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Analysis of the Major Gastrointestinal Parasites Community in Yili Horses in Zhaosu of Xinjiang, Western China

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Abstract

This investigation shows that is possible to determine fecundity and species composition of the gastrointestinal community in Yili horses and analyse the possible relationships with intestinal parasites using sex, age, and management strategy. A total of 118 of the 124 sampled horses were infested with oxyurids, ascaridids, Spiruridae, Anoplocephalidae, Gasterophilus, large strongyles (strongylids), and small strongyles (cyathostomins: cyathostomes). Adults and/or larvae from two strongylid and 11 cyathostomin species were identified, with the following proportions of oveall parasite abundance (as eggs per gram of faeces; EPG) in Yili horses: Strongylus equinus 82.26%, Strongylus edentatus 23.39%, Cyathostomum coronatum 34.68%, Cyathostomum subcoronatum 18.55%, Cylicostephanus longibursatus 56.45%, Cylicostephanus calicatus 75.81%, Cylicocyclus radiatum 3.23%, Cylicocyclus nassatus 72.58%, Cylicocyclus ultrajectinus 3.23%, Cylicocyclus elongatum 6.45%, Cylicodontophorus bicoronatum 8.87%, Cylicodontophorus euproctus 13.71%, Cylicodontophorus pateratum 23.39%. Significant differences in the prevalence of separate strongylid species or their proportions in the community were not observed between females and males or between age groups ($p > 0.05$). Young horses (< 3 years old) had more severe infections of P. equorum and Oxyuris equi. Free-ranging horses were more infected with S. equinus, O. equi, T. equi, and G. intestinalis than horses under other management strategies. The optimum treatment interval may vary depending on a range of factors, including the type of pasture, grazing practices, stocking density, time of the year, and climatic conditions. An EPG > 200 is the main deworming objective.

Keywords: Horse infection; EPG values; Yili horses; Strongylidae; cyathostomes; gastrointestinal parasites

Introduction

Gastrointestinal parasites are an important factor affecting the health of horses, as a severe infection can cause mortality. Therefore, evaluating the occurrence (prevalence and intensity) of intestinal parasites in reserve and stabled groups is important to prevent a health hazard. Horses are parasitised by more than 90 different helminth species [1]. The communities of intestinal helminths are commonly studied post-mortem in horses using autopsy methods [2,3]. However, it has become more important to judge the change in the parasite populations in animals using the drug deworming method. Host sex, age, and location may influence the infection and cause variations in the faecal egg count [4,5], which is an essential tool for quantifying gastrointestinal helminth burden and has been demonstrated to provide a reliable estimate of individual parasite burden in a range of host species [6,7].

Yili horses have been bred through long-term hybridization under herd-rearing conditions. The Yili horse is based on the Kazakh horse and is crossed with Russian Orlov, Don, and Budyonny breeds as well as the Turkmen Akhal-Teke horses to produce one or two generations of hybrid horses [8]. Several previous studies that monitored the gastrointestinal parasite community of Yili horses from different reserves have indicated high levels of infections with intestinal parasites, particularly with strongylids, which reach infection levels estimated to be thousands of eggs per gram of faeces before anthelmintic treatment [8,9]. Although anthelmintic treatment significantly reduces the burden levels of intestinal parasites, regular treatments before moving the horses to new locations are not routinely practiced in Xinjiang, China. Therefore, parasites may spread into new territories [8,9,10]. Xinjiang Province is one of the main horse industrial localities in China. The gastrointestinal parasitic fauna of Yili horses has been investigated among free-living horses as well as those living under natural and stabled conditions in Zhaosu, west of Xinjiang [8,9]. However, the study area was limited to one study farm location and no comparative analysis was conducted on differences in parasite infection rates. Our knowledge of the influences of various internal and external factors, such as age, sex, and management strategy, on the gastrointestinal parasitic community remains limited.

The current study examined the species composition of the gastrointestinal parasite community in Xinjiang Yili horses following deworming with an anti-parasitic drug. Special analysis of the Gasterophilus community structure in the horses was also conducted.

Materials and Methods

Study areas

Our study was carried out on three farms with different management strategies in the Zhaosu region of Xinjiang: the Stallion farm (N 43°02′25.03″, E 80°58′48.44″, altitude 1702–1919 m), the Research Breeding Centre of Yili horses (N 42°48′41.27″, E 80°48′38.22″, altitude 1638–2036 m), and an army horse farm (N 43°06′6.92″, E 81°0′35.00″, altitude 1679–1691 m).

Experimental design

A total of 124 Yili horses (96 females and 28 males) were included in this study between January and December 2019. Background information, such as age, sex, breed, condition, and source of the horses was collected where possible. According to the different management strategies, all horses were divided into three groups: Stabled (ST) horses (n = 42), Semi-Free (SF) horses (n = 42), and Free-Ranging (FR) horses (n = 40) (Table 1). All horses were divided into three age groups: foals and horses < 3 years old (n = 46), horses 3–10 years old (n = 48), and older horses > 10 years old (n = 230) (Table 1). Twenty-nine horses were killed, and 95 horses were dewormed at a local knackery and examined for the presence of gastrointestinal parasites. We administered oral ivermectin (2006 Good Manufacturing Practices for Veterinary Medicine No. 278) to Yili horses at a dosage of 0.1 g aversectin preparation per kg body weight. All horses had natural parasite infections and had not been treated with any anthelmintic for at least 8 months before the study began.

Table 1: Classification of horse conditions.

Categories		Number of horses	Proportion (%)
Sex	Female	96	77.42
	Male	28	22.58
Management strategies	Stabled horses (ST)	42	33.87
	Semi-free horses (SF)	42	33.87
	Free-ranging horses (FR)	40	32.26
Age groups	< 3 years	46	37.10
	3–10 years	48	38.71
	> 10 years	30	24.19
Acquisition mode	Slaughtered	29	23.39
	De-wormed	95	76.61

Post-mortem examination

The gastrointestinal tract, including the mesenteric arteries, was removed from each horse immediately after death. The gastrointestinal tract was divided into the stomach, small intestine caecum, ventral colon, dorsal colon, and small colon. Each section was opened separately, the contents were removed, and the mucosa was washed with water. Each subsample was washed through a 4-mm aperture mesh screen, collected on a 0.25-mm mesh, and stored in 70% ethanol at 4°C until further examination. Subsamples were examined at low magnification, and all parasites were removed and counted. The number of larvae found in each section was recorded and total larval burdens were estimated using conversion factors (×10 for the caecum and ×40 for the ventral and dorsal colon). Larvae were identified by a veterinary parasitologist on the faculty of Beijing Forestry University. Gasterophilus larvae were collected and counted for 4 days in all faecal samples of each horse after administering ivermectin.

Faecal worm egg counts and parasitological examinations

The level of infection with gastrointestinal parasites was determined by mean egg output counted as eggs per gram (EPG) using the McMaster method [11]). Fresh faecal samples were collected from the rectum of every horse or from the ground. Faecal sampling for expelled parasites was performed 24, 36, 48, and 60 h after treatment. The samples were washed with tap water and examined for adult and larval helminths under a stereomicroscope [12]. All helminths and protozoa collected were identified under a light microscope according to identification keys using morphological criteria [1,13,14,15]. All helminths were

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fixed in 4% formalin solution in physiological saline, clarified in 80% phenol-glycerine solution and identified under a Amplival light microscope (Carl Zeiss Inc., Jena, Germany). The Gasterophilus larvae were washed in saline (0.9% NaCl) and identified under a stereomicroscope (Leica MZ75 or Olympus-SZ4045TR) with a magnification range of 10–40×. The Gasterophilus larvae were identified morphologically based on the peritreme structure and the arrangement of spines on the surface of the segments using the descriptions of Zumpt (1965). The larvae were stored in 100% ethanol after identification.

Statistical analysis

The data were analysed using the Kruskal-Wallis test according to the horse breed. SPSS version 22 (SPSS Inc., Chicago, IL, USA) was used. The confidence level was 95% and the results were considered significant at a P-value < 0.05.

Results

The frequency of infection with gastrointestinal parasites is shown in Table 2. Parasites were found in 118 of the 124 horses (95.16%). Twenty-nine species of parasites were identified in this study; 17 were strongyles, including 11 small strongyles (cyathostomins: cyathostomes) and six species of large strongyle (strongylids). In addition, four species of Gasterophilus, two species of Anoplocephala and two species of Habronema were found in this study. One each of Oxyuris, Parascaris, Draschia, and Trichodectes parasites were found. Intestinal Strongylidae and Cyathostominae were the most abundant groups of parasites found in Yili horses in this study.

Strongylidae EPG values were determined for 121 of the 124 horses and the large strongyles Triodontophorus serratus and Triodontophorus tenuicollis were detected in 10 and 23 horses, respectively. The 11 species of Cyathostominae identified included four species each of the genera Cyathostomum, Cylicocyclus, Cylicodontophorus, and Cylicostephanus (Table 3). After administering the anthelmintic or dissection, 5506 larvae or adult parasites were obtained. The distribution of Cyathostominae species allowed us to separate the core species (prevalence > 50%) from the satellite species (prevalence < 50%). Three species were identified as core species, including Cylicocyclus nassatus, Cylicostephanus calicatus, and Cylicostephanus longibursatus. Specimens containing these three species were more numerous among the samples collected; the mean intensity of C. nassatus was 563 (72.58%), that of C. calicatus was 584 (75.81%), and that of C. longibursatus was 435 (56.45%). Eight species were identified as satellites and their mean intensities were as follows: Cyathostomum coronatum 266 (34.68%), Cylicodntophorus pateratum 181 (23.39%), Cyathostomum subcoronatum 143 (18.55%), Cylicodontophorus euproctus 106 (13.71%), Cylicodontophorus bicoronatum 69 (8.87%), Cylicocyclus elongatum 50 (6.45%), Cylicocyclus radiatum 25 (3.23%), and Cylicocyclus ultrajectinus 25 (3.23%) (Table 3).

A coprological examination of the Yili horses showed that Strongylus equinus comprised the highest proportion in the parasite community (%) at all farms, as 86.28% of horses were infected with Strongylidae. Eggs of Parascaris equorum were detected in 27.42% of horses, and Oxyuris equi was detected in 2.42% (Table 3). Eggs of Anoplocephala and Spiruridae were not observed in the faecal samples examined. Eggs of S. equinus, Strongylus vulgaris, Strongylus edentatus, Strongylus westeri, T. serratus, and T. tenuicollis were detected in 85.48%, 81.45%, 11.90%, 12.10%, 8.06%, and 18.55% of horses, respectively. An analysis of the results revealed dependences of level of intestinal helminth infection with (EPG value) with sex, age, and management strategy (Table 3). Young horses (< 3 years old) had significantly higher levels of P. equorum infection than older horses (P < 0.05). On the Stallion and army horse-breeding farms where horses were ST and FR, all FR horses had much higher levels of S. equinus infection (mean EPG = 232.49 ± 43.8) than ST horses (mean EPG = 189.57 ± 35.1). The level of S. equinus infection was significantly higher in females (mean EPG = 145.6 ± 37.5) than in males (mean EPG = 102.8 ± 14.7) (P < 0 .05). No significant differences in the levels of the infections caused by T. serratus, P. equorum, S. vulgaris, or S. westeri were observed between the sexes or management strategies (P > 0.05). No significant differences in S. westeri, S. equinus, S. vulgaris, or T. serratus egg counts (EPG) were observed among horses from the three age groups (P > 0.05) (Table 3). The mean EPG values of S. equinus, S. vulgaris, and P. equorum were 609, 404, and 136, respectively. S. equinus and S. vulgaris were the dominant species and had high infection rates. P. equorum was in the middle and T. serratus and O. equi infection rates were relatively low.

The prevalence rates of P. equorum, O. equi, and Trichodectes equi after diagnostic deworming and post-mortem examination were 86.29%, 46.77%, and 16.94%, respectively. Young horses (< 3 years old) had significantly higher levels of infection with these three parasites than older horses (P < 0.05). The proportions of O. equi, Gasterophilus intestinalis, and T. equi in the community were 1.42%, 11.93%, and 2.36%, respectively (P < 0.05). The level of G. intestinalis infection was significantly higher in FR than in ST (P < 0 .05), and the proportions of O. equi and T. equi were significantly higher in ST than in FR (P < 0 .05). The parasite infection interval was divided into three classes according to the difference in EPG infection prevalence.

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Table 2: *Common internal and external parasites in Yili horses.*

Family	Genus	Species	Aliases
Anoplocephalidae	*Anoplocephala*	*A. magna*	Tapeworms/ Cestodes
		A. perfoliata	
Strongylidae	*Strongylus* (*Strongylus* Mueller, 1780)	*S. equinus*	Large strongyles
		S. edentatus	
		S. westeri	
		S. vulgaris	
	Triodontophorus (*Triodontophorus* Looss, 1902)	*T. serratus*	
		T. tenuicollis	
Cyathostominae	*Cyathostomum* (*Cyathostomum* Molin, 1861 Hartwich, 1986)	*C. coronatum*	Small strongyles (cyathostomins, cyathostomes)
		C. subcoronatum	
	Cylicostephanus (*Cylicostephanus* Ihle, 1922)	*C. longibursatus*	
		C. calicatus	
	Cylicocyclus (*Cylicocyclus* Ihle, 1922)	*C. radiatum*	
		C. nassatus	
		C. ultrajetinus	
		C. elongatum	
	Cylicodontophorus (*Cylicodontophorus* Ihle, 1922)	*C. bicoronatum*	
		C. euproctus	
		C. pateratum	
Oxyuridae	*Oxyuris*	*O. equi*	Pinworms
Ascarididae	*Parascaris*	*P. equorom*	Ascarids/Large roundworms
Spiruridae	*Draschia*	*D. megastoma*	——
	Habronema	*H. muscae*	——
		H. megastoma	——
Gasterophilinae	*Gasterophilus* (*Gasterophilus* Zumpt, 1965)	*G. pecorum*	——
		G. intestinalis	——
		G. nasalis	——
		G. haemorrhoidalis	——
Trichodectidae	*Trichodectes*	*T. equi*	——

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Table 3: *Infection status and the dependence of parasites in Yili horses on sex, age, and management strategy: results of the Kruskal-Wallis test (H).*

Species		Prevalence (%)	Infection intensity (Mean ± SD)	Proportion in the community (%)	Sex		Age		Management strategies	
					H	P-value	H	P-value	H	P-value
EPG value data	*P. equorum*	27.42	136 ± 74	9.56	1.79	0.172	14.2	0.005*	4.65	0.091
	S. westeri	12.10	61 ± 11	4.29	0.94	0.375	8.17	0.076	1.58	0.465
	S. equinus	85.48	609 ± 31	42.83	4.62	0.034*	2.65	0.352	32.43	0.0001*
	S. vulgaris	81.45	379 ± 18	28.41	1.48	0.056	16.6	0.059	6.13	0.089
	S. edentatus	12.90	65 ± 4	4.57	1.27	0.094	12.1	0.074	5.58	0.096
	T. tenuicollis	18.55	92 ± 16	6.47	2.46	0.075	10.7	0.099	4.37	0.082
	T. serratus	8.06	42 ± 6	2.95	3.26	0.485	2.22	0.068	21.85	0.654
	O. equi	2.42	13 ± 2	0.91	4.38	0.629	6.97	0.024*	16.64	0.008*
Diagnostic deworming and post-mortem examination data	*S. equinus*	82.26	134 ± 26	2.43	3.28	0.045*	5.58	0.279	10.42	0.039*
	S. edentatus	23.39	38 ± 6	0.69	9.85	0.0615	6.34	0.062	5.25	0.068
	A. magna	55.65	91 ± 14	1.65	6.34	0.635	5.15	0.057	11.38	0.065
	A. perfoliata	45.97	76 ± 15	1.38	2.91	0.088	1.81	0.425	3.65	0.161
	P. equorum	86.29	143 ± 26	2.60	2.35	0.142	5.08	0.024*	4.05	0.157
	O. equi	46.77	78 ± 13	1.42	1.37	0.255	22.2	0.0001*	20.36	0.0003*
	H. muscae	63.71	116 ± 18	2.11	2.41	0.526	0.69	0.728	3.47	0.168
	H. megastoma	71.77	132 ± 44	2.40	3.98	0.074	15.3	0.988	6.64	0.087
	G. pecorum	70.16	129 ± 39	2.34	3.12	0.064	5.38	0.057	10.24	0.058
	G. intestinalis	85.48	657 ± 47	11.93	0.17	0.815	4.56	0.115	15.67	0.0008*
	G. nasalis	96.77	745 ± 38	13.53	2.35	0.085	2.07	0.368	5.12	0.079
	G. haemorrhoidalis	51.61	397 ± 24	7.21	3.68	0.062	3.16	0.254	6.84	0.061
	C. coronatum	34.68	266 ± 21	4.83	5.29	0.247	6.41	0.064	5.87	0.074
	C. subcoronatum	18.55	143 ± 32	2.60	6.34	0.358	5.39	0.582	6.96	0.089
	C. longibursatus	56.45	435 ± 57	7.90	7.84	0.264	6.12	0.641	6.39	0.052
	C. calicatus	75.81	584 ± 39	10.61	6.59	0.158	2.14	0.789	2.12	0.544
	C. radiatum	3.23	25 ± 5	0.45	8.12	0.098	1.27	0.063	1.98	0.322
	C. nassatus	72.58	563 ± 18	10.23	2.38	0.057	4.65	0.074	2.34	0.466
	C. ultrajectinus	3.23	25 ± 3	0.45	3.46	0.069	3.57	0.099	2.46	0.628
	C. elongatum	6.45	50 ± 22	0.91	2.55	0.097	3.85	0.152	2.48	0.671
	C. bicoronatum	8.87	69 ± 12	1.25	3.27	0.485	4.61	0.097	3.15	0.524
	C. euproctus	13.71	106 ± 31	1.93	2.64	0.379	3.74	0.287	3.65	0.349
	C. pateratum	23.39	181 ± 43	3.29	3.39	0.152	4.86	0.389	4.81	0.089
	D. megastoma	25.00	193 ± 16	3.51	2.49	0.984	4.12	0.897	2.17	0.852
	T. equi	16.94	130 ± 21	2.36	3.59	0.068	12.4	0.042*	6.58	0.049*

Table 4: *Different prevalence classes of EPG in Yili horses.*

Categories	EPG (%)(Mean ± SD)		
	0 < EPG < 200	200 < EPG < 800	800 < EPG
Males (M)	46.84 ± 12.15	35.98 ± 10.72	22.19 ± 7.46
Females (F)	56.02 ± 15.28	37.69 ± 11.43	6.54 ± 1.15
Stabled horses (ST)	36.29 ± 8.64	32.32 ± 10.89	31.39 ± 12.68
Semi-free horses (SF)	46.58 ± 11.16	45.32 ± 10.24	8.10 ± 2.18*
Free-ranging horses (FR)	60.24 ± 16.47	33.42 ± 9.45	6.34 ± 1.95*
< 3 years	35.42 ± 12.42	36.38 ± 15.85	28.2 ± 9.48
3–10 years	40.25 ± 17.54	35.43 ± 15.19	24.32 ± 11.21
> 10 years	43.15 ± 10.67	36.24 ± 12.47	20.61 ± 6.85

*Note: * significant difference (P < 0.05).*

Apparent differences in the gastrointestinal parasite community structures were observed between horses from different management strategies, ages, and sexes (Table 4).

Male Yili horses (22.19 ± 7.46 years) appeared to have a higher infection intensity range than females (6.54 ± 1.15) (EPG > 800), but no significant difference was found (P > 0.05). The SF and FR horses had significantly higher prevalences (EPG < 800) of gastrointestinal parasite species and their proportions in the community were higher than in ST horses (P < 0.05). No significant differences in the three levels (0 < EPG < 200, 200 < EPG < 800, and 800 < EPG) of infection were found in ST horses (P > 0.05). No significant differences in the three levels were observed in any of the age groups (P > 0.05).

Discussion

The prevalence of parasites (95.16%) in Yili horses was higher than previously reported in equines from Lesotho (88.2%) [16], Nicaragua (94%) [17], and Ethiopia (69.4%) [18]. The high prevalence observed in the current study may have been due to differences in management practices and habitat between the current horse population and those previously studied. In our study, H. muscae was recorded in 63.71% of infected Yili horses, while previously it was recorded in 56.67% of horses [8], 55–90% of donkeys [19], 2–72% of horses [19,20], or 0.7% of horses [21]. These data indicate that the distribution of this parasite among horses worldwide is quite serious, and also reflects the wide distribution of the intermediate host in China. The disease is associated with seasons when flies are abundant, and lesions commonly regress during the winter in temperate climates.

Draschia megastoma is maintained in the environment by muscid flies, which act as intermediate hosts [22]. In the present study, D. megastoma was reported in 25% of horses while it was reported in 0.69–47% of donkeys [23,24] and 5–66% of horses [19,20,25]. No other study has recorded D. megastoma in any Equidae group [26]. Clinical signs of parasites vary from mild to severe depending on the developmental stage and localisation site of the parasite. Habronematidosis is responsible for significant economic losses, mostly when sport horses are affected, because their performance is impaired and the infection can be unaesthetic [27]. A significantly higher prevalence of D. megastoma lesions has been observed from late winter through early summer with a second peak in autumn in horses from Western Australia [28]. However, no association could be established between the prevalence of adult D. megastoma and the age of the horses [28].

The prevalence of O. equi in the present study was 46.77% which was higher than the previously recorded prevalence rates of 8.53% [26], 6.4% [29] and 2.5% [30], 7–26% [19,31], 0.4% [9], and 11% [21]. This may be due to the differences in management systems or climatic conditions between the study areas [32]. Additionally, the development of O. equi appears to be favoured by high rainfall, as higher infection rates with adult worms have been observed in horses from areas with uniformly high rainfall rates [19,25]. A low prevalence (12.10%) of S. westeri has been previously reported in Yili horses, but this was still higher than in foals from Queensland (6%) [19]. The limited number of very young foals in this study could be a reason for the reported low prevalence, as most foals become resistant to the infection by 16 weeks of age [19,33]. However, the parasite may be more widespread that recognised, as it is anecdotally regarded as a common parasite in horses from serval regions of the country.

The prevalence of P. equorum (86.29%) was higher than previous rates of 29.26% [26], 17.3% [34], 43% [35], and 27.8% [30] recorded in Hungary and 13.7% [9], 5.3% [21], and 5–58% recorded in Australia [19,36]. This may be due to differences in grazing areas among horses and the lack of awareness of the health of animals. Older horses (> 3 years) were less likely to be diagnosed with P. equorum infection in the current study. It is widely acknowledged that horses develop age-related immunity to P. equorum, making infection a problem only for younger horses [37,38], with maximum ascarid egg shedding reported in foals [39]. However, several studies have reported the lack of a relationship between age and P. equorum infection in working horses [16] and donkeys [40,41]. Differences in infection patterns between horses in developed and developing countries could be due to compromised immunity as a result of underlying disease or malnutrition [16]. Higher prevalence rates are observed during summer,

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in paddocked rather than ST horses [19], and in males compared to gelding and female horses [25].

The EPG prevalence (proportion in the community) of large strongyles (89.52%) fell between the proportions of 99.5% [26], 96.77% [29], 92% [43], 53.8% [9], and 44.7% [21] cited in previous studies. These differences might be due to differences in the climate, agroecological conditions, variations in sample size, or different sampling methods [32]. In addition, horses might be neglected in these areas and receiving less attention from their owners [44]. Large strongyle infection is common in grazing horses, as daily access to pasture for 30 days before parasitological examination is associated with a greater risk of egg shedding [45]. By contrast, horses that are stall managed with limited access to pasture are at a reduced risk of developing large strongyle infection [46]. Management practices of ST Yili horses in the study area have been previously reported and showed no access to pasture grazing and limited contact between horses [8,9], which could explain why most horses had low infection intensities in the current study. The prevalence of large strongyle infection varied significantly in Zhaosu. This may have been caused by differences in availability of veterinary services, horse owners' knowledge about the importance of preventive veterinary care, type of anthelmintic commonly used, or other unknown factors between the study areas. Some studies have shown no associations between the variations in site preference and age, sex, horse breed, or the environment [19,21,25,47]. However, significant differences in the level of horse infections by S. equinus between sexes and management strategies were found in the present study ($P < 0.05$). At the same time, this study also found that seasonal variations may affect the distribution of parasites at different sites, and there could be an increase in the proportion of parasites in regions anterior or posterior to the preferred site during a particular season. This result has been confirmed by related research [19].

More than 50 species of cyathostomins have been recognised [48] and 10 species are most prevalent. The mean number of cyathostomin species expelled per horse was 11 (> 10) in this study. This result corresponds with those obtained in studies in Ukraine [1], Poland [49], the United States [50], Australia [19,25], Ethiopia [41], Sweden [51], and Britain [47]. The important epidemiological risk factors for cyathostomin infection are age, season, and time since last deworming [52]. Interestingly, access to grazing and shared grazing with other horses were only weakly associated with cyathostominosis. More than 90% of the cyathostomin burden may be in the mucosa at specific times of the year, as they are not affected by anthelmintic treatments [53,54,55,56]. A remarkable similarity in the predominant species is observed, regardless of geography. For example, C. calicatus, C. nassatus and C. longibursatus are among the most prevalent species in France, Ukraine, the United States, Brazil, and Australia. The results of this study are in good agreement with those findings. Other species that were not recognised in this study included Cylicostephanus minutus and Cylicocyclus insigne. No associations were found between horse age and the prevalence rates of cyathostomins or large strongyles, including S. vulgaris, S. westeri, and S. edentatus. This result is consistent with a previous study [57]. By contrast, cyathostomins showed an increasing worm burden with age, peaking in 2–7-year-old horses and decreasing in older horses [28]. Intensive anthelmintic use in the last few decades has led to a lower frequency of large strongyle infections in many places, whereas infections with small strongyles (cyathostomins) have increased. This seems to be because small strongyles have become resistant to many anthelmintics, whereas large strongyles have not. Horses that have been exposed to small strongyle infections may acquire resistance, but rather slowly and often not to the point that they become immune. Damage may be less dramatic but still causes clinical signs as the horse will continue shedding eggs and contaminating the pasture [14]. This is particularly significant for the transmission of worms to young foals through infective larvae produced by their mothers in shared pastures. Cyathostominae are the most relevant horse strongyles, mainly due to the diversity of genera and species, prepatent periods, host specificity, and biological cycles with hypobiotic larval stages.

Four species of Gasterophilus were identified, with the following proportions of overall parasite abundance: Gasterophilus pecorum 2.34%, Gasterophilus nasalis 13.53%, Gasterophilus haemorrhoidalis 7.21%, and G. intestinalis 11.93%. Furthermore, the 96.77% occurrence rate of Gasterophilus spp. larvae in this study exceeded previously reported rates of 9.9% [58], 2.25% [59], 0.72% [60], 28.57% [61], 43% [62], 53% [63], 85.90% [64], 86.60% [65], and 95.2% [66] but was lower than the 98.3% [67] and 100% [67,68,69] occurrence rates of several other studies. The widespread prevalence of G. nasalis and G. intestinalis in the present examination was similar to previous investigations [25,50,70]. G. nasalis and G. intestinalis were the most abundant Gasterophilus spp. in Yili horses in Zhaosu, which differed from studies in other regions of Xinjiang, China (Kalamaili Nature Reserve, KNR) where it was reported that G. pecorum is the most abundant species [71,72]. The oviposition site selection behaviour and genetic diversity of G. pecorum provide better opportunities for successfully infesting a suitable host after hatching and reduce the chance of offspring dying due to the lack of a host, explaining why it is the dominant species in the KNR

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[69,72]. The difference in Gasterophilus infection rates between Zhaosu and the KNR region may be related to habitat differences. The Zhaosu region is a humid climate of Alpine meadows, whereas the KNR region is an arid desert steppe climate.

Helminth parasites were generally more frequently found in females than in males, possibly because males are less exposed to infection because they tend to be more solitary [73]. In addition, female horses have higher infestation rates because they have lower immunity due to gestation, lactation, and stress during those times [42]. It is assumed that sex is a determining factor influencing the prevalence of parasitism [74].

Conclusion

Strongyles are considered the most important parasites of equids due to their wide distribution, prevalence, and pathogenicity. The number of parasitic eggs increased during early spring when the weather became warm, and then decreased during summer and autumn. Therefore, surface temperature and sunlight played a decisive role in the infection and transmission of parasite eggs. We recommend that large local horse farmers in Zhaosu deworm their horses between January and March (before spring) of each year. Annual or seasonal rotation or a combination of insecticides is recommended to avoid resistance and achieve better integrated control. At the same time, it is suggested that the EPG test should be carried out before deworming. We conclude that deworming is required if the EPG is > 200 in horses.

Patents

Author Contributions: S.-H. Liu contributed to the study design. X.-Z. Fan was responsible for study execution, data analysis and interpretation and preparation of the manuscript. Conceptualization: Li Kai; Data curation: Hu Defu; Investigation: Hu Defu; Methodology: name; Project administration: Li Kai; Resources:Li Kai. All authors gave their final approval of the manuscript.

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Institutional Review Board Statement: All study procedures were conducted after informing each participating horse's owner of all the procedures and products involved, and after owners voluntarily signed informed consent for participation of their horse. All study procedures were performed without harming any of the participating animals.

Informed Consent Statement: Not applicable

Data Availability Statement: The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

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Conflicts of Interest

The authors declare no conflict of interest.

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