



Factors influencing regional epidemiology of strongyle nematodes at organized sheep farms in Rajasthan

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ABSTRACT

A study was conducted to observe the influence of year, season, month, breed, age and sex on epidemiology of strongyle nematodes in different sheep breeds managed at organised farms in arid and semi-arid Rajasthan by evaluating 14,030 fresh faecal samples (from April 2016 to March 2019). The overall incidence of strongyle worms was significantly higher (74.1%) in semi-arid as compared to 27.4% in arid region. Among breeds, it varied from 25.6% in Magra to 74.8% in Malpura sheep. The effect of year was significant on regional as well breed-wise incidence. Season had significant effect on regional incidence with maximum incidence during monsoon. A significant breed variation in overall and seasonal incidence was found only in arid region. Irrespective of sheep breed, significantly higher incidence of strongyle worms was observed in adult sheep in both the regions. Male had significantly higher incidence of strongyle worms in both the regions. The effect of agro-climatic region was significant on overall intensity of strongyle worms with mean FECs of 117.8 ± 3.7 epg in arid and 1098.9 ± 45.2 epg in semi-arid region. Breed-wise, the effect of year on intensity of strongyle nematodes was significant in arid region only. Seasonal intensity was significantly higher during monsoon season in both the agro-climatic regions and in all the breeds. Effect of age on overall intensity of infection was also significant in both the regions with higher mean FECs in adult animals as compared to young ones. In both the regions, males possessed higher FECs as compared to females. On coproculture, *Haemonchus contortus*, *Trichostrongylus* sp and *Oesophagostomum* sp were recovered with maximum (71.1 \pm 2.1%) mean annual proportion of *H. contortus*. Availability of infective larvae of GI nematodes on herbage was observed during monsoon and extended up to post-monsoon season in semi-arid region. Comparatively higher herbage infectivity was not noticed in semi-arid farm with a peak of $2,100.0 \pm 97.9$ L₃/kg dry matter of herbage in September. The study suggest a marked influence of agro-climatic region on epidemiology and dynamics of strongyle nematodes in sheep flocks and on pasture. The breed variation was evident only in arid conditions. Further, the magnitude of monthly intensity of strongyle infection in arid region suggested anthelmintics intervention through targeted selective approach instead of strategic en-mass drench.

Keywords: Age, Breed, Gastrointestinal nematodes, Herbage, Rajasthan, Region, Season, Sex, Sheep

Gastrointestinal nematodes particularly *Haemonchus contortus* has a high fecundity and is a debilitating blood-sucking parasite in the abomasum causing significant production losses through severe chronic anemia, anorexia, loss of condition and eventual death of the affected animals. It is estimated that the costs of diseases generally may be as high as 35–50% of turnover within the livestock sector in developing countries (Bishop 2012). In addition, a rampant escalation for anthelmintic resistance in nematodes and high selection pressure due to limited classes of anthelmintics for use, the chemotherapeutic control of GINs in sheep has become less effective (Swarnkar and Singh 2012). Under these situations, it is imperative to reduce selection pressure by minimizing the use of anthelmintics based on level of resistance or resilience of sheep breeds of locality in question.

In organized farms of Rajasthan, Singh and Swarnkar (2014) observed the lowest susceptibility of Garole and its crosses followed by Malpura, Chokla, Kheri and the highest susceptibility in crossbreds in semi-arid while lowest susceptibility in Nali followed by Marwari, Chokla, Rambouillet crosses and the highest susceptibility in exotic sheep in arid region. Further, the climate change will probably lead to changes in epidemiology and intensity of parasite infections (van Dijk *et al.* 2010). Thus, a study was conducted to observe the influence of different factors on epidemiology of strongyle nematodes (predominated by *H. contortus*) in different sheep breeds managed at organised farms in arid and semi-arid agro-climatic conditions of Rajasthan.

MATERIALS AND METHODS

Animals and study area: The sheep breeds were maintained either in arid region at Arid Region Campus

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(ARC), Bikaner (Marwari, Magra and Chokla) or in semi-arid climate at ICAR-Central Sheep and Wool Research Institute (ICAR-CSWRI), Avikanagar, Rajasthan (Malpura and Avikalin (Rambouillet × Malpura)). All the sheep were raised under semi-intensive management system. Prophylactic health measures against enterotoxaemia, sheep pox and *peste des petits ruminants* were practiced in the flocks. For management of GINs, strategic anthelmintic drenches (with an annual rotation of anthelmintic type) were given during mid to late monsoon (early September) as per modified worm management programme (Swarnkar *et al.* 2008).

Climate: From November to April, mean monthly temperature remained relatively low in arid region as compared to semi-arid region. However, with the onset of monsoon a reverse trend was observed. In comparison to semi-arid region, mean monthly maximum temperature was markedly higher in arid region during July to October. Most of the total precipitation (>90%) occurred during June to August in arid and during June to September in semi-arid region. During the study period (2016–19), low and more rainfall occurred in semi-arid and arid region, respectively as compared to normal rainfall. For all the months, relative humidity remained higher in semi-arid region than arid region (Table 1).

Parasitological measurements: From April 2016 to March 2019, all the flocks were randomly screened for GI parasites at monthly interval and 14,030 fresh faecal samples were collected *per rectum*. The samples were evaluated for incidence and intensity (eggs/g of faeces, FEC) of strongyle worms by modified McMaster method (MAFF 1984) using saturated sodium chloride as the flotation fluid. To ascertain the generic composition of strongyle larvae, on each occasion breed wise pooled faecal samples were cultured at 25–28°C for 5–7 days and infective larvae were identified as per Soulsby (1965). At the time of faecal sample collection, herbage samples from grazing area were also collected for estimation of parasite burden as per Martin *et al.* (1990).

Data analysis: The incidence data (arc-sin transformed) were analyzed by cross-tab analysis and tested for

significance using chi-square test. The data on intensity of strongyle infection (\log_{10} FEC + 10) were tested by one-way analysis of variance to observe the effect of season, month, breed, age and sex using SPSS ver 20.

RESULTS AND DISCUSSION

Incidence of strongyle worms: Region-wise, the overall incidence of strongyle worms was significantly ($P < 0.001$) influenced by agro-climatic regions and breeds of sheep. Incidence was higher (74.1%) in semi-arid region as compared to arid region (27.4%). Among breeds, it varied from 25.6% in Magra sheep to 74.8% in Malpura sheep (Table 2). The significant ($P < 0.001$) influence of breed on overall incidence was noticed only in arid region with maximum (30.3%) in Chokla and minimum (25.6%) in Magra breed. The effect of year was significant ($P < 0.05/0.001$) on regional as well breed-wise incidence except for Magra sheep in arid region. In general, incidence of strongyle worms was relatively higher in 2017–18 in both the regions and majority of breeds. In 2017–18, a low precipitation (249 mm in arid and 408 mm in semi-arid) in comparison to other years (310 mm in arid and >475 mm in semi-arid) with decreased biomass availability in grazing area and higher stocking density might be responsible for relatively higher incidence in that year. Further, breed had significant ($P < 0.001$) effect on annual incidence of strongyle worms for all the three years in arid region while only in the year 2018–19 in semi-arid region. Season had significant effect ($P < 0.001$) on regional incidence with maximum incidence during monsoon and attributed to abundance of infective larvae on pasture due to favourable climatic conditions. The seasonal variation was more marked in arid region compared to semi-arid region. A significant ($P < 0.001$) breed variation in seasonal incidence was found only in arid region. A significant ($P < 0.001$) variation in monthly incidence was noticed for all the age and sex groups in all the breeds. In general, the monthly incidence was >50% from July to September in adult male, July to August in adult female, August to September / October in young male and only in August in young female in sheep breeds of arid region (Fig. 1). On the contrary, in

Table 1. Mean (\pm SE) monthly climatic observations in arid and semi-arid Rajasthan during 2016–19

Month	Min. Temperature (°C)		Max. Temperature (°C)		Total Rainfall (mm)		Relative Humidity (%)	
	Arid	Semi-arid	Arid	Semi-arid	Arid	Semi-arid	Arid	Semi-arid
Apr	22.23 \pm 0.34	22.62 \pm 0.28	40.00 \pm 0.44	40.46 \pm 0.25	7.67 \pm 5.70	0.93 \pm 0.74	37.35 \pm 4.00	45.90 \pm 0.72
May	27.41 \pm 0.53	27.13 \pm 0.23	43.37 \pm 0.24	43.05 \pm 0.22	8.27 \pm 5.70	5.53 \pm 3.32	37.70 \pm 5.43	49.05 \pm 0.68
Jun	28.89 \pm 0.87	27.74 \pm 0.28	41.29 \pm 0.85	40.35 \pm 0.39	77.17 \pm 22.94	52.07 \pm 26.19	51.81 \pm 1.57	60.62 \pm 1.10
Jul	28.00 \pm 0.26	26.58 \pm 0.77	38.37 \pm 0.34	33.22 \pm 0.36	108.97 \pm 46.39	177.23 \pm 24.25	64.36 \pm 1.68	77.38 \pm 0.85
Aug	26.43 \pm 0.21	24.73 \pm 0.11	36.20 \pm 0.70	31.80 \pm 0.27	100.70 \pm 29.88	129.40 \pm 45.68	67.40 \pm 3.56	80.76 \pm 0.69
Sep	24.11 \pm 0.10	22.96 \pm 0.12	37.47 \pm 0.48	33.79 \pm 0.38	2.00 \pm 2.00	46.03 \pm 33.9	55.44 \pm 0.78	75.63 \pm 0.80
Oct	18.99 \pm 0.51	18.92 \pm 0.33	37.11 \pm 0.82	35.82 \pm 0.20	9.40 \pm 9.40	5.37 \pm 5.37	42.23 \pm 5.74	62.00 \pm 0.83
Nov	11.29 \pm 0.07	11.57 \pm 0.28	30.94 \pm 0.35	30.13 \pm 0.23	0.73 \pm 0.41	0.00 \pm 0.00	49.77 \pm 1.27	61.06 \pm 0.56
Dec	6.85 \pm 1.19	7.80 \pm 0.30	26.42 \pm 1.36	25.89 \pm 0.79	0.67 \pm 0.67	2.20 \pm 1.82	54.68 \pm 2.04	67.84 \pm 0.58
Jan	5.87 \pm 0.31	6.72 \pm 0.35	22.72 \pm 1.39	23.86 \pm 0.30	1.63 \pm 0.83	4.67 \pm 3.29	62.20 \pm 5.03	69.24 \pm 0.71
Feb	9.13 \pm 0.75	10.58 \pm 0.37	26.97 \pm 1.77	27.92 \pm 0.41	0.00 \pm 0.00	0.83 \pm 0.83	53.07 \pm 3.77	65.34 \pm 0.87
Mar	15.06 \pm 1.04	15.26 \pm 0.38	33.15 \pm 1.42	33.51 \pm 0.46	1.33 \pm 0.29	2.57 \pm 1.29	36.77 \pm 8.96	61.49 \pm 0.93

Table 2. Factor-wise incidence (%) of strongyle nematode infection in different breeds of sheep in Rajasthan

Factor	Region			Breed						
	Arid	Semi-arid	Sig	Arid				Semi-arid		
				Marwari	Magra	Chokla	Sig	Malpura	Avikalin	Sig
Overall	27.4	74.1	**	26.9	25.6	30.3	**	74.8	73.1	NS
<i>Year</i>	**	**		**	NS	**		*	**	
2016-17	25.2	79.2	**	28.2	20.9	23.9	**	77.9	80.8	NS
2017-18	33.5	79.5	**	36.0	25.5	34.7	**	80.7	77.9	NS
2018-19	25.5	64.2	**	20.9	31.2	33.9	**	66.6	60.3	**
<i>Season</i>	**	**		**	**	**		**	NS	
Summer	10.2	70.9	**	8.8	11.9	12.0	**	71.2	76.4	NS
Monsoon	50.8	78.4	**	49.8	48.6	55.1	**	79.9	76.4	NS
Winter	20.8	72.8	**	22.7	14.9	21.7	**	74.0	71.1	NS
<i>Age</i>	*	**		**	**	NS		NS	NS	
Young	19.6	65.8	**	19.5	14.3	32.6	**	65.8	65.8	NS
Adult	29.4	77.0	**	29.7	28.0	30.1	NS	77.5	76.3	NS
<i>Sex</i>	**	**		NS	NS	**		**	**	
Male	32.0	79.0	**	30.8	26.4	39.5	**	80.1	77.3	NS
Female	25.2	70.5	**	25.3	25.2	25.1	NS	70.7	70.2	NS

**, Significant ($P < 0.001$); NS, non-significant ($P > 0.05$)

sheep breeds of semi-arid region, it was $>70\%$ from April/ May to December/January in adult sheep and from August to November in young sheep (Fig. 2). The variation among monthly incidence pattern in two agro-climatic conditions could be reflection of level of herbage infectivity, type and timing of anthelmintic used as well as amount and timing of precipitation.

Irrespective of sheep breed, significantly ($P < 0.05/0.001$) higher incidence of strongyle worms was observed in adult sheep in both the regions. However, on breed basis, the effect of age was significant only in Marwari and Magra

breeds reared in arid Rajasthan with significant ($P < 0.001$) breed effect in incidence of strongyle worms in young sheep only. Irrespective of breed, male had significantly ($P < 0.001$) higher incidence of strongyle worms in both the regions. However, on breed basis, the effect of sex was non-significant for Marwari and Magra breeds. Further among sex, significant ($P < 0.001$) effect of breed was observed only in male sheep of arid region only.

Intensity of strongyle worms: The effect of agro-climatic region was significant ($P < 0.001$) on overall intensity of strongyle worms with mean FECs of 117.8 ± 3.7 epg in arid

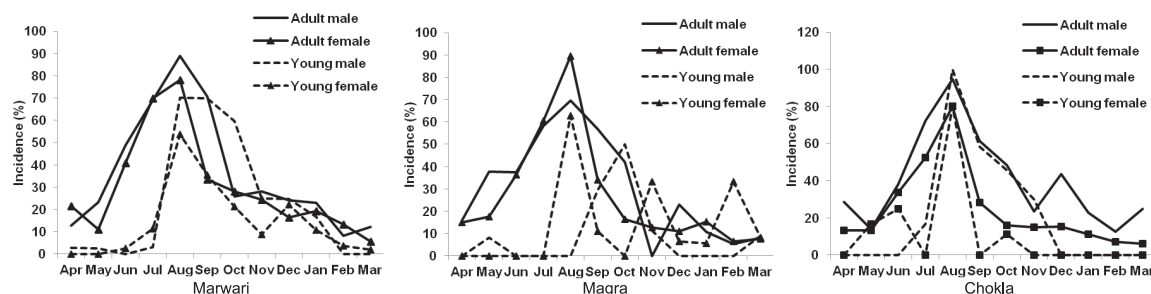


Fig. 1. Monthly incidence (%) of strongyle infection in sheep of arid Rajasthan.

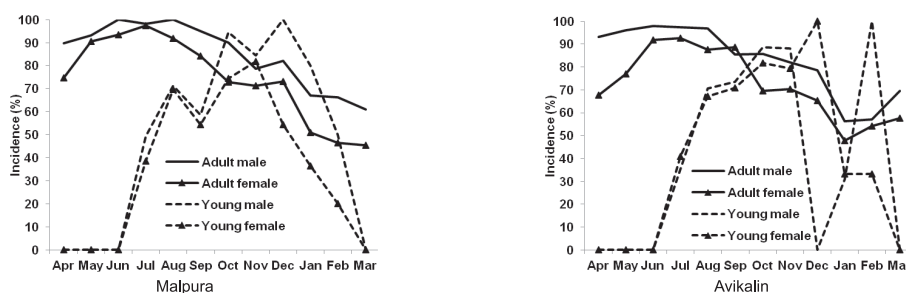


Fig. 2. Monthly incidence (%) of strongyle infection in sheep of semi-arid Rajasthan.

Table 3. Factor-wise intensity (mean \pm SE) of strongyle nematode infection in sheep of Rajasthan

Factor	Region			Breed						
	Arid	Semi-arid	Sig	Arid				Semi-arid		
				Marwari	Magra	Chokla	Sig	Malpura	Avikalin	Sig
Overall	117.8 \pm 3.7	1098.9 \pm 45.2	**	113.2 \pm 4.8 ^a	110.6 \pm 7.1 ^a	135.5 \pm 8.8 ^b	*	1050.2 \pm 49.4	1167.4 \pm 83.7	NS
<i>Year</i>	**	NS		**	**	**		NS	NS	
2016-17	107.0 \pm 5.6 ^A	1203.8 \pm 76.5	**	131.0 \pm 9.2 ^{bB}	88.6 \pm 9.8 ^{aA}	79.4 \pm 8.1 ^{aA}	**	1095.8 \pm 98.0	1340.3 \pm 120.9	NS
2017-18	137.5 \pm 7.9 ^B	1129.3 \pm 57.7	**	159.0 \pm 12.2 ^{bC}	83.4 \pm 9.8 ^{aA}	138.0 \pm 15.2 ^{bB}	**	1100.2 \pm 74.5	1168.0 \pm 91.0	NS
2018-19	115.0 \pm 6.0 ^A	983.5 \pm 96.4	**	74.4 \pm 5.0 ^{aA}	154.7 \pm 15.0 ^{bB}	200.9 \pm 21.2 ^{cC}	**	967.3 \pm 86.6	1009.4 \pm 209.5	NS
<i>Season</i>	**	**		**	**	**		**	**	
Summer	17.5 \pm 1.5 ^A	360.5 \pm 16.4 ^A	**	12.7 \pm 1.3 ^{aA}	29.1 \pm 5.7 ^{bB}	17.9 \pm 2.4 ^{aA}	**	322.8 \pm 19.2 ^A	417.2 \pm 29.0 ^A	NS
Monsoon	289.6 \pm 10.1 ^C	2102.6 \pm 110.7 ^B	**	282.9 \pm 13.6 ^{abC}	268.0 \pm 18.4 ^{aA}	325.0 \pm 23.4 ^{bC}	*	2079.7 \pm 122.5 ^B	2131.8 \pm 197.8 ^B	NS
Winter	48.1 \pm 2.4 ^B	557.1 \pm 26.7 ^A	**	54.6 \pm 3.5 ^{bB}	27.9 \pm 3.3 ^{aB}	51.5 \pm 5.2 ^{bB}	**	541.3 \pm 32.9 ^A	580.5 \pm 44.8 ^A	NS
<i>Age</i>	**	**		**	**	NS		**	**	
Young	64.6 \pm 4.9	817.8 \pm 55.3	**	65.8 \pm 5.6 ^{ab}	50.1 \pm 13.3 ^a	86.4 \pm 13.3 ^b	*	741.3 \pm 64.6	899.6 \pm 91.1	NS
Adult	131.5 \pm 4.4	1198.4 \pm 57.9	**	131.0 \pm 6.2	123.4 \pm 8.1	139.6 \pm 9.4	NS	1143.1 \pm 61.1	1284.2 \pm 113.4	NS
<i>Sex</i>	**	**		**	NS	**		**	NS	
Male	131.8 \pm 6.2	1269.5 \pm 60.9	**	120.7 \pm 8.3 ^a	105.1 \pm 10.8 ^a	177.4 \pm 14.6 ^b	**	1252.5 \pm 81.3	1294.9 \pm 91.2	NS
Female	111.2 \pm 4.5	973.7 \pm 64.3	**	110.0 \pm 5.8	113.5 \pm 9.2	111.7 \pm 10.9	NS	895.5 \pm 60.7	1079.2 \pm 126.8	NS

*, Significant (P<0.05); **, Significant (P<0.001); NS, Non-significant (P>0.05); Means with different superscripts differ significantly from each other in a row (small letter) and column (capital letter).

and 1098.9 \pm 45.2 epg in semi-arid region (Table 3). A significant (P<0.05) influence of breed on overall intensity was noticed only in arid region and varied from 110.6 \pm 7.1 epg (Magra) to 135.5 \pm 8.8 (Chokla). The effect of year on intensity of strongyle nematodes was significant (P<0.001) in arid but non-significant in semi-arid region. Breed-wise analysis exhibited that effect of year was significant (P<0.001) only in breeds maintained in arid region. Like-wise within a year, the intensity of strongyle infection differed significantly among breeds only in arid region as contrast to non-significant variation among breeds in semi-arid region.

Seasonal intensity was significantly (P<0.001) higher during monsoon season in both the agro-climatic regions (289.6 \pm 10.1 epg in arid and 2102.6 \pm 110.7 epg in semi-arid) and in all the breeds (from 268.0 \pm 18.4 epg in Magra to 2131.8 \pm 197.8 epg in Avikalin). Within season the breed variation in intensity of infection was significant for all the three seasons in arid region only. The monthly magnitude of FECs showed significant (P<0.001) monthly variation in all the breeds with a single peak of infection in August (arid) or September (semi-arid). For all the months, a higher intensity was observed in semi-arid region as compared to arid region (Figs. 3 and 4). All the three breeds in arid region

possessed significantly (P<0.001) lower FECs (110.6 \pm 7.1 to 135.5 \pm 8.8 epg) as compared to both the breeds in semi-arid region (1050.2 \pm 49.4 to 1167.4 \pm 83.7 epg). Further, in semi-arid region, higher intensity of infection was expressed by crossbred Avikalin sheep as compared to native Malpura.

Effect of age on overall intensity of infection was also significant (P<0.001) in both the regions for all the breeds except Chokla in arid region with higher mean FECs in adult animals (>1 yr old) as compared to young one (<1 yr old). Region-wise, it was 131.5 \pm 4.4 epg and 1198.4 \pm 57.9 epg in adult animals and 64.6 \pm 4.9 epg and 817.8 \pm 55.3 epg in young animals of arid and semi-arid region, respectively (Table 3). Breed-wise, in adult animals, the overall intensity of infection ranged from 123.4 \pm 8.1 epg in Magra to 1284.2 \pm 113.4 epg in Avikalin. A significant (P<0.001) effect of sex on intensity of strongyle infection was observed in all the breeds except Magra and Avikalin sheep. In both the regions male possessed higher FECs as compared to female.

In India, the coprological studies revealed an annual prevalence of GINs ranging from 40 to 95% with maximum incidence during monsoon depending upon the year and location of the study area (Sharma *et al.* 2007, Wani *et al.* 2011). Swarnkar *et al.* (2008) observed that in Rajasthan

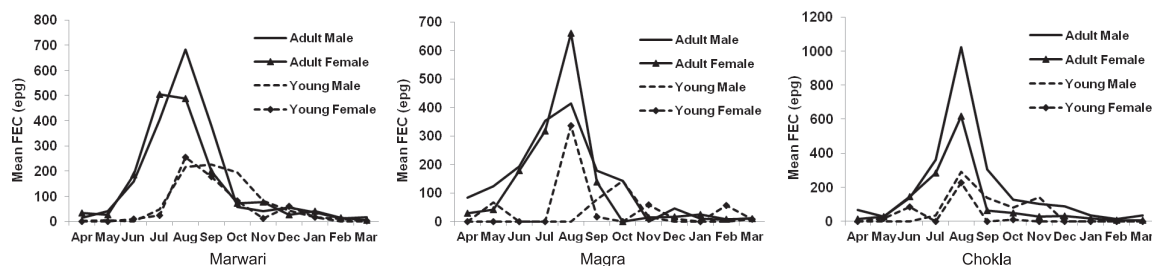


Fig. 3. Monthly mean intensity of strongyle infection in sheep of arid Rajasthan.

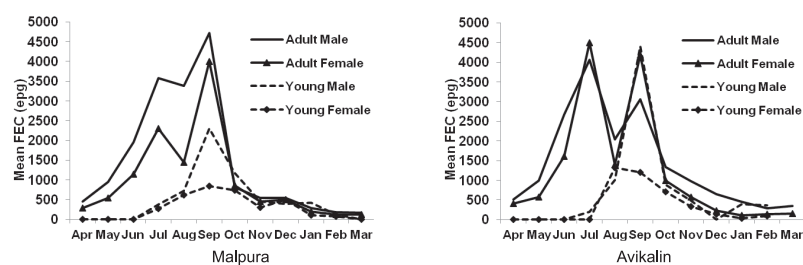


Fig. 4. Monthly mean intensity of strongyle infection in sheep of semi-arid Rajasthan.

among farm flocks, the incidence was higher (>65%) from May to November in semi-arid region and from July to November and April in arid region. Evidence for breed variation in resistance to GINs (particularly *H. contortus*) has been extensively documented in sheep (Amarante *et al.* 2004, Golding and Small 2009, Getachew *et al.* 2015). Similar to present findings, Singh and Swarnkar (2014) from Rajasthan and Nimbkar *et al.* (2003) from Maharashtra also reported significant effect of breed on monthly incidence of strongyle infection. Non-significant differences were also observed among breeds reared in same agro-climatic region and attributed to natural selection and adaptation of sheep breeds in particular climate (Idris *et al.* 2012). It is well documented that gastrointestinal parasitism in grazing animals is directly related to the availability of larvae on pasture and seasonal pasture contamination. Based on bioclimatograph, the occurrence of favourable conditions for translation of exogenous stages of *H. contortus* were reported from late-June / July to mid-August / September in arid and from early June to mid-September in semi-arid Rajasthan (Singh *et al.* 2018). This regional difference explains the occurrence of more conducive environment for prolonged period in semi-arid than arid region.

Similar to present findings, Wani *et al.* (2011) also reported lower incidence in young animals compared to adult animals. On the other hand, non-significant effect of age on GINs was also reported from Ethiopia (Yonas and Goa 2017) and Kenya (Waruiru *et al.* 2005). However, our findings were not in agreement with the findings Zvinorova *et al.* (2016) who reported that young animals are more susceptible to parasitic infections than older ones. Relatively low incidence in young sheep (particularly during summer) could be due to fact that majority of young animals start to graze on pasture during summer and not exposed to infection due to absence of infective larvae on pasture (Singh *et al.* 2018). On the contrary, in adult animals, around

40% incidence during summer season could be attributed to resumption of development of hypobiotic larvae and relaxation of immunity due to lactational, nutritional and summer stress (Swarnkar and Singh 2015, 2018).

In accordance with present findings, Badaso and Addis (2015) also reported significantly higher infectivity in males due to immunosuppressive effect of androgen. However, Zvinorova *et al.* (2016) and Yonas and Goa (2017) reported no effect of sex on prevalence of strongyle infection and attributed to equal exposure of both sexes to the same grazing pasture in similar agro-ecology. Like-wise, Bashir *et al.* (2012), Emiru *et al.* (2013) and Singh *et al.* (2017) reported higher prevalence of GIT parasites in females than in males and attributed to their lowered resistance due to reproductive events and insufficient /unbalanced diet against higher needs.

In general, the initial rising trend in FECs occurred in June probably due to resumption of development of hypobiotic worms within the host, giving peak of infection in July and provide the source of pasture contamination during monsoon (Swarnkar and Singh 2018). The decline in FEC in the following months may be due spontaneous occurrence of self-cure phenomenon following acquisition of fresh wave of infection from pasture and expulsion of old worms (Singh *et al.* 2018). In farm flocks of semi-arid region, high FECs occurred from late May to early September in adult sheep and from August to early November in young sheep (Singh *et al.* 1997). During monsoon, maximum intensity of strongyle infection was also reported from different parts of India (Yadav *et al.* 2006, Shankar *et al.* 2010, Sutar and Khan 2011, Singh *et al.* 2017). The present results are in agreement with other studies which showed that rainfall, relative humidity and presence of green vegetation are important factors in determining level of FECs (Keyyu *et al.* 2005, Sissay *et al.* 2007).

Table 4. Annual and seasonal (% mean \pm SE) of strongyle larvae on coproculture in different breeds of Rajasthan

Factor	<i>Haemonchus contortus</i>				<i>Trichostrongylus</i> sp				<i>Oesophagostomum</i> sp			
	Annual	Seasonal			Annual	Seasonal			Annual	Seasonal		
		S	M	W		S	M	W		S	M	W
Overall	71.1 ± 2.1	56.8 ± 4.1	83.1 ± 2.6	67.2 ± 3.7	13.5 ± 1.3	18.4 ± 2.7	9.2 ± 2.0	14.5 ± 2.2	15.4 ± 1.4	24.8 ± 3.2	7.7 ± 1.4	17.9 ± 2.8
<i>Region</i>												
Arid	82.6 ± 2.4	72.6 ± 6.0	89.7 ± 2.2	81.5 ± 4.3	2.9 ± 0.9	7.6 ± 3.5	0.9 ± 0.3	2.0 ± 0.4	14.5 ± 2.2	19.8 ± 5.5	9.3 ± 2.2	16.7 ± 4.2
Semi-arid	59.5 ± 3.0	42.2 ± 3.7	77.1 ± 4.4	49.3 ± 4.7	24.2 ± 2.0	28.4 ± 2.9	16.7 ± 3.4	31.3 ± 2.8	16.3 ± 1.8	29.4 ± 3.3	6.2 ± 1.7	19.5 ± 3.4
<i>Breed</i>												
Marwari	92.0 ± 2.7	82.0 ± 11.3	94.7 ± 1.7	95.1 ± 1.5	4.0 ± 2.5	13.2 ± 10.7	0.6 ± 0.3	2.0 ± 0.7	4.0 ± 1.1	4.8 ± 2.6	4.7 ± 1.7	2.9 ± 1.5
Magra	76.0 ± 5.1	57.5 ± 12.7	89.9 ± 3.1	72.5 ± 9.4	2.3 ± 0.5	4.3 ± 1.3	1.3 ± 0.7	2.3 ± 0.8	21.7 ± 5.0	38.2 ± 12.9	8.8 ± 3.3	25.3 ± 9.2
Chokla	79.7 ± 3.9	77.7 ± 6.3	84.5 ± 5.4	76.1 ± 7.9	2.4 ± 0.8	5.5 ± 2.8	1.0 ± 0.5	1.7 ± 0.4	18.0 ± 3.9	16.8 ± 7.0	14.5 ± 5.2	22.3 ± 7.9
Malpura	58.2 ± 4.3	39.8 ± 5.5	75.0 ± 6.3	49.9 ± 7.1	26.2 ± 3.0	34.9 ± 4.4	17.3 ± 4.8	33.7 ± 4.7	15.0 ± 2.4	25.3 ± 4.4	7.8 ± 3.0	16.4 ± 4.8
Avikalin	60.9 ± 4.3	44.7 ± 5.1	79.2 ± 6.3	48.6 ± 4.8	21.5 ± 2.6	21.9 ± 3.0	16.2 ± 4.9	28.8 ± 3.2	17.6 ± 2.7	33.4 ± 4.8	4.6 ± 1.7	22.6 ± 4.9

Generic profile of strongyle larvae: On coproculture, only 3 species of strongyle worms namely *Haemonchus contortus*, *Trichostrongylus* sp (both *T. axei* and *T. colubriformis*) and *Oesophagostomum* sp were recovered. Irrespective of agro-climatic region, mean annual proportion of *H. contortus* was significantly ($P < 0.001$) maximum ($71.1 \pm 2.1\%$) followed by *Oesophagostomum* sp ($15.4 \pm 1.4\%$) and *Trichostrongylus* sp ($13.5 \pm 1.3\%$) (Table 4). Seasonal proportion of *H. contortus* was observed to vary significantly ($P < 0.001$) from $56.8 \pm 4.1\%$ in summer to $83.1 \pm 2.6\%$ in monsoon. Significant seasonal variability was also observed for the proportion of *Trichostrongylus* sp ($P < 0.05$) and *Oesophagostomum* sp ($P < 0.001$). Region-wise, the annual proportion of *H. contortus* was higher in arid ($82.6 \pm 2.4\%$) as compared to semi-arid region ($59.5 \pm 3.0\%$), while a reverse trend was observed for *Trichostrongylus* sp. A non-significant variation was observed for annual prevalence of *Oesophagostomum* sp among both the agro-climatic regions. Seasonally, for *H. contortus*, almost similar pattern was evident for all the seasons with least agro-climatic variation during monsoon. The proportion of *Trichostrongylus* sp was higher in semi-arid for all the seasons and of *Oesophagostomum* sp during summer as compared to arid region. Breed-wise annual proportion of *H. contortus* varied from $58.2 \pm 4.3\%$ in Malpura to $92.0 \pm 2.7\%$ in Marwari. Like-wise, annual proportion of *Trichostrongylus* sp and *Oesophagostomum* sp varied from $2.3 \pm 0.5\%$ (Magra) to $26.2 \pm 3.0\%$ (Malpura) and from $4.0 \pm 1.1\%$ (Marwari) to $33.4 \pm 4.8\%$ (Avikalin), respectively. Almost similar breed-wise profile was noticed for seasonal proportion of all the three strongyle larvae.

The monthly profile exhibited that with the onset of monsoon, the proportion of *H. contortus* remained almost

similar in both the agro-climatic regions. The observed regional variations in monthly proportion of strongyle larvae could be attributed to type of anthelmintics used. Within region, sheep breed had no major evident effect on monthly proportions of different strongyle worms (Fig. 5).

The prevalence of strongyle species in an area is directly related to the ability of the pre-parasitic stages to withstand the environmental conditions. From similar agro-climatic conditions, Gupta *et al.* (1987) and Singh *et al.* (2018) also reported availability of *H. contortus*, *Trichostrongylus* and *Oesophagostomum* sp throughout the year with predominance of *H. contortus*. Keyyu *et al.* (2005) and Sissay *et al.* (2007) also observed similar results in African countries with distinct rainy and dry season, where the high biotic potential of *H. contortus* results in this parasite rapidly assuming dominance in times when climatic conditions on pasture are favourable for translation of worms. However, minor variation in proportion of hematophagous and non-hematophagous strongyle larvae occurred depending upon type of anthelmintics (Swarnkar *et al.* 2000).

Herbage larval burden: In grazing areas, an availability of infective larvae of GI nematodes on herbage was observed during monsoon (in both the agro-climatic regions) and observed to extend up to post-monsoon season in semi-arid region (Fig. 6). Comparatively higher herbage infectivity was not noticed in semi-arid farm with a peak of 2100.0 ± 97.9 L₃/kg dry matter of herbage in September.

Data on herbage larval count indicated that rainfall was the most important factor controlling the availability of L₃ on pasture. Consequently large numbers of L₃ were present on herbage only during the rains. The variations in the pasture larval burden under natural conditions might be due to an inequality of the contamination of pasture with

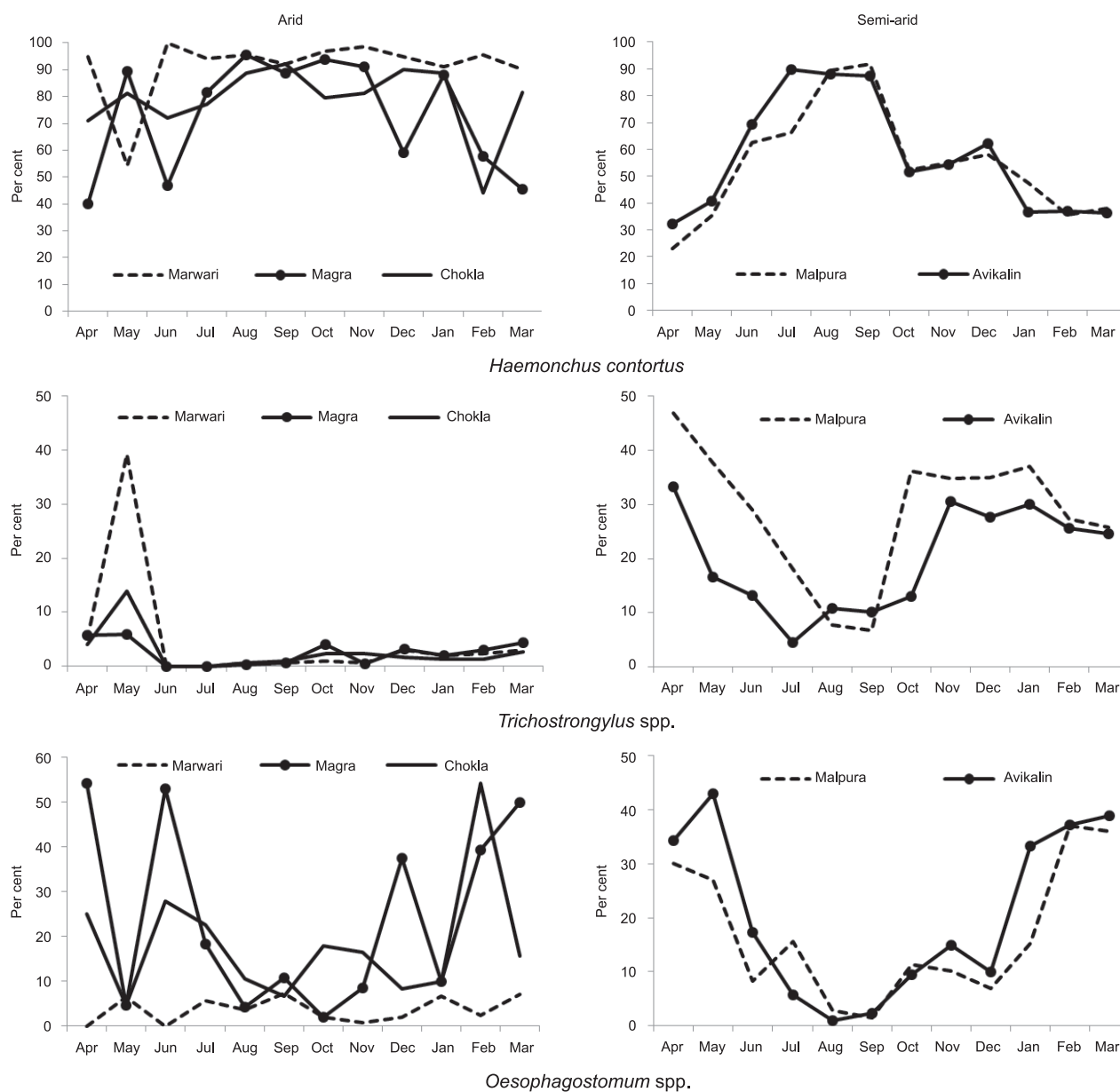


Fig. 5. Average monthly proportion (%) of strongyle larvae (L_3) on coproculture from sheep faeces.

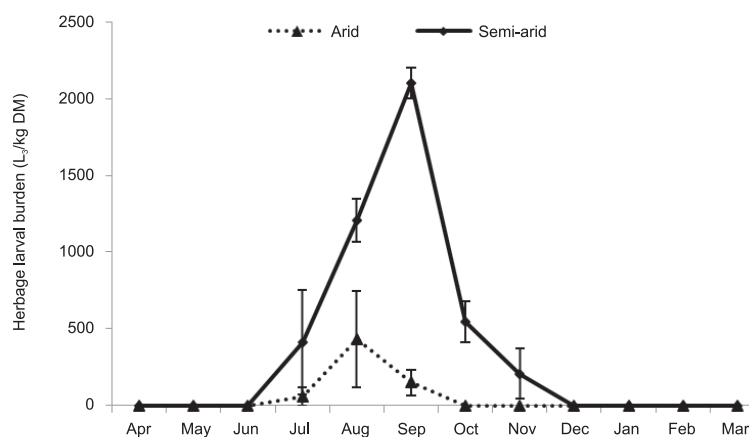


Fig. 6. Mean (\pm SE) herbage larval burden in grazing area of sheep farms in Rajasthan.

infective larvae (Swarnkar *et al.* 2008), seasonal climatic fluctuations (Al-Shaibani *et al.* 2008) and genetic backgrounds of animals (Reeg *et al.* 2005). Similar observations on the availability and abundance of nematode larvae on pasture during monsoon have been made earlier (Dey *et al.* 2008, Singh *et al.* 2018). In dry season, the reduced herbage cover in grazing area might expose the larvae to desiccation, resulting in high mortality.

The study suggested a marked influence of agro-climatic region on epidemiology and dynamics of strongyle nematodes in sheep flocks and on pasture. The breed variation was evident only in arid conditions. The lambing season, favourable climatic conditions for translation of exogenous stages of parasites on pasture and practice of first grazing of young sheep resulted in low incidence and intensity of strongyle worms in them. Irrespective of agro-climatic region, age and sex of animal had similar effect on dynamics of strongyle worms in Rajasthan. Further, the magnitude of monthly intensity of strongyle infection in arid region suggested anthelmintics intervention through targeted selective approach instead of strategic en-mass drench.

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