivermectin was effective against cyathostomes but pyrantel pamoate, fenbendazole, and oxibendazole were not. Six of the seven farms utilized in the study harbored *Parascaris equorum* and all seven had persistent cyathostome infections in at least one foal due to anthelmenthic resistance.

Hearn and Peregrine (2003) suspected a failure of ivermectin to control *Parascaris equorum* in a large horse farm near Toronto, Ontario. The researchers took samples from 16 foals three and one-half to eight months of age. After completing egg counts, the foals were treated with the manufacturer's suggested dose of ivermectin and retested 12 days later. Thirteen of the 16 foals still had eggs in the feces and seven of the animals showed an increase in egg numbers. The researchers then tested 21 more foals that had been treated at the same time as the 16 animals from the study and found that 12 horses still had eggs present in the feces. Further investigation revealed that foals that had spent their entire lives on the farm and were treated solely with ivermectin were

significantly more likely to have *Parascaris* egg counts of over 100 eggs per gram of feces than foals who received a drug other than ivermectin sometime in their lives, or foals who were brought in from other farms. Past studies suggested that ivermectin should eliminate all *Parascaris* egg production by seven days post treatment and prevent egg production for at least 35 days post treatment. Since eggs were found 12 days post treatment the authors had strong evidence that ivermectin's effectiveness had fallen, at least for this particular farm.

Slocombe et al. (2006) tried to determine a treatment protocol for *Parascaris equorum*. This clinical trial used 76 foals on three farms in southwestern Ontario. The researchers administered ivermectin, moxidectin, fenbendazole, and pyrantel pamoate at the manufacturer's recommended doses. Two farms were determined to have *Parascaris equorum* resistance to ivermectin and moxidectin. On the other farm marked egg count reductions were found, but they were also found in the untreated group leading the researches to believe that the reductions were due to natural age related immunity to the nematode; however, a later trial on the same farm showed a resistance to ivermectin. This finding is evidence that ivermectin worked in older foals, but not in younger ones. Overall effectiveness for *Parascaris,* determined by fecal egg count reduction on all farms, was 33.5% for ivermectin, 47.2% for moxidectin, and 97.6% for fenbendazole and pyrantel pamoate combined.

Craig et al. (2007) conducted a study on 32 foals from a single Texas horse farm to determine anthelmintic resistance. The farm had used ivermectin since 1984 as the primary anthelmentic. In 2002, pyrantel pamoate was rotated into the treatments. The

foals were treated with either ivermectin or pyrantel or a combination of both, depending on which species of nematode eggs were detected in the feces. At the study's conclusion, 24 of the foals on ivermectin developed patent *Parascaris* infections suggesting that ivermectin had become less effective due to increased tolerance by the nematode. The foals who received pyrantel at two times the manufacturer's recommended dose had a 98-100% reduction in *Parascaris* egg counts. Cyathostome eggs were reduced by 99.9% with ivermectin at 0.2 mg/kg, but only a 60.4% decrease occurred in pyrantel treated foals. This indicates that pyrantel's effectiveness against cyathostomes was waning as of 2007 as was ivermectin's effectiveness against *Parascaris*. Pyrantel resistance by cyathostomes has been reported throughout the southeastern United States, Canada, and northern Europe (Kaplan et al., 2004).

Although ivermectin is still widely used for treating cyathostomes, tolerance or resistance is increasing. A horse farm in central Kentucky was used to study the time frame from treatment to the reappearance of cyathostome eggs in the feces (Lyons et al, 2008a). The paper stated that this time interval should have been eight weeks. Testing yearlings and older horses, the investigators found that eggs started reappearing between 25 and 28 days in yearlings and 27 and 33days in older horses. The study concluded that eggs reappear at around four weeks post treatment with ivermectin in the young animals, half the time reported when the drug was first introduced, and show increases in egg numbers in weeks five and six. The authors also found that egg per gram counts rose twice as fast as when ivermectin was first utilized in 1983. Lyons et al. (2008a) believe that this field test shows a selection of a resistant phenotype in which the adult worms

survive with temporarily inhibited egg production. This observation could also be explained by emergent larvae that received an insufficient dose of ivermectin at the time of treatment. Since ivermectin is absorbed by the horse then metabolized slowly, cyathostome larvae emerging into the lumen shortly after treatment would have sufficient time to mature and produce eggs by four weeks post treatment, especially if they are resistant to levels of ivermectin that are lower than the manufacturer's recommended dosage levels.

Findings such as these should raise a concern with any horse owner. The observations from the above studies indicate that the effectiveness of benzimidazole and pyrantel anthelmintics are not at the level they were when the drugs first came on the market for treating cyathostomes; in fact, they have fallen to under the 90% standard reduction percentage that determines effectiveness. The only drugs that still have such effectiveness on cyathostomes is the macrocyclic lactones such as ivermectin and moxydectin, and as Lyons (2006, 2008a, 2008b) observed, even that is on the wane. As for *Parascaris* treatment, studies such as the ones by Craig (2007) and Slocombe (2006) clearly show that ivermectin is ineffective at lowering egg levels on the farms that were tested. Knowing that single anthelmintic treatment regimens may not control all the parasites on a farm, and that such a treatment program is selective for resistance, a multidrug approach may be required to control parasite populations on farms with anthelmintic resistance and thus prolong the effectiveness of the anthelmintics being used. There has been previous work on multidrug helminthic control. Rehbein et al. (2007) conducted a study in which they used 30, 18 month old ponies in New Forest,

United Kingdom. The ponies were treated with an ivermectin/praziquantel paste that was 1.55% ivermectin and 7.55% praziquantel which equals 0.2 mg and 1mg per kg, respectively. Ivermectin was used to target the cyathostomes, *Parascaris*, and bots, while praziquantel was used for tapeworm control. The study found the efficacy of the paste to be 100% against cyathostomes and *Parascaris*, along with tapeworms and bots. This treatment protocol is included here to demonstrate that anthelmintics of different modes of action can be used concurrently without counteracting each other.

From these past studies, it is easy to deduce that parasitic nematodes are becoming resistant to current anthelmintics now on the market. It is also evident that some drugs produce better results than others on each farm depending on which anthelmintics have been used on that farm in the past. Furthermore, drugs that are extremely effective on one farm may not have the same effect on another, or if a drug failed to produce optimal control levels on one farm, it doesn't mean that it will not work to control parasites at yet another location. To treat cyathostomes and *Parascaris*, one must know which anthelmithics will work on the particular farm being treated.

2. MATERIALS AND METHODS

For this trial, 30 Quarter Horse foals born at the Texas A&M University Horse Center were used. The foals were maintained in accordance with normal Horse Center practices as far as vaccinations, health issues, etc. The foals were naturally exposed to *Parascaris equorum* and cyathostomes. Since foals do not show patent infections of these nematodes until two months of age, no foals younger than four months were utilized for this trial. Foals were allocated by age then randomly assigned into three treatment groups. Group I received ivermectin and praziquantel, trade name EQUIMAX™ (Pfizer Animal Health), at a dose of 0.2 mg/kg. Group II received ivermectin and praziquantel, (EQUIMAX™) at 0.2 mg/kg and a 13.2 mg/kg dose of pyrantel pamoate, trade name Strongid® Paste (Pfizer). Treatments were given simultaneously, instead of at two different times, so that the effects of one drug do not skew the results of the other drug. Group III was administered the Panacur® PowerPac™, (Intervet), which is a dose of fenbendazole at 20 mg/kg for five consecutive days. Every two months, the foals of similar age cohorts were regrouped by randomization as to give statistically stronger results. At the end of six months, the most effective treatment regimen was applied to all foals. The ivermectin dose is the manufacturer's recommended dose for cyathostomes and *Parascaris* while the pyrantel treatment is two times the labeled dose for *Parascaris* but is approved for use at this dose for *Anoplocephala*, the horse tapeworm. The fenbendazole Panacur® PowerPac™ treatment has been shown to not only kill adult cyathostomes, but also larvae that are

arrested in the intestinal wall (Steinbach et al., 2006) and is the approved dose for cyathostomes and *Parascaris*.

Fecal samples were taken at the time of treatment and at two week intervals post treatment. In previous research, ivermectin was shown to produce false negatives in cyathostome numbers in early observations, thus samples taken one month after treatment may be more reliable than those taken two weeks post treatment (Lyons et al., 2008b). The cause of the false negative is that some adult cyathostomes are not killed by the drug, but egg production is temporarily halted. Samples were obtained by putting each foal in a separate stall for approximately two hours to give ample time to defecate. The number of fecal eggs per gram (epg) was determined by the modified McMaster's method; with a sensitivity of 25 eggs/gm. Twenty-eight milliliters of saturated NaCl solution (specific gravity of 1.20) were mixed with two grams of feces. The mixture was emulsified and then added to specifically designed counting slides with four grids being counted under 100 x magnification. Total number of eggs was multiplied by 25 to achieve eggs per gram (Herd, 1992). If either type of egg, *Parascaris* or cyathostomes, was not detected using the McMaster's method, a five gram Wisconsin double centrifugation test was performed on the sample, with a sensitivity of 0.2 epg of feces. Five grams of feces was mixed with 35 ml of tap water, strained through a single layer of cheese cloth, then centrifuged for five minutes at 1300 rpm to sediment the eggs and other undigested material. The sediment was then mixed into a sucrose solution (specific gravity 1.26) in a 15 ml centrifuge tube filled to a positive meniscus; a cover slip was applied then was spun by centrifugation for 10 minutes at 1500 rpm (Todd et al., 1975).

A fecal egg count (FEC) reduction was then calculated using the mathematical average from each group sampled at the time of treatment compared to values obtained 14 and 28 days later using the formula:

$$\frac{\text{FEC day of treatment} - \text{FEC 14 days post treatment}}{\text{FEC day of treatment}} \times 100$$

The average effects for each treatment group were analyzed, allowing for random effects for each individual (Littell et al., 1996). Resistant status was assigned to parasites that exhibited <90% reduction in accordance with the suggested recommendation (Kaplan et al., 2004). Fecal egg count reductions were calculated by mean epg counts per treatment group, and by egg count reductions per each individual foal in each treatment group. A repeated measures analysis of variance (ANOVA) model was performed on the FECR data from each individual foal per treatment group. Pair wise comparisons between groups were performed for variables which significantly affected the model using the Mann-Whitney rank sum test (STATA 10, College Station, TX).

3. RESULTS

3.1 Cyathostomes

After examining the data collected, we found that the 30 foals utilized for this study shed variable numbers of eggs, 1.6-6800 cyathostome eggs per gram of feces and 0-8700 *Parascaris* epg of feces (complete results for all foals utilized can be found in the appendix). Based on the repeated measures ANOVA model, fecal egg counts were significantly ($p<0.05$) affected by treatment type, week, and treatment by week interaction. All three treatments reduced egg numbers at two weeks post treatment. The ivermectin and combination groups had a higher mean reduction rate for cyathostomes than did the fenbendazole treated group, 100% (99.9%) and 100% (100%) as compared to 94.1% (94.8%) respectively, the reduction percentages are individual reduction percentages, group percentages are in parentheses. Actual egg counts at two weeks post treatment varied in individual animals in each group with numbers ranging from 0-25 epg in the Ivermectin group, 0-50 epg in the combination group, and 0-425 epg in the group treated with fenbendazole. Subsequent testing at four, six, and eight weeks post treatment showed increasing cyathostome egg counts in all treatment regimens.

The eight week post treatment egg counts ranged from 0-1175 epg for ivermectin with a mean of 270.9 epg, an 81.6% (89.1%) overall reduction in eggs per gram from the time of treatment. The combination treatment showed eggs per gram that ranged from 5.6-6800 epg with a mean of 922.3 epg, a 66.1% (37.8%) reduction from the mean epg at time of treatment. The fenbendazole treated group had epg's ranging from 2.4-2325 epg with a mean of 606.6, an overall reduction of 60.3% (67.2%) at eight weeks post treatment. The means, range, percent reductions, both by individual per group and per group epg reduction), is presented for cyathostome egg counts for each two week interval in Table 1.

The high effectiveness of both the combination treated group and the ivermectin treated group were found to be significantly different than the fenbendazole treated group, but not significantly different from each other at two weeks post treatment. This was also found to be the case at the four weeks post treatment as well. At six and eight weeks post treatment, no significant difference was found among the three treatment groups.

Table 1: Cyathostome Eggs per Gram (EPG) of Feces Results for Each Treatment over Time

	Treatment 1 Ivermectin	**Treatment 2 Combination**	**Treatment 3 Fenbendazole**
Mean EPG at Treatment (50-6800 range)	2493 (200-6800)	1482 (350-4750)	1848 (50-5900)
Mean EPG at 2 weeks (0-425 range)	1.8 (0-25)	0 (0-0.2)	95.8 (3.2-425)
% Reduction at 2 weeks for Individuals	100%a	100%a	94.1%b
Group Mean % Reduction at 2 weeks	99.9%a	100%a	94.8%a
Mean EPG at 4 weeks (0-1125 range)	11.3 (0-100)	18.9 (0-125)	329.2 (10.6-925)
% Reduction at 4 weeks for Individuals	99.6%a	98.7%a	76.2%b
Group Mean % Reduction at 4 weeks	99.6%a	98.7%a	82.2%a
Mean EPG at 6 weeks (0-3450 range)	169.9 (0-525)	399.1 (0-3450)	480.6 (8.4-1550)
% Reduction at 6 weeks for Individuals	87.4%a	80.%a	69%a
Group Mean % Reduction at 6 weeks	93.2%a	73.1%a	74%a
Mean EPG at 8 weeks (0-6800 range)	270.9 (6-1175)	922.3 (5.6-6800)	606.6 (10-2325)
% Reduction at 8 weeks for Individuals	81.6%a	66.1%a	60.3%a
Group Mean % Reduction at 8 weeks	89.1a	37.8%b	67.2%ab

All means and standard deviations in epg

a,b means in the same row with unlike letters are significantly different (P<0.05)

3.2 *Parascaris*

Contrary to the cyathostome results, *Parascaris* egg counts were reduced the most by fenbendazole at two weeks post treatment with a 100% (100%) reduction from mean egg counts with an average of 0.2 epg (0-2.6 epg). The combination group had a 95.8% (93.1%) mean reduction with a mean of 42.7 epg (0-500 epg), followed by ivermectin with a 56.9% (60.3%) reduction from original mean egg counts with an

average of 776.8 epg (0-3325 epg) two weeks post treatment. Unlike the cyathostomes, *Parascaris* egg counts fell in all subsequent testing to as low as zero eggs per gram in the fenbendazole treated group at eight weeks post treatment, in fact no *Parascaris* eggs were found in the fenbendazole group from four to eight weeks post treatment. Eight weeks post treatment, ivermectin treated foals had a mean of 46 epg (0-325 epg) and an overall reduction of 91.5% (97.6%) *Parascaris* egg counts from the mean at time of treatment. The combination group had better effectiveness with egg counts averaging 10 epg (0-75 epg), and a 99.3% (98.4%) overall reduction in treatment mean numbers. Table 2 indicates means, percent reductions, and standard deviations for *Parascaris.*

Overall, there were more significant differences among each treatment for *Parascaris* than for the Cyathostomes. As seen on Table 2, the two and six weeks post treatment results showed a significance difference between the ivermectin treatment group and the other two groups, no significant difference was seen between the combination and fenbendazole groups at those times. At four and eight weeks post treatment, *Parascaris* egg counts showed significant differences between the ivermectin and fenbendazole treatment groups, the combination group did not show significant differences between either of the other two groups.

Table 2: *Parascaris* Eggs per Gram (EPG) of Feces Results for Each Treatment over Time

	Treatment 1 Ivermectin	**Treatment 2 Combination**	**Treatment 3 Fenbendazole**
Mean EPG at Treatment (25-8700 range)	1957.1 (25-8700)	621.7 (50-2575)	1480 (25-8350)
Mean EPG at 2 weeks (0-3325 range)	776.8 (0-3325)	42.8 (0-500)	.2 (0-2.6)
% Reduction at 2 weeks for Individuals	56.9%b	95.8%a	100%a
Group Mean % Reduction at 2 weeks	60.3%b	93.1%ab	100%a
Mean EPG at 4 weeks (0-975 range)	201.7 (0-975)	16.6 (0-225)	0 (0)
% Reduction at 4 weeks for Individuals	83.7%a	99%ab	100%b
Group Mean % Reduction at 4 weeks	89.7%a	97.3%a	100%a
Mean EPG at 6 weeks (0-825 range)	121 (0-825)	10.8 (0-100)	0 (0)
% Reduction at 6 weeks for Individuals	74.9%b	99.4%a	100%a
Group Mean % Reduction at 6 weeks	93.8%a	99.3%a	100%a
Mean EPG at 8 weeks (0-325 range)	46 (0-325)	10 (0-75)	0 (0)
% Reduction at 8 weeks for Individuals	91.5%a	99.3%ab	100%b
Group Mean% Reduction at 8 weeks	97.6%a	98.4%a	100%a

All means and standard deviations in epg

a,b means in the same row with unlike letters are significantly different (P<0.05)

4. DISCUSSION

The goal of this study was to determine the effect of specific anthelmintics, or a combination of anthelmintics on *Parascaris* and cyathostome egg counts in foals. The experiments used naturally infected foals ranging in age from four months at the beginning of the trial to 10 months at its conclusion, all of which were housed, fed, and treated at the Texas A&M University Horse Center. Since it is TAMU Horse Center practice to treat monthly with ivermectin, (Golden, 2011), the ivermectin treated group served as a quasi-control. None of the 30 animals showed clinical signs of disease and all 30 exhibited expected weight gain throughout the trial.

Since only naturally infected foals were utilized, the risk of highly variable parasite burdens and egg counts was present. Consequently, a high degree of variation was observed among the animals used in this study. These variations may have also been affected by the fact that the horses used were born between late January and late May of 2009, thus resulting in some animals having increased parasite burdens based on the availability of forage at the time of first grazing. In fact, foals born from the middle of February to the middle of March had the highest mean egg counts for cyathostomes and *Parascaris* at 4450 epg and 3245.8 epg respectively. Foals born after mid-March to early May had the lowest average egg counts at 1247.2 epg for cyathostomes and 904.17 epg for *Parascaris.* Because of such a massive difference in egg counts at the time of the initial treatment and the fact that drugs were randomly assigned to each animal every eight weeks, statistical comparison of treatment groups is difficult.

Significant differences among the three groups at each two week period post treatment were determined. These calculations were derived from the individual foal's epg reduction percentages, not from group mean epg counts, to give a more accurate interpretation of the data by reducing the effect of zero egg counts at treatment. Group means do not take into account individual variation, and thus comparison of reduction percentages using this method would only yield a comparison of means, using the mean of each individual foal's reduction percentages allows for variation and stronger statistical analysis. As seen in the tables, for the most part the individual foal's egg reduction percentages and the group mean reduction percentages were similar for most collection times. However, differences can be seen, such as with cyathostomes eight week post treatment were reduction percentages for the foals treated with the combination treatment was 66.1% reduction for individuals and 37.8% for group mean, and *Parascaris* at six weeks post treatment for ivermectin was 74.9% for individuals and 93.8% for group mean reduction percentages.

The differences outlined above can be explained by how each percentage was calculated. Individual FECR% utilizes each individual foal's egg reduction percentage to find the reduction percentage for the group as a whole, while the group means reduction percentages are calculated by comparing the mean epgs of post treatment collections to the mean at treatment. Using individual FECR% allows the researcher to remove test subjects who had zero epg at all collection points from treatment to eight weeks post treatment because if no eggs were ever found, no FECR% can be calculated. It also dictates that if a zero epg is found at the time of treatment and any eggs are found any

subsequent collection time, the FECR% is zero. The group means epg reduction takes all epg data into account causing more outliers than the individual foal FECR% does, thus skewing the data more such as in the two examples stated above. This could was also seen when comparing the significance between individual percentage reductions and group mean reductions by the fact that only one significant difference was found for cyathostomes and one for *Parascaris* when group mean reductions were analyzed as opposed to multiple significant differences when comparing the individual percentage reductions.

For cyathostomes, the ivermectin treatment and the combination treatment mirrored each other with no significant differences being detectable at all post treatment samplings. The fenbendazole group, however, was significantly different than the other groups at two and four weeks post treatment. At six and eight weeks post treatment, each group had no significant difference in FECR from each other. Reduction percentages for six and eight weeks post treatment were 87.4% and 81.6% for ivermectin, 80% and 66.1% for the combination treatment, and 76.2% and 60.3% for the fenbendazole treated group.

The reason that the fenbendazole treatment group was significantly different that the other two groups was due to the fenbendazole treatment's reduced effectiveness compared to the ivermectin and combination treated groups at those times. It is possible that larval cyathostomes arrested in the tissues could have emerged and matured in the time since treatment, but, according to the label, the fenbendazole treatment should have

killed the larval stages as well as the adults in the lumen of the intestine, thus preventing this from occurring.

Against *Parascasris*, the combination and fenbendazole treated groups showed no significant differences at two, four, six, or eight weeks post treatment. The ivermectin treated group continuously was significantly different that the fenbendazole treated group for all post treatment epg counts. The reasons for this mostly stem from ivermectin's inability to effectively reduce *Parascaris* egg counts and fenbendazole's almost total elimination of this parasite's eggs in the feces. The ivermectin treated group was significantly different from the combination treated group at two and six weeks post treatment but no significant differences were found at four and eight weeks post treatment. While the combination treatment did reduce egg numbers by over 95%, it was still not quite as effective as fenbendazole, which had a 100% reduction rate at all post treatment egg counts. These finding indicates that even though ivermectin had over a 90% reduction rate at six and eight weeks post treatment, the combination and fenbendazole treatment groups statistically were much more effective at reducing egg numbers initially at the time of treatment and over the eight week span between treatments.

Each treatment was evaluated as to its effectiveness for both cyathostomes and *Parascaris* with theoretical reasons for each result.

Ivermectin was effective for treating cyathostomes with a 99.9% reduction of mean egg counts at two weeks post treatment. This finding indicates that it still has greater than 95% fecal egg reduction effectiveness. This finding mirrors that of Craig et

al from 2004 and 2005 on the same farm. In that study, ivermectin's percent reduction was also 99.9%. While this data does support ivermectin's initial effectiveness at killing cyathostomes, there was a rise in egg numbers at four weeks post treatment, where the egg count reduction was 99.5%, less than the percent reduction at treatment, with some of the treated foals increasing from 0 epg to 100 epg between the two and four weeks post treatment evaluations. In subsequent collections, the effectiveness dropped even lower to 81.6% at eight weeks post treatment, with one foal having an egg count of 1175 epg. It should also be noted that this particular foal had a count of only 200 cyathostome eggs per gram at the time of treatment supporting the observation that instead of reducing cyathostome egg counts, they increased substantially by eight weeks post treatment. The reasoning for this could be that a large influx of cyathostome larvae emerged from the mucosa after the initial population in the lumen had been removed, or the parasites in the lumen could have had their egg production halted without being killed. It is doubtful that egg production was halted for that long, but it could have contributed to the increase in egg numbers. The findings for the ivermectin treated group in general coincide with the studies of Lyons et al (2008b) and von-Samson-Himmelstjerna et al (2006) in which they each state that egg counts for the ivermectin treated animals begin to return four weeks post treatment with more rapid increases at six and eight weeks post treatment. Previous research conducted in 1992 concluded that ivermectin controlled egg count numbers for eight weeks post treatment (Little et al., 2003), studies performed by Lyons on the same farm as Little in 2007-2008 showed reduced numbers for only four weeks (Lyons et al, 2008a). A study performed by von-

Samson-Himmelstjerna et al (2006) showed an increase in cyathostome egg numbers three weeks post treatment in 9 of 14 foals and yearlings from one farm; this increase was hypothesized to be caused by less efficient immune responses in those animals. However, after testing the body conditions of the 14 horses with similarly aged horses on other farms, no difference could be found to explain this occurrence. The evidence now points to the drug's loss of effectiveness over time to control cyathostomes (von-Samson-Himmelstjerna et al, 2006).

Ivermectin failed to provide control of *Parascaris* at two weeks post treatment. Not only did it not achieve the 95% egg reduction that is the standard for setting effectiveness measures, it only managed to reduce mean egg counts by 56.9%, based on individual foal FECR%, from the numbers present at the time of treatment. A more startling point is that *Parascaris* egg counts actually increased in one animal two weeks post treatment. This foal went from 925 epg to 975 epg. While this does not indicate that the parasite burden increased in this particular foal, it does lead to the conclusion that the *Parascaris* population was only minimally affected if affected at all. A 50 epg increase in two weeks can be attributed to regular fluctuations; however, being that the increase happened only two weeks post treatment is further evidence of *Parascaris* resistance to ivermectin. The two week mean percent reduction of 60.3% is even less that the reduction that Craig et al. (2007) found on this same farm in 2004-2005, which was 84.8%. Although not the preferred choice for *Parascaris* treatment, ivermectin did show more effectiveness in the four, six, and eight week collections. The last collections had a total percent reduction of 91.5% with a range of 0-325 epg. Surprisingly, the reductions

were not linear; the foals with the highest initial counts had eight week egg counts near zero, while the foal with a starting level of less than 1000 epg had the highest eight week post treatment egg count. This observation could possibly be explained by the variation in number of migrating larvae and immature *Parascaris* in each individual foal as well as possibly the related to immunity that causes resistance to *Parascaris* after exposure and the loss of adult worms due to their sensitivity to the drug. The fact that ivermectin's effectiveness increased over time can be explained by the drug's mode of action on parasites.

Macrocyclic lactones work by causing a flaccid paralysis, if this does not immediately kill the adults; it may have weakened them enough for the foal's immune system to develop a response and may even assist in developing the natural immunity to *Parascaris* faster than the other drugs because of the parasite's now inactive inhabitation in the small intestine.

The combination treatment showed 100% effectiveness at reducing cyathostome egg counts at two weeks post treatment with only one foal having any detectable epg levels, 0.2 epg; however, the subsequent collections showed a marked drop in effectiveness, with an overall reduction of only 66.1%, (37.8% based on group means), at the eight week collection. Two foals showed an increase in egg counts at the eight week post treatment collection, with one of them having a three-fold increase in egg numbers from those at the time of treatment, this is further evidence of ivermectin's reduced longevity. At eight weeks post treatment, the egg counts ranged from 0-6800 epg with eight animals being under 25 epg, six being over 700 epg, and four being

between 200-600 epg. This variation could have been due to the numbers of cyathostome larvae in the mucosa of the large intestine and the previous exposure of each individual animal.

As far as the *Parascaris* egg counts, the two week post treatment sampling revealed an overall mean percent reduction of 95.2% with a range of 0-500 epg. Just as had been observed with the group treated solely with ivermectin, the four, six, and eight week collections all had improved effectiveness over the two week post treatment counts, with a final reduction of 99.3% and a range of 0-75 epg. While the two week post treatment reductions failed to achieve the 95% egg reduction standard based on the group mean of 93.1%, the individual FECR% did meet the criteria for effectiveness both the group mean and individual foal FECR% were over 95% for the four, six, and eight week post treatment collections. Although the combination treatment was only 7.8% more effective at reducing egg counts than the ivermectin alone treatment, the initial reduction is worth the added drug administration because it lowers the number of *Parascaris* more quickly to begin with while still having the residual effect seen in the later samplings of the ivermectin treated group. Also, as had been reported in earlier research, ivermectin's effect on *Parascaris* is less pronounced in older foals, this statement is supported by this study (Craig et al.,2007.). In the ivermectin treated group, four month old treated foals still had egg counts exceeding 2000 epg; some did not even achieve a 50% reduction at two weeks post treatment. By giving the combination of drugs to the foal, especially young ones, the initial *Parascaris* burdens can be drastically lowered quickly by pyrantel, while ivermectin's residual effect can possibly supply some

sustained protection against *Parascaris* due to the observation that its effectiveness increased in the subsequent EPG tests after treatment. It should be noted that effectiveness may have been due more to acquired immunity than ivermectin's effectiveness, but that can only be speculated.

The fenbendazole treated group had a 94.1% mean reduction in cyathostome egg counts two weeks post treatment with a range of 0-425 epg; however, subsequent collections found that effectiveness fell each two week interval to an eight weeks mean reduction of only 60.3% with a range of 2.4-2325 epg. This is a lower reduction than was seen at eight weeks in the ivermectin treated group. Though cyathostomes have been reported to have resistance to benzimidazoles, with one researcher stating that a single dose of fenbendazole is now ineffective at controlling cyathostomes on almost all farms in the southern US (Kaplan et al, 2004), this study utilized a double dose of the fenbendazole Powerpac® treatment, which is 20mg/kg for five consecutive days. Previous research done by Steinbach et al in 2006 showed that animals treated with this amount of fenbendazole shed no cyathostome eggs after treatment. Also, of the eight animals given the treatment in that study, only two of them had cyathostome adults present on the post mortem examination, and those two particular animals only harbored low numbers (under 50 adults) (Steinbach et al , 2006). Comparing the findings of Steinbach to those seen in this study, resistance levels vary over geographic location and simply from farm to farm, making it necessary to test each individual farm to know which drugs are effective on parasite populations on those farms.

The fenbendazole treatment group had one undeniable advantage over the other two treatment groups: the most effective reduction of *Parascaris* egg counts of all the treatment regimens. At two weeks post treatment, egg numbers where reduced by 99.9% from the time of treatment with only one foal having a detectable egg level, and that was only 2.4 epg. Following collections revealed no *Parascaris* eggs at all. This shows that the five day fenbendazole Powerpac at 20mg/kg treatment is effective against *Parascaris* on this particular farm.

The data reveled in this study and the observations seen from previous work point to the conclusion that if we continue to try to treat all horses with a single anthelmintic, further resistances will occur. To add to this, with animals being routinely transported over long distances, the spread of resistant strains of worms is highly likely to occur. Since there is evidence that one common type of parasite is susceptible to one antihelmenthic and resistant to another, and the other most common is just the opposite, a dual dewormer approach seems reasonable.

5. CONCLUSION AND RECOMMENDATIONS

Although the fenbendazole did show the highest percent reduction rates for *Parascaris,* its inability to meet the 95% egg count reduction for cyathostomes at four weeks post treatment, as well as the necessity to be given for five consecutive days make it a less desirable treatment for this particular farm. Ivermectin's ability to control cyathostomes was much greater four weeks post treatment with a percent reduction of 99.5% compared to the fendendazole's rate of 76.2% at four weeks. Though this does bode well for ivermectin, its effectiveness against *Parascaris* at four weeks was only a 83.7% reduction from the numbers at the time of treatment. The combination treatment of ivermectin and pyrantel had the most effective results for both parasites with cyathostome egg counts falling by 98.7% four weeks post treatment and *Paracaris* egg count reductions of 99% from original numbers at four weeks post treatment. Therefore, it is believed that the combination treatment would provide the most protection to the foals at this particular farm for the time being.

The observation that the combination treatment offers the highest reductions in fecal egg counts of both parasites in this study strongly supports its use as a standard treatment for the facility. It is the recommendation of this researcher that the combination treatment should be administered to foals three months of age at the Texas A&M University Horse Center to cause not only a large reduction in adult worm populations, but more importantly, stop the large number of eggs these parasites would produce from contaminating the environment. This would diminish the exposure of

subsequent populations of foals in the following years, thus reducing the chance of disease over time. Since eggs of *Parascaris equorum*, can be viable for years after being passed in the environment, treatment at this point in the foals' lives could provide a substantial exposure reduction to subsequent generations of foals born on this farm. From the data collected, foals who initially received the combination treatment showed no substantial *Parascaris* egg counts throughout the rest of the study, indicating that once the primary levels of this parasite have been treated, future numbers of reproducing adults are relatively controlled, even if subsequent treatments are not the combination treatment. Even though this study utilized foals as young as four months of age, this was only done to ensure substantial *Parascaris* egg numbers; three months is ample time to develop patent *Parascaris* infections since the parasite's prepatent period is 75-80 days.

After the initial combination treatment, a monthly treatment of ivermectin is recommended to reduce the likelihood of cyathostome related disease, and provide some relief to *Parascaris* infections. This treatment regimen would continue to reduce cyathostome egg numbers in the environment, protecting not only the current population of foals, but future generations as well as adult horses on the farm since cyathostomes can infect equines of any age. The reason for using the ivermectin only treatment for *Parascaris* is that even though this study has proven that it does not reduce egg counts for this particular parasite to the standard 95% reduction rate at two weeks post treatment, it does show improved egg reduction numbers at four weeks through eight weeks post treatment. While no hard evidence has been uncovered by this study to suggest why this occurred, speculations can be made which include increased horse

immunity to *Parascaris* or if prolonged exposure to ivermectin is the cause of the decline in egg numbers.

It should also be noted that the mares at the TAMU Horse Center share the same grazing areas as the foals. Because of this, the foals' exposure to infective *Parascaris* is reduced. *Parascaris* should not mature in the mares because of acquired immunity, if they have had previous exposure to the parasite, thus contributing to a reduced amount of infective eggs ingested by the foals. Cyathostomes will mature in adult horses, but their numbers are usually lower than the numbers in foals, thus also reducing the foals' exposure to cyathostomes as well. While egg per gram analysis was not conducted on mares at the TAMU Horse Center in this study, other research does support this hypothesis. It has been observed that, in general, egg counts are lower in mature horses than in foals. Research has also revealed that egg reappearance in feces is often longer and egg numbers lower in adult horses compared to foals (Klei, 1999). Though adult horses will not acquire complete immunity to cyathostomes with exposure and age the way they do to *Parascaris*, evidence shows that mature horses will develop age related resistance to large numbers of adult cyathostomes (Klei, 1999).

Grazing both mares and foals together will not keep the foals from getting infected with intestinal parasites, but it can reduce the foal's exposure to infective stages in the environment. If the mares undergo fecal egg count analysis, and treatment is administered only to mares with high egg counts as opposed to all mares each treatment cycle, pasture contamination by the mares would be reduced. This would also slow the development of anthelmintic resistance by letting the untreated mares serve as a

reservoir for cyathostomes that haven't been exposed to anthelmintics on a regular basis. Reduction to infective parasites by combined mare and foal grazing was not purpose of the study, nor was it a parameter of it. It is only speculation as far as this particular horse farm goes, but it is a possibility for future research.

The longevity of this treatment regimen cannot be extrapolated, thus future studies will need to be conducted to see if the combination treatment's effectiveness has waned or continues to show the same level of effectiveness against cyathostomes and *Parascaris*, as well as that of ivermectin to those parasites. It should also be mentioned that this treatment is meant to control egg shedding levels, not eradicate parasite burdens. It is effectively treating one year's foals to reduce the exposure of the next year's animals. Also, the combination treatment is not meant to assist with the horse's immunity development to *Parascaris*. The migrating *Parascaris* larvae are more responsible for acquired immunity than are the adults in the small intestine because when the larvae migrate through the liver, eosinophils, macrophages, neutrophils, and lymphocytes invade the tracts cut by the larvae in the liver and surround the parasite (Brown et al, 1979). As more larvae migrate through the liver, these cells and the cytokines produced by the host become more efficient at isolating the larvae and preventing migration and maturation. Also, pyrantel, unlike ivermectin, is not absorbed by the foal, thus the parasites do not have a prolonged exposure to pyrantel in this treatment regimen. The data from this study show that *Parascaris* egg counts fell over time in the ivermectin treated group from a mean of 776.8 epg at two weeks post treatment to one of 46 epg at eight weeks post treatment, a reduction of 91.5% at eight

weeks from counts at the time of treatment with most foals having no observable levels of eggs in the feces. This could be due ivermectin's mode of action on the parasite causing the adults to be expelled from the body slower than with the pyrantel treatment, or at least reducing egg production for a time. It is not the purpose of this study to remark on this hypothesis; however, it is a possible basis for future research.

This treatment regimen needs to be regularly evaluated for effectiveness. The monthly treatment of ivermectin is an ideal way to select for parasite resistance. The purpose of this study was to determine which of the three drugs were effective at the time of the study and for which parasites they were effective on, what will work in the future is unknown. It is the recommendation of this researcher that yearly evaluations of this treatment regimen be performed to test its continued effectiveness against cyathostomes and *Parascaris*. It is possible that after the initial treatment, monthly ivermectin treatments are not necessary, treatment may only be needed every two months. This would assist in prolonging the effectiveness of the anthelmintic by reducing the exposure of the parasites to it, as well as still providing sufficient protection to the foal.

If future testing does indicate resistance to the treatment regimen by *Parascaris* on this farm, the effectiveness of both ivermectin and pyrantel will need to be reevaluated to determine which drug has failed. If ivermectin is found to have lost its effectiveness but pyrantel still works, a monthly dose of both drugs should be considered as a new treatment regimen. If pyrantel is found to failed, the fenbendazole Powerpac treatment should be considered as an option to control *Parascaris*. A single dose of

fenbendazole at 20 mg/kg (double the manufacturer's recommended dose for *Parascaris equorum*) may be just as beneficial without the added need for the subsequent dosing that the Powerpac requires. The reason for suggesting a double dose at 20mg/kg instead of a single dose is because that was the amount of drug administered to the foals in the fenbendazole treatment group each day they received fenbendazole as part of the Powerpac regimen. Recent research shows that it does have a high effectiveness against *Parascaris;* however, the effectiveness of a single fenbendazole dose was not evaluated as part of this study, and therefore its ability to control *Parascaris* on this farm is unknown at this time.

If the proposed treatment regimen loses its effectiveness at controlling cyathostomes, it is this researcher's opinion that a new study be undertaken to determine an effective drug or combination of drugs that will control cyathostomes. Since ivermectin was the only drug tested in this study that showed an egg reduction of over 90% one month after treatment, different anthelmintics than the ones used in this study should be evaluated for effectiveness.

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APPENDIX

STRONGYLE FECAL EGG COUNTS

IVERMECTIN

Animal ID	#		Weight	DOB	date	Str EPG	date	Str EPG	date	Str EPG	date	Str EPG	date	Str EPG
BJ		1	466	1/27/2009	18-Jun	2625	6-Jul	0	20-Jul	25	3-Aug	200	17-Aug	300
Dixie		5	477	2/7/2009	18-Jun	3675	6-Jul	0	20-Jul	100	3-Aug	425	17-Aug	
Freddy		8	502	3/13/2009	20-Jul	5900	3-Aug	0	17-Aug	25	31-Aug	175	14-Sep	275
Toad		10	405	3/23/2009	20-Jul	3000	3-Aug	0	17-Aug	0.8	31-Aug	675	14-Sep	250
BJ		1	522	1/27/2009	17-Aug	300	31-Aug	0	14-Sep	0	28-Sep	0.4	12-Oct	0.2
Willy		6	535	2/1/2009	17-Aug	450	31-Aug	0	14-Sep	0.2	28-Sep	0	12-Oct	0
Mikey		14	490	3/28/2009	31-Aug	8.2	14-Sep	0	28-Sep	0	12-Oct	0	26-Oct	1.6
Tito		16	446	4/8/2009	31-Aug	1975	14-Sep	0	28-Sep	0	12-Oct	0	26-Oct	50
Maggie		23	416	5/9/2009	28-Sep	4375	12-Oct	25	26-Oct	0.8	9-Nov	75	23-Nov	475
Luigi		24	438	5/10/2009	28-Sep	475	12-Oct	0	26-Oct	0	9-Nov	100	23-Nov	350
		25	389	5/27/2009	12-Oct	200	26-Oct	0	9-Nov	2.4	23-Nov	525	7-Dec	1175
		28	472	5/18/2009	12-Oct	2175	26-Oct	0	9-Nov	0	23-Nov	150	7-Dec	250
Streak		15	580	4/19/2009	26-Oct	200	9-Nov	0	23-Nov	0	7-Dec	0	21-Dec	12.4
George		17	541	3/17/2009	26-Oct	10	9-Nov	0	23-Nov	0	7-Dec	0.2	21-Dec	1
Mario		19	450	5/10/2009	23-Nov	2250	7-Dec	0	21-Dec	1.4	4-Jan	17.6	18-Jan	28.6
Homer		22	388	5/7/2009	23-Nov	225	7-Dec	0	21-Dec	0	4-Jan	3	18-Jan	50
		27		5/27/2009	7-Dec	6800	21-Dec	0	4-Jan	2.6	18-Jan	31.4	1-Feb	300
		29		5/15/2009	7-Dec	1025	21-Dec	0	4-Jan	0	18-Jan	1	1-Feb	6
mean						**1982**	**2 weeks**	**1.4**	**4 weeks**	**8.8**	**6 weeks**	**132.1**	**8 weeks**	**207.4**
% red						100		**99.9**				**93.8**		**89.5**

COMBINATION

Animal ID	#	Weight	DOB	date	Str EPG	date	Str EPG	date	Str EPG	date	Str EPG	date	Str EPG
Charlie	2	391	2/7/2009	18-Jun	2225	6-Jul	0	20-Jul	25	3-Aug	575	17-Aug	1750
Willy	6	456	2/1/2009	18-Jun	550	6-Jul	0	20-Jul	50	3-Aug	525	17-Aug	450
Toots	7	481	2/26/2009	20-Jul	4525	3-Aug	50	17-Aug	25	31-Aug	375	14-Sep	750
Catfish	12	493	2/25/2009	20-Jul	4750	3-Aug	0	17-Aug	50	31-Aug	350	14-Sep	700
Charlie	3	513	2/2/2009	17-Aug	400	31-Aug	0	14-Sep	0.2	28-Sep	0	12-Oct	0.4
Dixie	5	516	2/4/2009	17-Aug		31-Aug	0	14-Sep	0	28-Sep	0.4	12-Oct	0
Streak	15	534	4/19/2009	31-Aug	2025	14-Sep	0	28-Sep	0	12-Oct	75	26-Oct	200
George	18	476	5/6/2009	31-Aug	1425	14-Sep	0	28-Sep	3	12-Oct	375	26-Oct	575
Mario	19	450	5/10/2009	28-Sep	1725	12-Oct	0	26-Oct	3.6	9-Nov	325	23-Nov	2250
Homer	22	388	5/7/2009	28-Sep	2250	12-Oct	0	26-Oct	25	9-Nov	50	23-Nov	225
	27	492	5/27/2009	12-Oct	2025	26-Oct	0	9-Nov	125	23-Nov	3450	7-Dec	6800
	30	381	5/30/2009	12-Oct	1375	26-Oct	0	9-Nov	0	23-Nov	250	7-Dec	825
Mudpie	13	544	3/28/2009	26-Oct	350	9-Nov	0	23-Nov	0	7-Dec	0	21-Dec	23
Bozo	18	502	5/6/2009	26-Oct	525	9-Nov	0	23-Nov	0	7-Dec	0.8	21-Dec	7.8
Marge	20	471	5/12/2009	23-Nov	375	7-Dec	0	21-Dec	0	4-Jan	5.2	18-Jan	6
Luigi	24	438	5/10/2009	23-Nov	350	7-Dec	0.2	21-Dec	2.2	4-Jan	2	18-Jan	9.4
	26		6/4/2009	7-Dec	1450	21-Dec	0	4-Jan	0	18-Jan	2	1-Feb	8.4
	30		5/30/2009	7-Dec	825	21-Dec	0	4-Jan	0	18-Jan	2.2	1-Feb	5.6
mean					**1508**	2 week	**2.8**	**4 weeks**	**15.8**	**6-week**	**353.5**	**8-week**	**810.3**
% red							**99.8**		**99**		**76.6**		**46.3**

FENBENDAZOLE

Animal ID	#	Weight	DOB	date	Str EPG	date	Str EPG	date	Str EPG	date	Str EPG	date	Str EPG
Oscar	3	434	2/2/2009	18-Jun	875	6-Jul	150	20-Jul	450	3-Aug	350	17-Aug	400
Big John	4	486	2/4/2009	18-Jun	3050	6-Jul	125	20-Jul	225	3-Aug	350	17-Aug	525
Turtle	9	470	3/5/2009	20-Jul	2625	3-Aug	125	17-Aug	350	31-Aug	500	14-Sep	450
Russel	11	488	2/14/2009	20-Jul	5900	3-Aug	250	17-Aug	925	31-Aug	450	14-Sep	250
Charlie	2	473	2/7/2009	17-Aug	1750	31-Aug	0	14-Sep	175	28-Sep	1.4	12-Oct	20
Big John	4	579	2/4/2009	17-Aug	525	31-Aug	0	14-Sep	250	28-Sep	400	12-Oct	9.8
Mudpie	13	515	3/28/2009	31-Aug	675	14-Sep	3.2	28-Sep	125	12-Oct	175	26-Oct	350
George	17	483	3/17/2009	31-Aug	1375	14-Sep	25	28-Sep	75	12-Oct	25	26-Oct	10
Marge	20	471	5/12/2009	28-Sep	2150	12-Oct	19.8	26-Oct	200	9-Nov	450	23-Nov	375
Taco	21	495	5/1/2009	28-Sep	3325	12-Oct	175	26-Oct	1125	9-Nov	1475	23-Nov	2325
	26	416	6/4/2009	12-Oct	1025	26-Oct	25	9-Nov	375	23-Nov	1550	7-Dec	1450
	29	462	5/15/2009	12-Oct	2450	26-Oct	10.2	9-Nov	200	23-Nov	250	7-Dec	1025
Mikey	14	504	3/28/2009	26-Oct	1.6	9-Nov	0.6	23-Nov	2	7-Dec	3.8	21-Dec	2.4
Tito	16	493	4/8/2009	26-Oct	50	9-Nov	4.2	23-Nov	10.6	7-Dec	8.4	21-Dec	21.6
Taco	21	495	5/1/2009	23-Nov	2325	7-Dec	425	21-Dec	375	4-Jan	825	18-Jan	1375
Maggie	23	416	5/9/2009	23-Nov	475	7-Dec	25	21-Dec	27.4	4-Jan	100	18-Jan	17.4
	25		5/27/2009	7-Dec	1175	21-Dec	50	4-Jan	175	18-Jan	125	1-Feb	275
	28		5/18/2009	7-Dec	250	21-Dec	25	4-Jan	300	18-Jan	575	1-Feb	250
mean					**1667**	**2 week**	**79.9**	**4 weeks**	**298.1**	**6 weeks**	**423**	**8-week**	**507.3**
% red							**95.2**		**82.1**		**74.6**		**69.6**

PARACARIS FECAL EGG COUNTS

IVERMECTIN

Animal ID	#		Weight	DOB	date	ParEPG	date	ParEPG	date	ParEPG	date	ParEPG	date	ParEPG
BJ		1	466	1/27/2009	18-Jun	4350	6-Jul	175	20-Jul	0	3-Aug	1.8	17-Aug	1.2
Dixie		5	477	2/7/2009	18-Jun	1175	6-Jul	2100	20-Jul	325	3-Aug	700	17-Aug	
Freddy		8	502	3/13/2009	20-Jul	6125	3-Aug	3325	17-Aug	725	31-Aug	0	14-Sep	0
Toad		10	405	3/23/2009	20-Jul	2900	3-Aug	575	17-Aug	5.2	31-Aug	0	14-Sep	0
BJ		1	522	1/27/2009	17-Aug	1.2	31-Aug	0	14-Sep	0	28-Sep	0	12-Oct	0
Willy		6	535	2/1/2009	17-Aug	0	31-Aug	0	14-Sep	0	28-Sep	0	12-Oct	0
Mikey		14	490	3/28/2009	31-Aug	0	14-Sep	0	28-Sep	0	12-Oct	0	26-Oct	0.6
Tito		16	446	4/8/2009	31-Aug	925	14-Sep	700	28-Sep	975	12-Oct	825	26-Oct	325
Maggie		23	416	5/9/2009	28-Sep	925	12-Oct	100	26-Oct	11.4	9-Nov	5.8	23-Nov	75
Luigi		24	438	5/10/2009	28-Sep	8700	12-Oct	2650	26-Oct	700	9-Nov	1.4	23-Nov	0
		25	389	5/27/2009	12-Oct	350	26-Oct	275	9-Nov	75	23-Nov	100	7-Dec	175
		28	472	5/18/2009	12-Oct	1875	26-Oct	950	9-Nov	8	23-Nov	0	7-Dec	0
Streak		15	580	4/19/2009	26-Oct	0	9-Nov	0	23-Nov	0	7-Dec	20.6	21-Dec	20.4
George		17	541	3/17/2009	26-Oct	0	9-Nov	0	23-Nov	0	7-Dec	0	21-Dec	0
Mario		19	450	5/10/2009	23-Nov	25	7-Dec	0	21-Dec	0	4-Jan	11.6	18-Jan	0
Homer		22	388	5/7/2009	23-Nov	50	7-Dec	25	21-Dec	4.6	4-Jan	25.8	18-Jan	0
		27		5/27/2009	7-Dec	0	21-Dec	0	4-Jan	2	18-Jan	2.4	1-Feb	0.6
		29		5/15/2009	7-Dec	0	21-Dec	0	4-Jan	0	18-Jan	0	1-Feb	1.2
mean						**1481**	**2 weeks**	**604**	**4 weeks**	**157.3**	**6 weeks**	**94.1**	**8 weeks**	**35.2**
% red						100		**59.2**		**92.1**		**93.6**		**97.6**

COMBINATION

Animal ID	#	Weight	DOB	date	ParEPG	date	ParEPG	date	ParEPG	date	ParEPG	date	ParEPG
Charlie	2	391	2/7/2009	18-Jun	1000	6-Jul	0	20-Jul	0	3-Aug	0	17-Aug	0
Willy	6	456	2/1/2009	18-Jun	1300	6-Jul	0	20-Jul	0	3-Aug	0	17-Aug	0
Toots	7	481	2/26/2009	20-Jul	1325	3-Aug	775	17-Aug	150	31-Aug	0	14-Sep	0
Catfish	12	493	2/25/2009	20-Jul	750	3-Aug	75	17-Aug	0	31-Aug	0	14-Sep	0
Charlie	3	513	2/2/2009	17-Aug	0	31-Aug	0	14-Sep	0	28-Sep	0	12-Oct	0
Dixie	5	516	2/4/2009	17-Aug		31-Aug	25	14-Sep	0	28-Sep	0.2	12-Oct	0.2
Streak	15	534	4/19/2009	31-Aug	1750	14-Sep	1	28-Sep	0	12-Oct	0	26-Oct	0
George	18	476	5/6/2009	31-Aug	50	14-Sep	0	28-Sep	0	12-Oct	0	26-Oct	0
Mario	19	450	5/10/2009	28-Sep	2575	12-Oct	500	26-Oct	225	9-Nov	100	23-Nov	25
Homer	22	388	5/7/2009	28-Sep	975	12-Oct	50	26-Oct	0	9-Nov	12.6	23-Nov	50
	27	492	5/27/2009	12-Oct	325	26-Oct	3.2	9-Nov	0	23-Nov	0	7-Dec	0
	30	381	5/30/2009	12-Oct	600	26-Oct	12.2	9-Nov	0.2	23-Nov	0	7-Dec	0
Mudpie	13	544	3/28/2009	26-Oct	0	9-Nov	0	23-Nov	0	7-Dec	0	21-Dec	0
Bozo	18	502	5/6/2009	26-Oct	0	9-Nov	0	23-Nov	23.6	7-Dec	50	21-Dec	75
Marge	20	471	5/12/2009	23-Nov	0	7-Dec	0	21-Dec	0	4-Jan	0	18-Jan	0
Luigi	24	438	5/10/2009	23-Nov	0	7-Dec	0	21-Dec	0	4-Jan	0	18-Jan	0
	26		6/4/2009	7-Dec	0	21-Dec	0	4-Jan	0	18-Jan	0	1-Feb	0
	30		5/30/2009	7-Dec	0	21-Dec	0	4-Jan	0	18-Jan	0	1-Feb	0.2
mean					**589**	2 week	**80.1**	**4 weeks**	**22.6**	**6-week**	**9**	**8-week**	**8.4**
% red							**86.4**		**96.2**		**98.5**		**98.6**

FENBENDAZOLE

Animal ID	#	Weight	DOB	date	Par EPG	date	Par EPG	date	Par EPG	date	Par EPG	date	Par EPG
Oscar	3	434	2/2/2009	18-Jun	6575	6-Jul	0	20-Jul	0	3-Aug	0	17-Aug	0
Big John	4	486	2/4/2009	18-Jun	875	6-Jul	0	20-Jul	0	3-Aug	0	17-Aug	0
Turtle	9	470	3/5/2009	20-Jul	8350	3-Aug	0	17-Aug	0	31-Aug	0	14-Sep	0
Russel	11	488	2/14/2009	20-Jul	25	3-Aug	0	17-Aug	0	31-Aug	0	14-Sep	0
Charlie	2	473	2/7/2009	17-Aug	0	31-Aug	0	14-Sep	0	28-Sep	0	12-Oct	0
Big John	4	579	2/4/2009	17-Aug	0	31-Aug	0	14-Sep	0	28-Sep	0	12-Oct	0
Mudpie	13	515	3/28/2009	31-Aug	600	14-Sep	0	28-Sep	0	12-Oct	0	26-Oct	0
George	17	483	3/17/2009	31-Aug	2100	14-Sep	0	28-Sep	0	12-Oct	0	26-Oct	0
Marge	20	471	5/12/2009	28-Sep	425	12-Oct	0	26-Oct	0	9-Nov	0	23-Nov	0
Taco	21	495	5/1/2009	28-Sep	275	12-Oct	0	26-Oct	0	9-Nov	0	23-Nov	0
	26	416	6/4/2009	12-Oct	200	26-Oct	0	9-Nov	0	23-Nov	0	7-Dec	0
	29	462	5/15/2009	12-Oct	2200	26-Oct	0	9-Nov	0	23-Nov	0	7-Dec	0
Mikey	14	504	3/28/2009	26-Oct	0.6	9-Nov	0	23-Nov	0	7-Dec	0	21-Dec	0
Tito	16	493	4/8/2009	26-Oct	325	9-Nov	0	23-Nov	0	7-Dec	0	21-Dec	0
Taco	21	495	5/1/2009	23-Nov	0	7-Dec	2.6	21-Dec	0	4-Jan	0	18-Jan	0
Maggie	23	416	5/9/2009	23-Nov	75	7-Dec	0	21-Dec	0	4-Jan	0	18-Jan	0
	25		5/27/2009	7-Dec	175	21-Dec	0	4-Jan	0	18-Jan	0	1-Feb	0
	28		5/18/2009	7-Dec	0	21-Dec	0	4-Jan	0	18-Jan	0	1-Feb	0
mean					**1233**	**2 week**	**0.1**	**4 weeks**	**0**	**6 weeks**	**0**	**8-week**	**0**
% red							**99.9**		**100**		**100**		**100**

VITA

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