Summary

Resistance of gastrointestinal nematodes (GIN) to anthelmintics and a need for nonchemical control of GIN necessitates investigation of alternative control methods. This study examined the efficacy of garlic juice (99.5 percent pure) (G), copper oxide wire particles (COWP), levamisole (L), moxidectin (M), a combination treatment of COWP and G (CG), and no treatment (C) for GIN control in lactating Boer x Kiko does. Treatments were administered at d 0 and the G treatment was repeated every 7 d throughout the 28 d study. Mixed-model procedures for repeated measures were used to evaluate the effect of treatment and date of sampling on fecal-egg counts (FEC), and percent-packed-cell volume (PCV). Larval cultures from fecal samples at d 0 contained H. contortus, but Teladorsagia and Trichostrongylus were the predominant parasites. There was no difference ($P > 0.05$) in FEC or PCV of does due to GIN-control method. The PCV was greater ($P < 0.05$) at d 0 (31.2 percent ± 0.7 percent) when compared to d 7 (29.1 percent ± 0.7 percent), d 14 (28.7 percent ± 1.1 percent), and d 21 (28.8 percent ± 0.8 percent). The PCV at d 28 (23.5 percent ± 0.9 percent) was lower ($P < 0.001$) than all other sampling d. The FEC did not differ ($P > 0.05$) at d 0 (756 eggs/g ± 414 eggs/g), d 7 (1349 eggs/g ± 448 eggs/g), and d 14 (1782 eggs/g ± 436 eggs/g). The FEC at d 21 (2259 eggs/g ± 464 eggs/g) was trending ($P = 0.08$) higher as compared to d 0. The FEC at d 28 (3935 eggs/g ± 449 eggs/g) was greater ($P < 0.05$) than FEC at all other sampling d. Trichostrongylus and Teladorsagia were the primary GIN species and not H. contortus as is often assumed at the research and farm level. These data support determining which GIN species are present in a goat herd at various times of the year and applying an internal-parasite-management protocol accordingly. Treatments used in this study were not effective in controlling any of the GIN species present.

Key Words: Goat, Parasitism, Garlic, Copper Wire, Anthelmintic
Introduction

The small-ruminant industry has relied heavily on the use of conventional anthelmintics to control gastrointestinal nematodes (GIN), resulting in increased levels of parasite resistance and a search for alternate methods of control. Some alternatives to traditional anthelmintics include pasture- and grazing-management techniques, feeding condensed tannins, dosing with copper oxide wire particles (COWP), and garlic.

Some of the pasture- and grazing-management techniques include mixed species grazing (Marley et al., 2006) and pasture rotation (Barger et al. 1994). Min et al. (2004) concluded that sericea lespedea, a forage high in condensed tannins, effectively reduced fecal-egg production from GIN.

Several authors have reported using copper oxide wire particles (COWP) to control GIN in small ruminants. Burke et al. (2007) researched the effectiveness and safety of COWP in sheep using 0 g, 0.5 g, 0.75 g, 1 g, or 2 g boluses. It was found that administration of a 2 g bolus was effective in preventing a rise in fecal-egg counts (FEC). Similarly, Soli et al. (2010) concluded that a 2 g COWP bolus administered to sheep and goats significantly reduced FEC compared with control 12 days after administration. A later study by Burke et al. (2009) found conflicting results. That experiment involved the administration of a 1 g COWP bolus in 90-d-old kids. Results showed an increase in FEC over time and no decrease due to COWP.

Garlic is thought to have anti-parasitic, immune-boosting, and anti-helminthic properties (Schmidt, 1973; Guarrera, 1999). There have been conflicting results in use of garlic to decrease the parasitic load in small ruminants. Noon et al. (2003) showed reduced levels of Haemonchus contortus, when all groups were treated with garlic on the last week of the study. Although the data were not statistically analyzed, some small-ruminant producers look to it to validate their use of garlic for GIN control. In a later experiment, Wang et al. (2008) studied feeding Spanish wethers a hay-based diet for four weeks at maintenance level of intake with or without 2 percent of garlic powder. They reported that continual feeding of garlic powder reduced FEC. It was attributed to cell-mediated immunity. In contrast, O’Brien et al. (2009) evaluated a single administration of 4.54 grams of garlic juice in goats and found that a single dose of garlic juice was not effective in reducing FEC. In Burke et al. (2009), three treatment groups, garlic juice, garlic bulbs, and a water-dosed control were evaluated. Results from their study showed that a one-time dosage of garlic juice tended to reduce the mean FEC compared to the control by d 7, but FEC were similar on d 14 regardless of treatment.

The objective of this experiment was to determine the effectiveness of garlic alone, COWP, COWP and garlic, levamisole, and moxidectin against GIN in Boer x Kiko goats. Fecal egg counts (FEC), percent-packed-cell volume (PCV), and fecal cultures were used as indicators of GIN parasitism.

Materials and Methods

The Purdue University Animal Care and Use Committee (PACUC) reviewed and approved all experimental procedures used in this study. The research was conducted at the Purdue University Southern Indiana Agriculture Center (SIPAC) located near Dubois, Ind., U.S.A.

Mature (3- to 5-year-old) Boer x Kiko cross does were used in a five-week study (June - July 2010). Does kidded on pasture in May and were lactating throughout the study. Does were placed on the kidding pasture in late April. The kidding pasture was predominately a forage base of Kentucky 31 tall fescue (Festuca arundinacea) and had been grazed consistently by goats for the previous five years. After kidding, does and kids were then moved to a pasture containing predominately annual ryegrass (Lolium multiflorum) from late May to early June (May 28, to June 4, 2010) which had been grazed by goats the previous two springs. The goats were then returned to the Kentucky 31 tall fescue pasture just prior to the study (June 4, to June 8, 2010). Does were grazed on these two pastures for a total of 50 days, of which 42 of these days were on the fescue pasture. This amount of grazing time should have resulted in ample opportunity for natural infection of the goats by GIN. A summary timeline of events follows: treat goats (June 9, 2010; d 0); graze fescue pasture (d -4 to d 0); graze ryegrass pasture (d -11 to d -5); and graze fescue pasture (d -50 to d -12).

Once the study began, does were housed in an open-sided, concrete-floored barn without access to pasture for the duration of the study. A total mixed ration of 2/3 soyl hulls and 1/3 chopped hay was fed at a rate of 1.8 kg per day for each doe. Does had access to clean water and free-choice mineral.

Does (n = 8/treatment) were assigned randomly by age and number of kids to be treated (June 9, 2010) with 12 ml of garlic juice (1:1 dilution with 6 ml 99.3 percent formula Garlic Barrier and 6 ml of water, according to label directions), 2-gram copper oxide wire particles (COWP), levamisole (12 mg/kg orally, moxidectin (0.2 mg/kg injectable), or a combination treatment of garlic juice (1:1 dilution of 99.3 percent formula Garlic Barrier) and COWP (2-gram bolus). Dosages for levamisole and moxidectin were administered in accordance with the American Consortium for Small Ruminant Parasite Control (ACSRPC) dosing guidelines. All treatments were administered once at the beginning of the study on day 0. The garlic-treatment groups were dosed every 7 d in order to further test the decreased FEC results of the garlic-juice-treatment group as reported by Burke et al. (2009).

Blood was collected from the jugular vein weekly to determine packed-cell-volume (PCV). If PCV scores dropped below 18 percent, the animals were removed from the study. Fecal samples were collected per rectum every 7 d for fecal egg count (FEC) analysis by a modified McMaster technique sensitive to 50 eggs per gram (Whitlock, 1948). Extra fecal samples were collected on d 0, d 14, and d 28 for a pooled culture to recover nematode larvae analyzed at Louisiana State University. Larvae were recovered from cultures using the Baermann procedure. On d 0 and d 28 does were weighed and a body condition score (BCS) was determined using a system of 1 to 5, with 1 being emaciated and 5 being obese.

Data were analyzed using repeated measures by the mixed-models procedure of SAS 9.1 (SAS Institute, Inc., Cary, N.C.). The mathematical model used for PCV, FEC, BW, and BCS included treatment, day, and treatment-by-day interaction. FEC were log trans-
formed and statistical inferences were made on transformed data but untransformed means are presented. Differences among means were considered significant when $P < 0.05$.

### Results and Discussion

An Indiana weather collection station, located at SIPAC, reported temperature and precipitation data to a National Weather Service site located in Louisville, Kentucky. Results are reported in Figure 1 for two months prior to the study (April through May), when natural GIN infection occurred. Compared to long term (30 years), temperatures in these months were slightly higher than the long term; and precipitation was slightly lower in April and slightly higher in May.

Doe BWT and BCS are presented in Table 1. There was no ($P > 0.05$) difference between beginning and ending BWT or beginning and ending BCS due to treatment.

Figure 2 illustrates the effect of sampling and GIN treatment regimen on FEC. Treatment did not affect ($P > 0.05$) the difference in FEC. Sampling d was significant ($P < 0.05$) for FEC. The FEC did not differ ($P > 0.05$) at d 0 (756 eggs/g ± 414 eggs/g), d 7 (1349 eggs/g ± 448 eggs/g), and d 14 (1782 eggs/g ± 436 eggs/g). The FEC at d 21 (2259 eggs/g ± 464 eggs/g) tended ($P = 0.08$) to be higher as compared to d 0. The FEC at d 28 (3935 eggs/g ± 449 eggs/g) was greater ($P < 0.05$) than FEC at all other sampling days.

The PCV data are presented in Figure 3. There was no difference ($P > 0.05$) in PCV of does due to GIN-control treatment. There was a ($P < 0.05$) d effect on PCV results from the does. The PCV was greater ($P < 0.05$) at d 0 (31.2 percent ± 0.7 percent) when compared to d 7 (29.1 percent ± 0.7 percent), d 14 (28.7 percent ± 1.1 percent), and d 21 (28.8 percent ± 0.8 percent). The PCV at d 28 (23.5 percent ± 0.9 percent) was lower ($P < 0.001$) than all other sampling days.

Culture results at d 0 showed that although H. contortus (Figure 4) was present, Teladorsagia and Trichostrongylus were the predominant parasites (Figures

| Table 1. Beginning and ending BWT and BCS for COWP, Control, COWP + Garlic, moxidectin, Garlic, and levamisole. |
|---------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Treatment                       | Beginning |          |          |          | Ending  |          |          |          |
|                                | BWT,kg  | SEM   | BCS\(^1\) | SEM   | BWT,kg  | SEM   | BCS | SEM   |
| COWP                            | 48.2    | 3.8    | 2.3      | 0.22  | 45.7    | 5.3    | 1.9  | 0.31  |
| Control                         | 47.4    | 3.8    | 2.2      | 0.22  | 52.8    | 5.3    | 2.5  | 0.31  |
| COWP + Garlic                   | 48.1    | 3.8    | 2.3      | 0.22  | 46.8    | 5.3    | 1.9  | 0.31  |
| Moxidectin                      | 47.5    | 3.8    | 2.3      | 0.22  | 55.7    | 5.3    | 2.2  | 0.31  |
| Garlic                          | 47.2    | 3.8    | 2.1      | 0.22  | 49.3    | 5.3    | 1.9  | 0.31  |
| Levamisole                      | 47.6    | 3.8    | 2.2      | 0.22  | 47.4    | 5.3    | 1.5  | 0.31  |

\(^1\) BCS = 1 to 5; 1 being emaciated and 5 being obese

Figure 2. Least squared means and standard errors of fecal egg counts (FEC) of ewes treated with nothing (closed square), COWP (shaded square), levamisole (open square), garlic (closed circle), moxidectin (shaded circle), or COWP and garlic (open circle) treated on d 0. There was a significant (P < 0.0001) day effect on FEC.

5 and 6, respectively). At d 28 H. contortus larvae was present at levels below 1 percent.

The FEC increased over time across all treatments and was significantly greater on d 28 due to ineffective control of the Teladorsagia and Trichostrongylus population. The increased numbers of Teladorsagia and Trichostrongylus relative to H. contortus may have been due to the experiment being conducted in the earlier months of summer, with the 50 d infective-grazing period ending in early June. According to O’Connor et al. (2006), optimum temperatures for trichostrongylid parasites from unembryonated egg to L3 stage were 16° C to 30° C for Teladorsagia, 22° C to 33° C for Trichostrongylus, and 25° C to 37° C for H. contortus. The temperature data revealed average temperatures of 15° C in April and 19° C in May at the study site, when the does were grazing and exposed to GIN larvae. These lower environmental temperatures could have resulted in the greater amounts of Trichostrongylus and Teladorsagia seen in the culture results relative to H. contortus. It is clear from the culture results that the predominant egg-laying adults were Teladorsagia and Trichostrongylus, and not H. contortus.

The ineffectiveness of COWP against Teladorsagia and Trichostrongylus is in congruence with an experiment done by Burke et al. (2006). Their study showed similar results with a sustained-release, multi-trace, copper-containing vitamin that was administered to does six weeks before kidding (Burke et al., 2006). The proportion of Trichostrongylus from the culture data increased from 23 percent to 55 percent, while the H. contortus population decreased (Burke et al., 2006). Chartier et al. (2000) concurred, stating that Trichostrongylus appeared to be less affected by COWP than H. contortus.

Although the infections of Teladorsagia and Trichostrongylus did not decrease, Figure 4 shows that the COWP treatment effectively decreased H. contortus 7 d after administration. Burke et al. (2007) used varying dosages of COWP from 0 grams to 2 grams and found that 2 g of COWP was sufficient to reduce H. contortus.

Levamisole has been an effective dewormer in this herd in the past. A fecal-egg-count-reduction test used in the herd in 2009 showed 94 percent efficacy of levamisole, while moxidectin had resistance issues at that time. The resistance to levamisole in this study is not fully understood.

Even though the PCV value of 23.5 percent at d 28 was at the lower limits of a normal range for a lactating doe, the reduction from 28.8 percent at d 21 indicated a modest effect of parasitic infection on PCV. It is possible that lactation was a source of variation in doe-PCV values. However, does at d 28 of the study, when the drop in PCV values occurred, were in the last third of lactation (90-d kid weaning age) and past the peak lactation period. Doe BWT and BCS did not significantly decrease from d 0 to d 28 of the study, indicating nutrition was adequate to support lactation demands.

While lactation could have been a factor, PCV reduction from d 21 to d 28 was more likely due to H. contortus infection. Although the cultured larvae revealed very low numbers of H. contortus, it is possible that the goats became infected with H. contortus late in the pre-grazing period due to lower than optimum environmental temperatures for H. contortus larvae development. If H. contortus was acquired later in the infective grazing period, then the increase in infection was most likely due to maturing larvae not affected by the initial GIN-control treatments. The L4 stage of H. contortus does not shed eggs, but does feed on the blood and can cause anemia. Once development of L4 to immature adult H. contortus occurs, egg production doesn’t initiate for about 14 d, which could explain the lack of H. contortus from the culture results. Anthelmintic treatments at the beginning of the study had no effect on the adult egg-laying Teladorsagia, Tri-
chostrongylus, and possibly the immature larval stages of H. contortus. The lack of efficacy of treatment, particularly if H. contortus larvae were in an immature development stage, could be a function of timing of treatment and not the treatment itself. The garlic-alone treatment was continued every seven d, so timing of treatment would not have been a factor in lack of control of GIN by garlic.

Conclusions

Garlic juice alone, garlic juice and COWP, moxidectin, and levamisole were not effective in controlling GIN in lactating goats as measured by FEC and PCV. COWP was not effective in controlling Trichostrongylus and Teladorsagia, but may have been effective against H. contortus. The predominant, egg-laying-GIN species in this study were Teladorsagia and Trichostrongylus and not H. contortus. PCV results indicated a H. contortus infection, but the culture results did not support this, possibly due to the L4 or non-egg productive stage of H. contortus. The fact that in this specific research herd and during the specific time period the study was performed Trichostrongylus and Teladorsagia were the primary species and not H. contortus, has implications at the farm level and at research stations. These data support the recommended practice of determining which GIN species are present in a goat herd at various times of the year and applying an internal-parasite-management protocol accordingly.

Literature Cited


Figure 5. Fecal culture results with percentages of *Telodorsagia* treated on d 0 with nothing (control; closed square), COWP (shaded square), levamisole (open square), garlic (closed circle), moxidectin (shaded circle), or COWP and garlic (open circle).


