Prevalence of anthelmintic resistant cyathostomes on horse farms

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Objective—To determine prevalence of anthelmintic resistance in cyathostome nematodes of horses in the southern United States.

Design—Cross-sectional study.

Animals—786 horses on 44 farms and stables in Georgia, South Carolina, Florida, Kentucky, and Louisiana.

Procedure—Fecal egg count (FEC) reduction tests were performed on 44 large farms and stables. Horses on each farm were treated with an oral paste formulation of fenbendazole, oxibendazole, pyrantel pamoate, or ivermectin at recommended label dosages. A mixed linear model was fitted to the percentage reduction in FEC, accounting for differences among farms, states, ages, treatments, and treatment by state interactions.

Results—By use of a conservative measure of resistance (≤ 80% reduction), the percentage of farms with anthelmintic-resistant cyathostomes was 97.7%, 0%, 53.5%, and 40.5% for fenbendazole, ivermectin, oxibendazole, and pyrantel pamoate, respectively. Mean percentage reductions in FEC for all farms were 24.8%, 99.9%, 73.8%, and 78.6% for fenbendazole, ivermectin, oxibendazole, and pyrantel pamoate, respectively. Pairwise contrasts between states for each treatment revealed that in almost all instances, there were no significant differences in results between states.

Conclusions and Clinical Relevance—The prevalence of resistance found in this study was higher than that reported previously, suggesting that anthelmintic resistance in equine cyathostomes is becoming a major problem. Furthermore, data from these 5 southern states, which are geographically and physiographically distinct, were remarkably similar. This suggests that drug resistance in cyathostomes is highly prevalent throughout the entire southern United States and probably nationwide. (J Am Vet Med Assoc 2004;225:903–910)

The concept of strategic parasite control for horses was introduced almost 40 years ago in a program that became known as the interval dose system.1 Horse owners were advised to treat all horses every 6 to 8 weeks to prevent parasite maturation and subsequent contamination of the environment with infective stages. This strategy was novel in that it not only addressed the treatment of current infections but was also designed to prevent future infection and disease. These recommendations were adopted widely and dramatic reductions in clinical cases of colic caused by Strongylus vulgaris were noted by equine veterinarians whose practices spanned this period of transition.2 Consequently, the prevalence of S vulgaris became reduced markedly, and by the early 1980s, it was recognized that cyathostomes (small strongyles) frequently accounted for virtually 100% of the parasite egg output of grazing horses.3 This major change in species prevalence has caused an important shift in the relative importance of these nematodes; cyathostomes are now recognized as the principal parasitic pathogen of horses.4 Larval cyathostomes encyst in the cecal and colonic mucosa, where they induce a mild inflammatory enteropathy that causes a subclinical alteration in gastrointestinal function.4 However, synchronous emergence of larval cyathostomes from the colonic mucosa may cause a life-threatening disease known as larval cyathostomosis, which is characterized by protein-losing enteropathy, chronic diarrhea, severe weight loss, colic, rough hair coat, and debilitation.5 Because immunity to cyathostomes is slow to develop and is incomplete6 in the absence of other parasite control measures, most horses require regular anthelmintic treatment throughout their lives.

Presently, 3 major classes of anthelmintics are used to control nematodes in horses, including benzimidazoles (fenbendazole, oxibendazole, oxibendazole, and others), tetrahydropyrimidines (pyrantel salts), and avermectin-milbemycins (macrocyclic lactones [ivermectin and moxidectin]). When first introduced, all of these drugs had good to excellent efficacy against...
cyathostomes. However, reports of drug-resistant cyathostomes are becoming increasingly common, and this is gaining recognition as a serious concern in the health management of horses. The earliest documented cases of anthelmintic resistance in cyathostomes of horses were to phenothiazine. Resistance to thiabendazole was reported shortly thereafter, after only a few years of use, and resistance to benzimidazole anthelmintics is now highly prevalent and widespread throughout the world. The prevalence of resistance to pyrantel has remained fairly low in comparison to the benzimidazole drugs; nevertheless, pyrantel resistance has been reported throughout the southeastern United States, Canada, and northern Europe. Ivermectin was first introduced as an equine anthelmintic in 1983 and remained the only avermectin-milbemycin anthelmintic used in horses until the recent introduction of moxidectin in 1997. Interestingly, there are still no reports of cyathostome resistance to ivermectin despite > 20 years of use as the most commonly administered anthelmintic drug. It is not known why ivermectin resistance has not appeared yet, although several hypotheses have been proposed. However, considering the growing reliance on these drugs and the fact that ivermectin resistance is becoming increasingly common in gastrointestinal tract nematode parasites of small ruminants and cattle, most equine parasitologists suspect that resistance in cyathostomes is inevitable.

It is well established that anthelmintic resistance is a growing problem for the control of cyathostome parasites throughout the world. Yet, few studies investigating the prevalence of this resistance in the United States have been published, and these were performed within 2 small geographic areas in Florida and Georgia and on relatively few farms. Thus, confidence limits for estimations of resistance prevalence were large, and it remained unknown whether these results were representative of the larger region. The purpose of the study reported here was to establish an accurate estimation for the prevalence of cyathostome resistance on horse farms throughout the southern United States.

Materials and Methods

Horses—Overall, 1,274 horses of various breeds on 44 farms (or stables) in Georgia, South Carolina, Florida, Kentucky, and Louisiana were evaluated in this study. Farms were located in the immediate regions surrounding the universities that participated in the study (eg, northeast Georgia, northwest South Carolina, north Florida, central Kentucky, and southern Louisiana). Farm types included breeding, training, pleasure, boarding, and assorted combinations of these 4 categories. Inclusion criteria for farms were a minimum of 24 horses available for testing on the property and a willingness of the owners or managers to cooperate with the study. All horses used in the study were not treated with an anthelmintic for at least 8 weeks prior to testing, and to accommodate the needs of the study, this interval on most farms was substantially longer than 8 weeks. Horses ranged in age from weanlings to 29 years old, with mean age of 8 years and median age of 7 years.

Experimental procedures—Fecal egg count reduction (FECR) tests were performed on 44 large farms in Georgia, South Carolina, Florida, Kentucky, and Louisiana. Horses on each farm were randomly assigned to 1 of 4 treatment groups, including fenbendazole (5.0 mg/kg [2.3 mg/lb]), oxibendazole (10 mg/kg [4.6 mg/lb]), pyrantel pamoate (6.6 mg base/kg [3.0 mg/lb]), and ivermectin (0.2 mg/kg [0.09 mg/lb]). All anthelmintics were administered orally in a paste formulation, and dosages for each horse were determined after estimating weight by use of a girth weight tape. Fecal samples were collected from the rectum of each horse prior to dosing and 10 to 14 days later. In locations in which lecces could unequivocally be determined to come from a particular horse (eg, from a horse alone in a stall), fresh leces were obtained from the ground. Additionally, (although not required by the protocol) on all farms in Kentucky and Louisiana and some farms in Georgia (when logistically feasible), screening pretreatment FECs was performed. These data were used to ensure that sufficiently high FECs were present in the horses to warrant treatment and, on some farms, to block horses by FEC before random assignment into treatment groups in order to balance them. On all farms, an attempt was made to include 6 horses/treatment group; nevertheless, on many farms, < 6 horses were available for testing because the presence of horses with 0 or low FECs precluded the gathering of reliable treatment efficacy data in those horses. On 1 Florida and several Louisiana farms, to increase the number of horses in each treatment group, horses were initially treated with only fenbendazole or oxibendazole; 60 or more days after treatment, pyrantel pamoate and ivermectin were tested in the same horses. The FECs were performed by use of a modified Stoll technique with a sensitivity of 5 (Georgia/South Carolina, Florida, and Louisiana) or 10 (Kentucky) eggs per gram (EPG).

Statistical analyses—A mixed linear model was fitted to the percentage FECR, accounting for differences between farms, states, age, treatment, and treatment by state interactions. Differences among horses were accounted for by allowing for extra variability attributable to horses. This is done by allowing for a random term in the statistical model that captures the variability of individual horses. Furthermore, this allows one to combine information on horses with similar traits. Because only 4 farms, which were in close proximity to the northeastern border of Georgia, were tested in South Carolina, statistical analyses were performed by combining farm data for all farms in both South Carolina and Georgia. Percentage reductions in FEC were calculated for each horse on a particular farm by use of linear mixed model-corrected EPG values and the following formula:

\[
\text{FECR} = \frac{[\text{pretreatment EPG} - \text{posttreatment EPG}] - \text{pretreatment EPG}) \times 100}{\text{pretreatment EPG}}
\]

Mean values for percentage FECR were then calculated for each treatment group on each farm. When FEC for an individual horse increased after treatment, the percentage FECR was considered to be 0. No agreed upon international standards exist for evaluating the FECR test in horses, but it has been suggested that FECR < 90% be used to indicate resistance on a farm. Considering this value and given the large innate variability in FECs, the cutoff values for resistance used in this study were selected to minimize the chances of overestimating the prevalence of resistance and minimize the impact that small numbers of large-strongyle eggs might have on the interpretation of FECR. Treatments were categorized as effective (parasites susceptible) if the FECR was ≥ 90%, equivocal (parasites suspected resistant) if the FECR was from 80% to 90%, and ineffective (resistant) if the FECR was < 80%. Horses that were treated with an anthelmintic but had pretreatment FEC < 25 EPG (Georgia/South Carolina, Florida, and Louisiana) or < 50 EPG (Kentucky) were excluded from the analysis of FECR.
This was done because the sensitivity of egg detection was too low to assess accurately treatment efficacy in horses with low FECs. The higher cutoff used for Kentucky horses reflected the lower sensitivity for FEC determination used at that site. Additionally, susceptibility results for individual drugs on a given farm were included in the final data set only if at least 2 horses with sufficiently high FECs, as defined, were present in the treatment group or if omitting 2 or more horses with low FECs did not change the result from the 1 remaining horse. For purposes of analyses and reporting of data, all strongyle eggs in feces were considered to be from cyathostomes. This was done on the basis of consistent findings of earlier studies that indicated that the prevalence and intensity of large strongyle species have become quite low, cyathostomes typically account for >95% of all strongyle eggs in feces of managed horses, and the percentage of cyathostome eggs is often >99% of the total. Furthermore, a parallel study performed on 2 farms in Kentucky that also participated in the study reported here found that 100% of larvae examined were cyathostomes. The possibility exists that small numbers of large-strongyle eggs were in the feces of some horses on some farms, but this would have little impact on the results because FEC < 800 was required to declare resistance. Least-square means for percentage FECR, 95% confidence intervals for mean percentage FECR for each treatment, and 95% confidence intervals for the percentage prevalence of resistance were also calculated. A value of P < 0.05 was considered significant.

Results
Testing for anthelmintic resistance was performed on 466 horses on 15 farms in Georgia and South Carolina, 166 horses on 7 farms in Florida, 336 horses on 12 farms in Kentucky, and 361 horses on 10 farms in Louisiana. Overall, 1,274 horses were evaluated on these farms, but data from only 786 horses were included in the analysis. Additionally, 75 of these 786 horses were tested on 2 occasions with different anthelmintics. Of the remaining 488 horses that were not included, 460 (94%) were excluded from the study because pre-treatment FECs were too low to meet the inclusion criteria for the study. The remaining 28 horses were excluded for a variety of reasons but most often because they were not available for posttreatment sampling. Pretreatment FECs were determined in horses on an additional 18 farms but were not used because too few horses had a sufficiently high FEC to meet inclusion criteria. On 1 farm in Georgia, only ivermectin and pyrantel pamoate were tested, and on 1 farm in Louisiana, only fenbendazole and oxibendazole were tested. An additional farm in Kentucky did not meet inclusion criteria for the pyrantel pamoate group. The number of horses per treatment group ranged from 1 to 13 with means (medians) of 5.3 (5), 4.9 (4), 5.2 (5), and 4.8 (4) for the fenbendazole, ivermectin, oxibendazole, and pyrantel pamoate groups, respectively. Of the 171 treatment groups included in the data analysis, 156 (91.2%) had 3 or more horses/group. Mean FECs were lowest in Kentucky horses and highest in Louisiana horses (Table 1); however, Florida had the highest percentage of farms that were excluded on the basis of low FECs (41.7%). The overall model-corrected mean FECRs for the 44 farms were 24.8%, 99.9%, 73.8%, and 78.6% for fenbendazole, ivermectin, oxibendazole, and pyrantel pamoate, respectively (Table 2). Distribution of FECR results for individual farms was determined (Figure 1). On the basis of criteria for resistance established for this study, we found an overall prevalence of resistance for fenbendazole of 97.7%, for ivermectin of 0%, for oxibendazole of 53.5%, and for pyrantel pamoate of 40.5% (Table 3). A substantial proportion of horses screened for use in this study had low FECs, despite not having been

<table>
<thead>
<tr>
<th>State</th>
<th>FBZ</th>
<th>IVM</th>
<th>OBZ</th>
<th>PP</th>
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<tbody>
<tr>
<td>GA/SC</td>
<td>27.4% (0.0–71.8)</td>
<td>99.9% (99.9–100)</td>
<td>73.6% (21.8–93.9)</td>
<td>62.7% (6.8–100)</td>
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<tr>
<td>FL</td>
<td>19.9% (0.0–72.7)</td>
<td>99.9% (99.9–100)</td>
<td>73.7% (10.4–96.6)</td>
<td>78.5% (31.8–99.9)</td>
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<tr>
<td>KY</td>
<td>18.2% (0.0–81.3)</td>
<td>99.9% (99.1–100)</td>
<td>66.7% (5.5–96.1)</td>
<td>65.1% (4.5–99.8)</td>
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<tr>
<td>LA</td>
<td>34.6% (6.3–77.5)</td>
<td>99.9% (92.2–99.8)</td>
<td>80.9% (44.6–98.3)</td>
<td>86.3% (63.7–99.0)</td>
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Mean of all farms without regard to state: 24.8% for fenbendazole, 99.9% for ivermectin, 73.8% for oxibendazole, and 86.3% for pyrantel pamoate. CI = Confidence interval. For each drug, values for states with different superscripts within a column are significantly (P < 0.05) different. Table 1 for remainder of key.
treated with an anthelmintic for > 8 weeks. On 18 of 62 (29%) farms screened for inclusion in this study, most horses had an FEC of < 25 EPG and these farms could not be used. On the 44 farms included in this study, 33.3% of horses had an FEC of < 25 EPG and more than 50% of horses had an FEC of < 200 EPG at the time of treatment. The distribution of all pretreatment FECs of horses sampled on the 44 farms was determined (Figure 2).

Statistical analyses of pretreatment FEC values for each state revealed that randomized assignment of horses to a treatment group was effective in creating groups that were not significantly different. The horses in Florida and Kentucky had homogeneity with respect to breed and age. Also, there were no significant differences attributable to farm between Florida and Kentucky. A similar pattern was observed for Georgia and Louisiana. Therefore, to perform contrasts for treatment effect on posttreatment values, the data from Florida and Kentucky were combined, as were data from Georgia and Louisiana. Results of these contrasts revealed that differences in posttreatment FECs were highly significant (P = 0.005) for all contrasts in Georgia and Louisiana and in all contrasts for Florida and Kentucky, except for oxibendazole-pyrantel pamoate (Table 4). Therefore, in all instances except for oxibendazole-pyrantel pamoate in Florida and Kentucky, the choice of drug had a significant effect on the resulting posttreatment FEC.

Ninety-five percent confidence intervals for percentage FECR by treatment and state revealed that the results of this study cannot be used to predict the resistance status of a farm for ivermectin, oxibendazole, and pyrantel pamoate. Conversely, the highest upper 95% confidence interval for fenbendazole in any state was only 72.2%, suggesting that there were sufficient data to conclude that resistance to this drug is ubiquitous.

Pairwise contrasts were performed between states for each treatment to determine whether response to treatment differed between states. In 22 of 24 contrasts, there were no significant differences in results between states. Significant differences were found for results of pyrantel pamoate in contrasts between Kentucky and Georgia (P = 0.0467) and between Kentucky and Louisiana (P = 0.0071). Least-square means that represent the mixed model-based mean for the response (percentage reduc-
The prevalence of resistance to fenbendazole, oxibendazole, and pyrantel pamoate found in this study was far greater than in any previous report. These data suggest that the problem of anthelmintic resistance in cyathostomes may be worsening rapidly and may be more severe in the United States than elsewhere in the world. Single-dose use of fenbendazole is now ineffective on virtually all farms in the southern United States, and oxibendazole and pyrantel pamoate were not effective (<90% FECR) on 77% and 55% of all farms tested, respectively. In contrast, ivermectin continued to be virtually 100% effective in eliminating eggs from feces. Ivermectin failed to reduce FEC by >90% in 2 of 13 horses on 1 farm in Louisiana, but subsequent retesting of 43 horses on that farm (after completion of the present study) revealed an FECR of >99.5% in all horses. It is interesting that the high prevalence of resistance to pyrantel pamoate found in our study has not been detected in studies performed outside the United States.

The activity of pyrantel against internal parasites of horses is independent of the attached salt (pamoate or tartrate) and method of administration. Therefore, it is highly likely that resistance to either pyrantel pamoate or pyrantel tartrate will confer resistance to the other. Because the United States and Canada are the only countries in which daily feeding of low-dose pyrantel tartrate is practiced, we wonder whether this mode of administration is having a major impact on the selection for resistance to pyrantel.

The 5 states included in this study represent geographically different and physiographically distinct areas of the southern United States. Additionally, farm types and management styles were quite different. Farms in Florida and Kentucky were predominantly breeding facilities with high-level management and valuable horses. In contrast, farms in Georgia, South Carolina, and Louisiana were a mixture of breeding, training, pleasure, and boarding facilities, most of which had horses of much lower economic value and lower management investment. Despite these distinctions, prevalence of resistance in the different states was remarkably similar.

Most recent studies investigating the prevalence of anthelmintic resistance have used an assortment of arithmetic and simple statistical tests for conducting data analysis. Recently, it has been suggested that parasitologic data should be analyzed with mixed models that are capable of overcoming many of the inherent problems associated with analysis of these types of data. In our study, we used a linear mixed model to account for differences among farms, states, ages, treatments, and treatment by state interactions and the large differences in pretreatment FECs caused by the aggregated distribution of FECs among horses. To our knowledge, this is the first time a mixed model has been used in this type of study. By use of this model, we compared the results of treatment among states and found few significant differences; analyses revealed only 2 of 24 comparisons with significance. These results strongly suggest that horses in the southern United States share a relatively homogenous population of cyathostomes. This conclusion is further supported by comparison of least-square means calculated by the mixed linear model. This result supports the findings of a recent study that detected a high level of gene flow between geographically distant populations of several strongylid nematode species of cattle and sheep. Because horses are moved around the country much more frequently than cattle, and horses from distant locations often graze shared pastures, widespread dispersal and transmission of resistant parasites are virtually assured. Therefore, the levels of resistance reported here for the southern United States are probably similar to those found nationwide.

These data suggest that a serious situation is emerging for cyathostome control in horses in the United States. More than 40% of all farms tested have cyathostome populations that are resistant to fenbendazole, oxibendazole, and pyrantel pamoate, meaning that on almost half of all farms, only a single drug class (avermectins-milbemycins) that has been in use for over 20 years remains effective. It is not known how long it will be before resistance to avermectin-milbemycin drugs develops in cyathostomes, but such resistance seems inevitable. Avermectin resistance is extremely common and widespread in closely related strongylid nematode parasites of sheep and goats, reports of avermectin-milbemycin resistance in Cooperia spp of cattle are becoming increasingly common, and avermectin-milbemycin resistance is suspected in Parascaris equorum of horses.

The high prevalence of multiple-drug resistance found in our study suggests that present strategies for nematode parasite control in horses need to be reexamined. Modern nematode control programs must be modified to address the challenges posed by the biological and epidemiologic features of cyathostomes, taking into consideration egg reappearance periods after treatment and anthelmintic resistance.

Figure 3—Least-square means of FECR (%) for 4 states among anthelmintic treatments in horses. GA = Georgia and South Carolina (combined data). See Figure 1 for remainder of key.
unselected parasites in a population.22-24 The unselected portion of the population, called refugia, provides a pool of genes susceptible to anthelmintics, thus diluting the frequency of resistant genes in a population of parasites. It is suggested that as the relative size of the refugia increases, the rate of evolution toward resistance decreases. Therefore, it is likely that, by serendipity, the lack of efficacy of ivermectin against mucosal cyathostome larvae has helped to preserve its efficacy. These mucosal larvae, which are usually present in far greater numbers than the luminal adult stages, provide a large refugia when ivermectin is administered to a horse. Although speculative, it has been suggested that the relatively good efficacy of moxidectin against these mucosal larval stages may increase the selection for resistance.25 Alternatively, the need for fewer treatments each year when using moxidectin, because of its long egg-reappearance period, may nullify this effect. Presently, no strong arguments can be made either way, although we do know that control programs should be designed to maintain the largest refugia that is consistent with good parasite control.

Successful nematode parasite control, while maintaining limited refugia, is only possible if routine FECs are performed to identify those horses that require treatment and those that do not. Although this recommendation is contrary to the treat-all-animals paradigm that often has been taught in the past, it is highly compatible with the host-parasite dynamics of cyathostomes. In the study reported here, most farms deliberately delayed scheduled anthelmintic treatments and farm data were only included if sufficient horses were passing adequate numbers of cyathostome eggs, a condition met by only 44 of 62 (71%) farms. Nevertheless, we still found that >33% of all horses on these 44 farms had an FEC ≤ 20 EPG, and on some farms, this value exceeded 50%. On all farms not included in the study on the basis of low FEC for which an adequate treatment history was available, horses had received frequent and relatively recent treatments with ivermectin or moxidectin.

We used a sensitive method for determining FEC, which improved the precision of our measurement. Conversely, the more commonly used McMaster method, which is the technique recommended by the senior author for clinical use, has a minimum sensitivity of 25 EPG. By use of the McMaster method, all of these horses would theoretically have had negative results of fecal examinations. This skewed distribution of FECs, combined with high degrees of anthelmintic resistance and frequent deworming, suggests that parasite control is being neglected severely in some horses, whereas many other horses are being treated much more frequently than necessary. Leaving horses with low FECs untreated will have little impact on overall nematode control, but the small numbers of eggs shed will greatly dilute the contribution to pasture contamination made by treated horses that may be shedding eggs produced by drug-selected worms. Such an approach will succeed in reducing selection pressure for resistance while improving overall parasite control. Because this will require a fresh view toward parasite control as well as diagnostic capabilities, the only way this treatment scheme can be successful is by having veterinarians once again take an active and leading role in designing and monitoring the effectiveness of parasite control programs.

There is no absolute cutoff in FEC that can be used to determine whether a horse needs treatment or not. This will change on the basis of season, stocking rates, age of horse, overall health of horse, and tolerance of the owner. Additionally, it is important to remember that nonlarrycidial treatments only remove the intraluminal parasites, which are considered far less pathogenic than the larval mucosal stages. Thus, the ultimate goal of cyathostome control in horses is to prevent future infections by minimizing egg shedding onto pasture. In response to the question “At what FEC value should you treat a horse?,” 7 equine parasitologists gave answers ranging from 200 to 500 EPG.26 The FECs do not directly correlate with luminal worm burdens, but it is very unlikely that horses with FECs < 200 EPG will have ill effects from those infections. Assuming an equivalent fecal output of all horses in this study, horses with an FEC of ≥ 300 EPG accounted for 88% of total egg output, yet made up only 31% of the population. This result was not surprising and conforms to a typical pattern of overdispersion seen in nematode infections in grazing animals, whereby a small percentage of the animals harbor most of the parasites.26-28 Applying a more intensive treatment regimen to these high-FEC animals and treating the others as needed will greatly reduce pasture contamination with infective larvae and substantially improve overall cyathostome control while reducing total treatments and achieving the goal of maximizing refugia.

The high prevalence of multiple-drug resistance on horse farms demands that the efficacy of anthelmintics be tested routinely. Presently, this can be done only by performing a small on-farm clinical trial on the basis of FECR. The common practice of rotating drugs with each treatment does not appear to slow the development of resistance,29 and because cyathostomes are pathogens that predominantly cause subclinical disease, rotation of effective drugs with ineffective drugs will likely mask the clinical impact of using drugs with moderate to poor efficacy. As a result, horse owners, stable managers, and veterinarians are almost always unaware of the drug resistance problem. As an alternative to rotation with each treatment, it has been recommended by some parasitologists to perform annual (slow) rotation, whereby a single anthelmintic is used for an entire year and a second drug is used the next.30 However, because available anthelmintics lack broad-spectrum activity against all types of parasites, this approach may fail to control other important parasites such as bots or tapeworms. Given this fact and the present high prevalence of resistance in cyathostomes, this approach can no longer be recommended broadly. Instead, drugs should be selected on the basis of a number of considerations that take into account efficacy against a variety of different parasites as well as time of the year.

It is important to remember that oxibendazole and pyrantel pamoate are still effective on many farms and that these drugs should continue to be
used where they remain efficacious. Nonetheless, data from this study clearly indicate that avermectin-milbemycin anthelmintics will remain the cornerstone of chemical control programs. Because ivermectin and moxidectin cannot be expected to remain effective forever and there are presently no new anthelmintic classes in the later stages of pharmaceutical development, strategies must be implemented to decelerate further selection for drug resistance to prolong the effective lifespan of this drug class. Given this situation (ie, the frequently encountered no-parasite goal of horse owners), the objective to treat horses frequently enough to keep FEC near 0 year-round clearly is not sustainable. If one accepts that ivermectin and moxidectin will not remain effective indefinitely, the horse industry must be prepared to modify the current nematode parasite control paradigm to help preserve the efficacy of these drugs. During the past few decades, the ready availability of safe, effective, inexpensive, and easily administered anthelmintics to horse owners has led to an important decrease in parasitological involvement in parasite control. This trend must change, and veterinarians need to become more involved in developing and monitoring parasite control programs because the growing problem of anthelmintic resistance will only worsen in the future.

References


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