Indian Journal of Animal Sciences **81** (3): 216–23, March 2011

Role of bioclimatographs in forecasting of strongyle infection in Rajasthan

C P SWARNKAR[1] and D SINGH[2]

Central Sheep and Wool Research Institute, Avikanagar, Rajasthan 304 501 India

Received: 2 June 2009; Accepted: 1 December 2010

ABSTRACT

The present communiqué describes the role of bioclimatographs in forecasting the periods suitable for translation of predominant nematode parasite of sheep (*Haemonchus contortus*) in Rajasthan. Bioclimatographs were useful in predicting the periods that are suitable for translation of exogenous stages of *H. contortus* in both arid and semi-arid environment with resultant peak of infection in host. Further, the study provides the possibility that climatic consideration in combination with grazing practices can be taken into account in evaluating expected level of *refugia* and thus treatments can be avoided at times when *refugia* are likely to be small. Thus, integration of climate and biology of parasite in the form of bioclimatograph may strengthen our tool box in combating the menace caused by gastrointestinal parasites.

Key words: Bioclimatograph, *Haemonchus contortus*, Rajasthan, Sheep, Strongyle worm

Management and epidemiological factors responsible for emergence of anthelmintic resistant strains of parasites in population are complex and not yet fully understood (van Wyk *et al*. 2002, Sanyal 2004). Traditionally the worm control in sheep flocks is typically based on frequent prophylactic treatments (3–5 times a year) without considering the prevailing climate, status of infection in host and on pasture and grazing practices (Anonymous 2004). Further, practices such as shearing of flock and deworming en-mass treatment of flock in face of any disorder, no consideration on prevalent worm species, un-systemized way of anthelmintic treatments in health camps and wrong choice of drug aggravated the problem not only in India but throughout the world (Lloyd *et al*. 2000, O' Meara and Muleahy 2002, Swarnkar *et al.* 2003). The study on interaction between climatic conditions of a particular region, pattern of anthelmintic use and grazing resources for sheep flocks revealed significant fluctuation in resistant and susceptible alleles according to seasons (Swarnkar *et al.* 2006) and suggested possible role of *refugia* in the form of community dilution strategy in reversion to susceptibility in worm population.

In view of challenges in management of worms *vis-a-vis* anthelmintic resistance, now there is a general consensus among researchers to shift prime target from adult parasite in host to exogenous stages in environment with the main aim to break life cycle of parasite. Under such circumstances climate has a major role on development, survival and dissemination of free-living stages of strongyle and so the size of *refugia* varies during different seasons of the year. Hence knowledge of climate and its influence on life cycle of parasite is crucial in formulating the worm management programmes that provide sound protection, minimize use of anthelmintics and slow down the development of anthelmintic resistance as much as possible. Preparation of bioclimatographs through integration of climate and biology of parasite may strengthen our tool box in combating the menace caused by gastrointestinal parasites. The present study was designed to observe the role of bioclimatographs in forecasting the propagation of *H. contortus* (predominant strongyle species) in host and environment to reduce the anthelmintic use by systematizing the worm control programme, maintenance of quantum of *refugia* and thereby sustain anthelmintic efficacy.

MATERIALS AND METHODS

The study was conducted in arid and semi-arid climates of Rajasthan under the ICAR sponsored All India Network Programme on Gastrointestinal Parasitism. The climatic observations in last decade revealed that the annual total rainfall ranged from 310.92 (2002) to 665.64 mm (2004) with an average of 575.16 mm and from 122.88 (2002) to 378.84 mm (2008) with an average of 284.16 mm in semi-arid and arid region, respectively.

Preparation of bioclimatographs: The data pertaining to average maximum temperature, minimum temperature, total monthly rainfall and average relative humidity were obtained for the period from January 2000 to December 2008 from

---

Present address: [1]Scientist (Selection Grade) (e mail: swarnkarcp@yahoo.com), [2]Principal Scientist (e mail: dherindra.singh56@gmail.com), Division of Animal Health.

India Meteorological Department, Jaipur. The data pertains to 10 districts of Rajasthan situated in different regions. These data were also used to characterize the prevailing weather in particular region during different seasons. The total monthly rainfall for each region was plotted against the mean monthly maximum temperature and resultant points were joined by a closed curve. On these graphs a window was overlayed indicating the limits of climatic conditions most favourable for the free-living stages of *H. contortus* (total monthly rainfall to the tune of 50 mm or more with average monthly maximum temperature ranging from 18 to 37 °C). The resultant bioclimatographs were compared with the known incidence of parasites in different localities.

Infectivity in sheep flocks: To record the monthly profile of strongyle infection, field flocks situated in both agroclimatic regions were monitored at regular intervals. During the period from November 2001 to December 2008 a total of 46 064 faecal samples were collected directly per rectum and assessed quantitatively by modified McMaster technique (MAFF 1986). The generic composition of strongyle nematodes was determined through coproculture on each occasion. The intensity for *H. contortus* was determined by taking generic composition of strongyle larvae into consideration.

Pasture larval burden: Representative samples of herbage were taken in 'W' shaped fashion from community grazing land where sheep flocks were taken for grazing. The pasture larval burdens were assessed as per Martin *et al.* (1990).

Analysis: The monthly means for each parameter of climatic and parasitological data were calculated by using SPSS version 15.0.

RESULTS AND DISCUSSION

Climatic characterization of Rajasthan: The climatological observations for the period from 2000 to 2008 were obtained from 10 observatories located in different districts and used for characterization of prevailing climate in both the arid and semi-arid regions of Rajasthan. On the basis of quarterly averages of climatic observations, the prevailing climate during the year varied from cold-humid during December to February to hot-dry (March to May) and hot-humid during June to November (Table 1). Broadly among the 2 regions, major difference was in amount of rainfall from June to November, where semi-arid region received almost double amount of precipitation compared to arid region. The other major variation was noticed in maximum temperature during the period from June to August and in arid region it remained about 4 °C higher than semi-arid region.

Bioclimatographs: These explain the distribution in space and time of larval nematodes on pasture and represent the first rational attempt to utilize climatic observations to explain important features of epidemiology of helminthic diseases. To assess the usefulness of bioclimatographs in prediction

Table 1. Climatological characterization of different zones of Rajasthan

Period	Agroclimatic region	
	Semi-arid	Arid
December - February	Av. minimum temperature - 11.36±0.95 °C Av. maximum temperature – 25.87±1.01 °CTotal monthly rainfall – 4.04±2.73 mmAv. relative humidity – 60.34±2.51 %**Cold-humid** (low temperature, moderate humidity and scanty rainfall)	Av. minimum temperature - 9.65±0.98 °C Av. maximum temperature – 25.49±1.17 °CTotal monthly rainfall – 6.57±3.17 mmAv. relative humidity – 66.33±1.76 %**Cold-humid** (low temperature, high humidity and scanty rainfall)
March - May	Av. minimum temperature - 23.33±2.83 °C Av. maximum temperature – 37.64±2.24 °CTotal monthly rainfall – 10.16±5.10 mmAv. relative humidity – 36.24±3.39 %**Hot-dry** (high temperature, low humidity and scanty rainfall)	Av. minimum temperature - 22.22±2.86 °C Av. maximum temperature – 38.29±2.49 °CTotal monthly rainfall – 11.33±4.04 mmAv. relative humidity – 47.62±3.13 %**Hot-dry** (high temperature, low humidity and scanty rainfall)
June - August	Av. minimum temperature - 26.98±0.55 °C Av. maximum temperature – 34.70±1.97 °CTotal monthly rainfall – 152.93±38.19 mmAv. relative humidity – 71.17±6.86 %**Hot-humid** (high temperature, high humidity and high rainfall)	Av. minimum temperature - 27.25±0.53 °C Av. maximum temperature – 38.25±1.28 °CTotal monthly rainfall – 65.99±11.23 mmAv. relative humidity – 69.71±4.51 %**Hot-humid** (high temperature, high humidity and moderate rainfall)
September - November	Av. minimum temperature - 19.98±2.62 °C Av. maximum temperature – 33.24±1.32 °CTotal monthly rainfall – 24.60±20.39 mmAv. relative humidity – 57.43±6.34 %**Hot-humid** (high temperature, moderate humidity and low rainfall)	Av. minimum temperature - 19.79±3.06 °C Av. maximum temperature – 35.10±1.80 °CTotal monthly rainfall – 10.83±8.47 mmAv. relative humidity – 60.00±5.03 %**Hot-humid** (High temperature, moderate humidity and scanty rainfall)

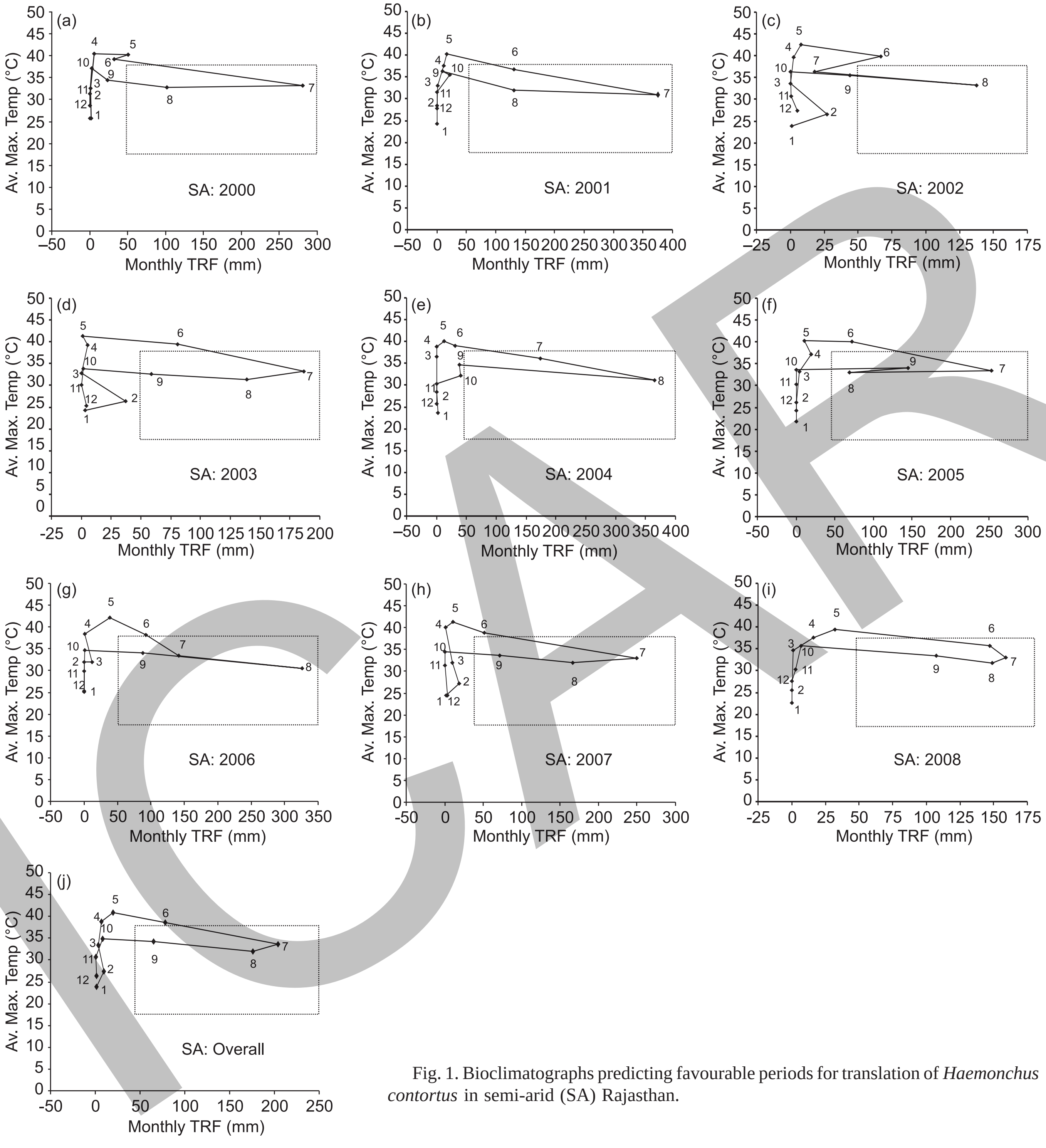

Fig. 1. Bioclimatographs predicting favourable periods for translation of *Haemonchus contortus* in semi-arid (SA) Rajasthan.

of favourable period for translation of *H. contortus* (predominant nematode of sheep in Rajasthan), bioclimatographs were prepared based on the time series data on climate and depicted in Figs 1 and 2. Based on bioclimatograph using data for the period from 2000 to 2008, the period in which climatic conditions suitable for development, survival and dissemination of exogenous stages of *H. contortus* was from June to mid-September in semi-arid (Fig. 1-J) and from late June to mid-August in arid Rajasthan (Fig. 2–J). On comparison of bioclimatographs for different years within similar agro-climatic region, a slight to moderate variation in prediction of suitable period for propagation of *H. contortus* was encountered in both the regions. The year-wise bioclimatographs indicated that in

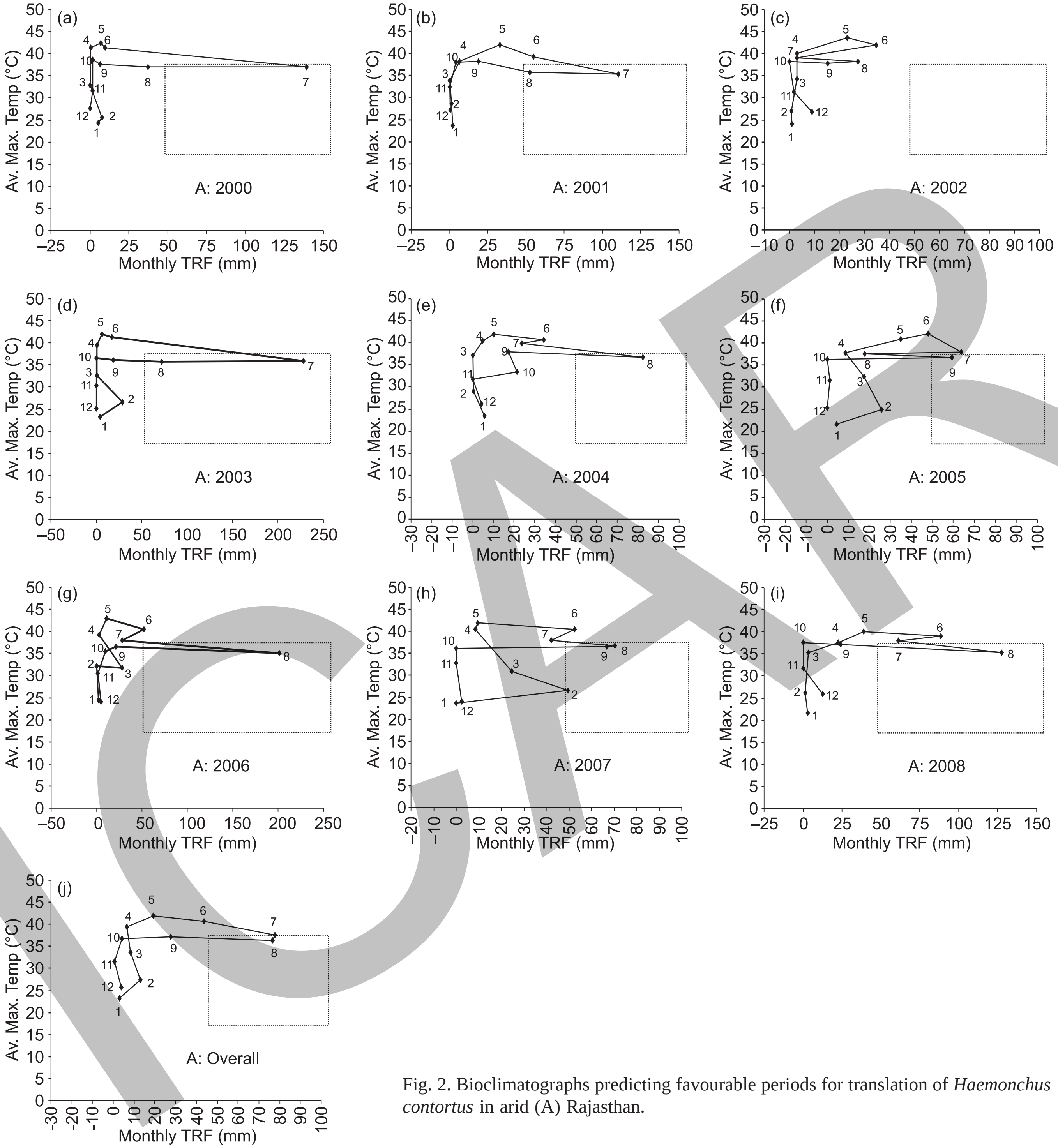

Fig. 2. Bioclimatographs predicting favourable periods for translation of *Haemonchus contortus* in arid (A) Rajasthan.

majority of the years, the onset of favourable climate for *H. contortus* trigger from June with the exception in the year 2001 and 2008 (mid-May) in semi-arid Rajasthan. The termination of favourable climate was usually in the month of September in most of cases except in the year 2000 and 2001. Compared to semi-arid conditions, in arid region, bioclimatographs indicated that initial period favourable for development of *H. contortus* was from mid-July to mid-August in most of the cases except in the year 2005 and 2007 where it extended up to mid-September. According to bioclimatograph there was no favourable season for translation of *H. contortus* in the year 2002 in arid Rajasthan, however larvae were recovered from its pasture on few occasions.

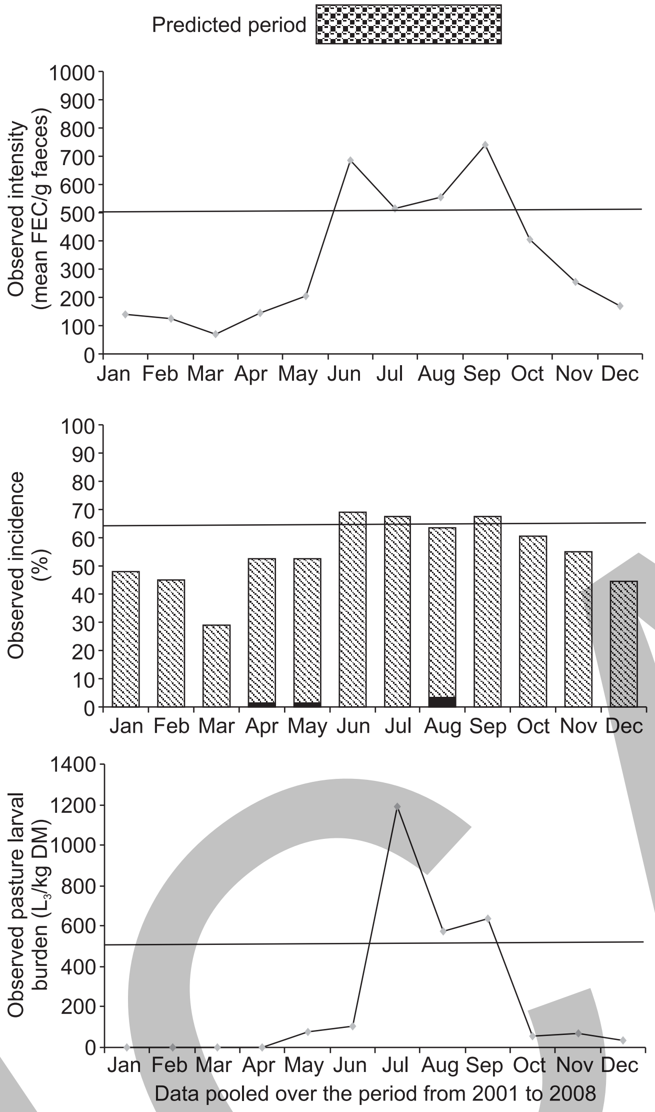

Fig. 3. Comparison of predicted favourable period with real-time profile for *Haemonchus contortus* in semi-arid Rajasthan.

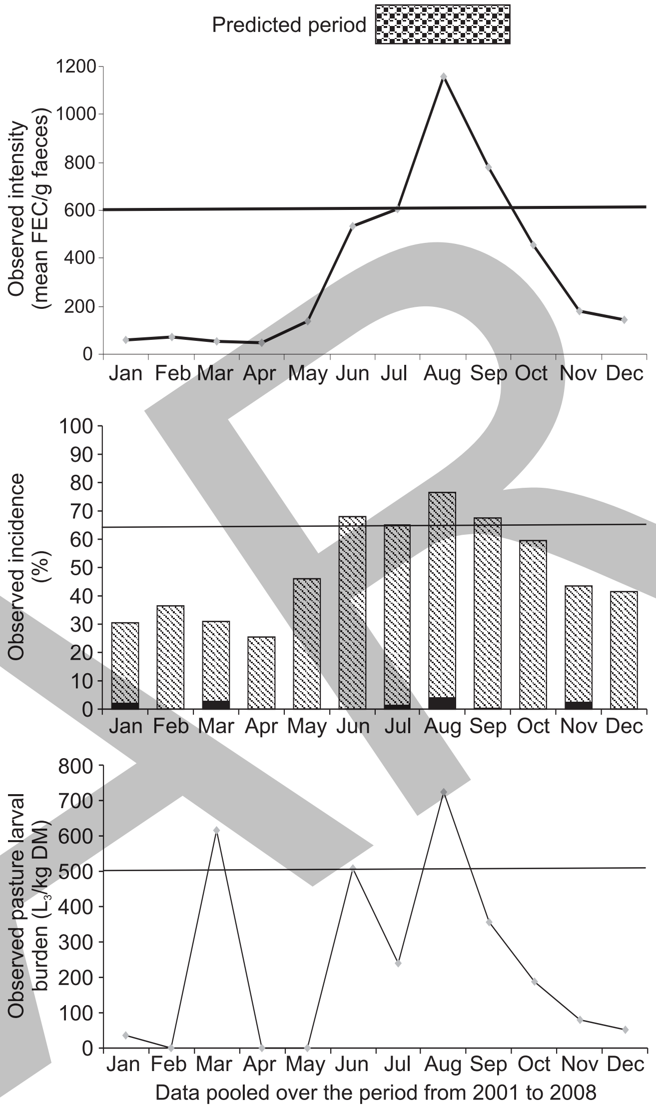

Fig. 4. Comparison of predicted favourable period with real-time profile for *Haemonchus contortus* in arid Rajasthan.

Comparison of predicted response with real-time infectivity with H. contortus: Prediction based on bioclimatograph prepared on long-term basis was fully in agreement with real-time observations made for incidence and intensity of *H. contortus* in sheep flocks as well as translation and availability of exogenous stages on pasture in both the agro-climatic regions of Rajasthan (Figs 3 and 4). However, there were minor variations between predicted and observed responses when compared on annual basis (Table 2).

Initially climatographs were used to observe the effect of temperature and precipitation on development and survival of supra-population of parasites (Gordon 1948) where total precipitation was plotted against the mean monthly maximum temperature for the month and resultant points were joined by a closed curve. On these graphs he superimposed lines indicating the limits of climatic conditions most favourable for the free-living stages of different nematodes and then compared the resultant bioclimatographs with the known incidence of parasites in different localities. These gave valuable information in predicting the general pattern of parasitism to be found in locality in question. In earlier years these were the part of study of the ruminant nematode epidemiology in Australia (Gordon 1950, Forsyth 1953, Puller 1953), Canada (Cameron 1956) and in USA (Levine 1959). Australian workers considered that a total monthly rainfall of 50 mm or more together with a mean monthly maximum temperature above 18.3°C provided optimum conditions for the transmission of *H. contortus* of sheep.

The role of weather and climate in the distribution and prevalence of nematodes are different. Weather is a composition of atmospheric conditions like temperature,

Table 2. Comparison between predicted response and real-time infectivity for *H. contortus*

Year	Predicted favourable period as per bioclimatograph	Observed months		
		Incidence (> 70%)	Intensity (>500 epg)	Pasture infectivity (> 200 L_3/kg DM)
		Semi-arid Rajasthan		
2000	Jun–Aug	ND	ND	ND
2001	May–Aug	ND	ND	ND
2002	July–Sep	Jun–Nov	Jun–Sep	Jun–Nov
2003	Jun–Sep	Jun–Sep	Jun–Sep	Jul–Sep
2004	Jun–Sep	Jul	Jul–Oct	Jul–Sep
2005	Jun–Sep	Aug–Oct	Aug–Oct	Jul–Sep
2006	Jun–Sep	Aug	Jun–Oct	Jul–Aug
2007	Jun–Sep	Aug	Aug	Jul–Sep
2008	May–Sep	Jul	Jul	Jul–Aug
Overall	Jun–Sep	Jun–Sep	Jun–Sep	Jul–Sep
		Arid Rajasthan		
2000	Jun–Jul	ND	ND	ND
2001	Jun–Aug	ND	ND	ND
2002	None	Jun–Sep	Jun–Sep	Jun–Aug
2003	Jun–Aug	Jun–Aug	Jun–Aug	Jun–Oct
2004	Jul–Aug	Aug–Sep	Jul–Oct	Jul–Oct
2005	Jul–Sep	Aug–Oct	Aug–Nov	Jul–Sep
2006	Jul–Aug	Jul–Aug	Jun–Sep	Jul–Sep
2007	Jul–Sep	Aug	Aug–Sep	Aug–Sep
2008	June–Aug	Jul	Jul	Aug–Oct
Overall	Jul–Sep	Jun–Sep	Jun–Sep	Jun–Sep

barometric pressure, precipitation, humidity, wind direction and velocity, sun light, sunshine hours, cloud cover etc at a particular time (Levine 1963). Climate is the sum of weather conditions over a larger period of times. It determines which nematodes are generally found in a locality, while weather determines which one can develop and infect their host at a particular place at a particular time of a particular year. The exogenous phase of life cycle is comprised of two process (i) development of infective larvae and (ii) survival of infective larvae thereafter. The environmental conditions which favour one may not favour the other. Temperature and moisture dominantly influences the free-living stages of strongyle worms with the effects of pasture conditions playing a significant modulating role (O' Conner *et al.* 2006). Dinaburg (1944a, b) studied the effect of climate on the development of ruminant nematode larvae and observed that no *Haemonchus contortus* egg developed into L_3 when the monthly mean maximum temperature was below 18.3°C regardless of rainfall, but that at mean maximum temperature between 18.9–28.9°C, the number of larvae recovered varied with the amount of rainfall. Kates (1950) observed the survival pattern of sheep parasite larvae on pasture under various climatic conditions and defined (i) optimum survival as survival of many larvae for 2 or more months during grazing season or over winter, (ii) intermediate survival as survival of many larvae longer than one month but less than 2 months during grazing season and (iii) minimum or no survival as survival of few or no larvae after exposure of one month or less during the grazing season or over winter. In general cool summer and cold winter appeared to favour larval survival (Dimander 1999). Cold temperatures are usually limiting to development regardless of moisture availability and the interaction between moisture and temperature becomes increasingly important as warmer conditions prevail (Berbigier *et al.* 1990). In hot climates, summers are the critical season for larval translation (Nielsen *et al.* 2007). *Haemonchus* larvae are more resistant and their optimum survival require warm, moist weather (summer with high maximum temperature and adequate rainfall), intermediate survival took place in cool moist weather (spring with moderate temperature and adequate rainfall) and minimum or no survival took place in warm, dry weather (summer with high temperature and low rainfall or drought), in cool, dry weather (spring with moderate temperature and low rainfall) or over winter. The unique manipulation of both evaporation rate and precipitation rate has provided new insight in to the interactive efficacy of these two determinants of moisture availability on the success of *H. contortus* free – living development (O' Conner *et al*. 2008). Once the infective stage is reached, the influences of temperature and moisture on survival are less important, resulting in considerable survival times under conditions lethal to pre-infective stages. The free-living development process is often expressed as the time taken for freshly deposited eggs to reach the infective larval stage. The grazing system together with the success rate of development is used to predict the timing and extent of pasture infectivity and hence provides valuable information for grazing and deworming strategies.

Bioclimatographs suffer from a number of deficiencies. These are based on average conditions over a period of years and since the weather may vary considerably from year to year, these cannot be used to predict the situation for any single year. Further in these other climatic factors are ignored which may affect the survival of larvae on pasture. In spite of their limitation, the use of the bioclimatographs to explain the distribution in space and time of larval nematodes on pasture must not be condemned out of hand because it represented the first rational attempt to utilize climatic data, to explain important features of the epidemiology of helmintic diseases (Ollerenshaw and Smith 1969). The large body of data illustrate that pasture larval burden can be greatly reduced in response to certain climatic conditions. The ability to predict the timing and magnitude of infection level in host and on pasture and plan grazing and worm control strategies accordingly is a key mean of preventing losses caused by gastrointestinal nematodes. Since last five decades time-to-time introduction of efficacious chemotherapeutics put the interest on role of biology of free-living stages of parasites in corner but development of anthelmintic resistance now forces us to resurrect this discipline and give full attention on it in formulation of strategies for worm management. Climatic consideration in combination with grazing history and practices can be taken into account in evaluating expected levels of *refugia* and thus treatments can be avoided at times when *refugia* are likely to be small. Anthelmintic treatment of livestock for the purpose of controlling strongyle parasites should be restricted to the active parasite transmission season. Thus present strategies of frequent deworming as practiced throughout the country should be suspended. In our situation more attention and research is needed for a thorough quantitative discipline of strongyle larval bionomics and a better understanding of their basic epidemiology on regional basis. Furthermore, we should divert our approach towards rationalization of anthelmintic use particularly timing of their application through formulation and implementation of simulation and / or forecasting modules on regional basis.

ACKNOWLEDGEMENTS

The study was supported by ICAR, New Delhi, under All India Network Programme on Gastrointestinal Parasitism. The facilities provided by Director, CSWRI, Avikanagar are thankfully acknowledged. Much appreciation is extended to officers and staff of Department of Animal Husbandry, Rajasthan and to many sheep breeders that made this study possible.

REFERENCES

Anonymous. 2004. Annual progress report: *All India Network Program on Gastrointestinal Parasitism*.pp.1–45. *CSWRI, Avikanagar.*

Berbigier P, Gruner L, Mambrini M and Sophie S A. 1990. Faecal water content and egg survival of goat gastrointestinal strongyles under dry tropical conditions in Guadeloupe. *Parasitology Research* **76**: 379–85.

Cameron T W M. 1956. *Parasites and Parasitism*. Methuen, London, England.

Dimander S O. 1999. The origin and overwintering survival of the free-living stages of cattle parasites in Sweeden. *Acta Veterinaria Scandinavica* **40**: 221–30.

Dinaburg A G. 1944a. The survival of the infective larvae of the common ruminant stomach worm, *Haemonchus contortus*, on outdoor grass plots. *American Journal of Veterinary Research* **5**: 32–37.

Dinaburg A G. 1944b. Development and survival under outdoor conditions of eggs and larvae of the common ruminant stomach worm, *Haemonchus contortus*. *Journal of Agricultural Research* **69**: 421–33.

Forsyth B A. 1953. Epidemiological studies on helminthosis of sheep in southern New South Wales. *Australian Veterinary Journal* **29**: 349–56.

Gordon H McL. 1948. The epidemiology of parasitic diseases with special reference to studies with nematode parasites of sheep. *Australian Veterinary Journal* **24**: 17–45.

Gordon H McL. 1950. Some aspects of parasitic gastroenteritis of sheep. *Australian Veterinary Journal* **26**: 14–28.

Kates K C. 1950. Survival on pasture of free-living stages of some common gastrointestinal nematodes of sheep. *Proceedings of Helminthology Society* **17**: 39–58. *Washington DC.*

Levine N D. 1959. The relation of climate to the epidemiology of gastrointestinal nematodes of sheep and cattle. *Journal of Parasitology* **45**(Suppl): 59–60.

Levine N D. 1963. Weather, climate and the bionomics of ruminant nematode larvae. *Advances in Veterinary Science* **8**: 215–61.

Llyod S, Smith J, Connan R M, Hatcher M A, Hedge T R, Humphrey D J and Jones A C. 2000. Parasite control methods used by horse owners: factors predisposing to the development of anthelmintic resistance in nematodes. *Veterinary Record* **146**: 487–92.

Martin R R, Beveridge I, Pullman A L and Brown T H. 1990. A modified technique for the estimation of the number of infective nematode larvae present on pasture and its application in the field under South Australian conditions. *Veterinary Parasitology* **37**: 133–43.

Nielsen M K, Kaplan R M, Thamsborg S M, Monrad J and Olsen S N. 2007. Climatic influences on development and survival of free-living stages of equine strongyles: Implications for worm control strategies and managing anthelmintic resistance. *The Veterinary Journal* **174**: 23–32.

O'Connor L J, Walkden-Brown S W and Khan L P. 2006. Ecology of the free-living stages of major trichostrongylid parasites of sheep. *Veterinary Parasitology* **142**: 1–15.

O'Connor L J, Khan L P and Walkden-Brown S W. 2008. Interaction between the effect of evaporation rate and amount of simulated rainfall on development of the free-living stages of *Haemonchus contortus. Veterinary Parasitology* **155**: 223–34.

Ollerenshaw C B and Smith L P. 1969. Meteorological factors and forecasts of helminthic disease. *Advances in Parasitology* **7**:

283–23.

O' Meara B and Muleahy, G. 2002. A survey of helminth control practices in equine establishments in Ireland. *Veterinary Parasitology* **109**: 101–10.

Puller E M. 1953. The epidemiology of helminthosis in sheep in winter rainfall regions of Australia. *Australian Veterinary Journal* **29**: 357–62.

Sanyal P K. 2004. Is 'the emperor" without clothes in farming with good worms? : Onderstepoort revisited. *Journal of Veterinary Parasitology* **18**: 105–08.

Swarnkar C P, Singh D, Khan F A, Tiwari R and Dubey S C. 2003. A survey of sheep worm control practices and status of anthelmintic resistance in *Haemonchus contortus* in Rajasthan. *Proceedings of 14th National Congress of Indian Association for the Advancement of Veterinary Parasitology*. Pp. 149. 15–17 October 2003, Nagpur, Maharashtra, India.

Swarnkar C P, Singh D, Kumar S, Khan F A and Tiwari J. 2006. Investigations on the seasonal pattern of Strongyle infection in sheep and interaction between genotypes of *Haemonchus contortus* in refugia and benzimidazole resistance in Rajasthan. *Proceedings of 17th National Congress of Indian Association for the Advancement of Veterinary Parasitology*. pp. 139 –40. 15–17 November 2006, Puducherry.

Van Wyk J A, Coles G C and Krecek R C T. 2002. Can we slow the development of anthelmintic resistance? An electronic debate. *Trends in Parasitology* **18**: 336–37.