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Distribution and abundance of ticks infesting livestock population along Karakorum highway from Mansehra to Gilgit, Pakistan

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ABSTRACT. Ticks and tick-borne infections pose major economic threats to the livestock industry throughout the world. The present study reports the point prevalence of ticks in the free range livestock population of the plain and hilly areas of Khyber Pakhtunkhwa (Mansehra, Haripur, Shangala, Kohistan), and Gilgit Baltistan (Diamer, Gilgit, Astor) along the Karakoram highway. Through convenient and snowball sampling techniques, a total of 813 animals, consisting of 232 sheep, 163 cattle, 365 goats and 53 buffaloes were screened for their tick burden. During the study, the two tick species identified were *Hyalomma anatolicum* and *Rhipicephalus microplus*. The overall prevalence of tick infestation among the screened livestock was 75.03%, with the highest distribution in sheep (81.47%) followed, in order, by cattle (77.91%), goats (72.05%) and buffalo (58.49%). The district-wise prevalence of ticks was the highest in Haripur (85.58), followed, in order, by Gilgit (83.10%), Mansehra (81.14%), Batagram (81.05%), Shangala (77.78%), Kohistan (75.38%), Diamer (72.28%) and Astor (32.22%). The prevalence of ticks was found to be higher (85.67%) in younger livestock than adults (66.44%), and in females (80.33%) than males (66.44%). The present study provides the first report of the tick distribution in higher altitudes of northern Pakistan and confirms the presence of *Hyalomma* and *Rhipicephalus* ticks in the plains, as well as the hilly geoclimates of Pakistan. Furthermore, the data on risk factors allows us to make recommendations to restructure the existing husbandry system of northern areas of Pakistan with the aim of reducing the tick burden on livestock.

Keywords: Ticks; Khyber Pakhtunkhwa; Gilgit- Baltistan; Pakistan; *Hyalomma anatolicum*; *Rhipicephalus microplus*

INTRODUCTION

Ticks (Acari: Ixodidae), blood imbibing ectoparasites of mammals, birds and reptiles, have an epidemic dissemination in tropical and sub-tropical regions (Gaisuddin et al., 1994; Vesco et al., 2011). Ticks are prevalent worldwide from Asia (Haque et al., 2011; Bilkis et al., 2011; Sajid et al., 2011; Razmi and Ramoon, 2012; Singh and Rath, 2013), Africa (Reye et al., 2012; Tiki and Mekonnen, 2011; Elghali and Hassan, 2012), North and South Americas (Guimaraes et al., 2001; Lohmeyer et al., 2011), Australia (Springell, 1974; Kamau, 2011) and Europe (Kirby et al., 2004; Scharlemann et al., 2008). Ticks not only

cause direct losses, but also act as vectors for various pathogens of bacterial, rickettsial, protozoal, and viral origin (Petney et al., 2007). The direct production losses caused by ticks include loss of milk production, reduced weight gain (Peter et al., 2005; Sajid et al., 2007), low quality skins and hides (Jongejan and Uilenberg, 2004), and mortality (Niyonzema and Kiltz, 1986). Besides these production losses, ticks also cause clinical and sub-clinical infections such as anaemia, dermatitis, paralysis, otoacariasis (Drummond, 1983; FAO, 1998) and secondary bacterial infections (Ambrose et al., 1999). Various diseases vectored by ticks are babesiosis, theileriosis, anaplasmosis, lyme

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disease, tick typhus, Rocky Mountain spotted fever and Crimean-Congo haemorrhagic fever (Otim, 2000; Bell-Sakyi et al., 2004). During the last three decades tick-borne infections have increased globally (Patz et al., 2005). Production and economic losses are proportional to the tick burden on the body of host, which results in increased irritation, restlessness, weight loss and disease transmission (Gosh et al., 2007; Agarwal and Gupta, 2010). It has been estimated that economic losses due to vector transmitted diseases and cost of tick control worldwide is 7.0 billion dollars annually (Harrow et al., 1991; Garcia, 2003).

The distribution of ticks in any region is closely associated with certain biotic and abiotic features (Sonenshine, 1993). Tick dispersal in any area depends upon the environmental factors (Estrada-Peña, 2003) e.g. temperature of 27-39 °C and relative humidity range of 60-80% render ticks more active (Rodríguez and Domínguez, 1998); however, ticks can also survive at temperatures down to -18.5°C (Clark, 1995; Vandyk et al., 1996, Schulze et al., 2001). In the past few decades, due to global warming, ticks have been reported in areas of higher altitudes which were previously tick-free. In Pakistan, studies conducted on prevalence of tick species across the country report the frequency distribution within the range of 6.99 to 80% in small and large ruminant population. However, studies on the tick distribution in the northern areas of Khyber Pakhtunkhwa (KPK) and Gilgit Baltistan (GB) are not available except a single study by Khan (1993) in Kaghan valley, almost two decades ago. The present study was aimed to explore the northern area of Pakistan for the distribution of tick fauna in livestock population.

MATERIALS AND METHODS

Study Area

The present study was conducted in selected areas of the provinces of KPK and GB including: Haripur (33.988 °N 72.95 °E), Mansehra (34°20' N 73°12'E), Shangala and Batagram (34.41°N 73.1°E), Kohistan (34° 54' and 35° 52' N and 72°43' and 73°57 E), Astor (35° 22' N, 74° 51' E) and Gilgit (35°55'19" N 74°18'31" E). The average distance between each study area ranged from 30 to 100 kilometers. In these areas, animals are reared under a traditional management system (i.e. farmers followed practices of their forefathers and deal with animals

according to traditional beliefs and knowledge) in which the livestock is entirely dependent upon grazing. Variation in temperature, rainfall, and humidity levels of the study districts depends upon the differences in the landscape, climate and elevation of these areas from sea level (Anonymous, 2011). The present study was conducted during June which is the hottest month of summer season in Pakistan.

Selection of Animals

Convenience and snowball sampling techniques were applied in order to select the sample animals/farms along the Karakoram Highway screened during this study. A questionnaire was designed to acquire essential information relating to animals (sex, age and species), qualitative and quantitative abundance of ticks and/or other parasites and the environmental conditions, including management (Thrusfield, 2007).

Collection and Identification of Ticks

For collection of ticks, the whole body of the animal was screened. Ticks were removed with the help of a fine tweezer with minimum damage to the mouth parts (Soulsby, 1982), transferred to McCartney sample collection bottles containing 70% ethanol and labelled appropriately. After collection, specimens were brought to the Department of Parasitology, Faculty of Veterinary Science, University of Agriculture, Faisalabad, Pakistan for taxonomic identification. Ticks were identified using stereomicroscope (IM-SZ-500 IRMECO Germany) according to standard keys (Walker et al., 2007).

Statistical Analyses

Prevalence and association of determinants was analyzed by using multivariate analysis (multiple logistic regressions) and odds ratio. Pairwise comparison was carried out by keeping buffaloes (animal species), *Rhipicephalus* spp. (tick species), males (sex), adults (age) and the Astor district (area) in group 2 of the analysis (Schork and Remington, 2010). All statistical analyses were conducted using SAS software package (SAS, 2010).

RESULTS

The overall prevalence of tick infestation in the

Table 1. Frequency distribution of hard ticks (Ixodidae) in different livestock species of Khyber Pakhtunkhwa and Gilgit-Baltistan, Pakistan

Variables	Levels	Animals Screened	Tick Positive	Prevalence (%)	95% Confidence interval		Odds Ratio	P-value
					Lower limit	Upper limit		
Animal Species	Sheep	232	189	81.47	76.07	86.06	1.39	0.167
	Cattle	163	127	77.91	71.06	83.78	1.33	0.289
	Goats	365	263	72.05	67.28	76.48	1.23	0.378
	Buffalo	53	31	58.49	44.94	71.13	-	-
Tick Species	<i>Hyalomma spp.</i>	813	309	38.01	34.72	41.38	1.03	0.782
	<i>Rhipicephalus spp.</i>	813	301	37.02	33.75	40.39	-	-
Sex	Female	483	388	80.33	76.61	83.69	1.19	0.105
	Male	330	222	67.27	62.07	72.18	-	-
Age	Young	393	311	79.13	74.90	82.94	1.11	0.322
	Adult	420	299	71.19	66.72	75.37	-	-
Province	KPK	498	403	80.92	77.29	84.74	1.23	0.063
	GB	315	207	65.71	60.34	70.80	-	-
Districts	Manshera	162	132	81.14	74.94	86.91	2.53	0.000
	Haripur	104	89	85.58	77.82	91.38	2.66	0.000
	Batagram	95	77	81.05	72.24	88.00	2.52	0.000
	Shangala	72	56	77.78	67.11	86.25	2.41	0.002
	Kohistan	65	49	75.38	63.86	84.69	2.34	0.003
	Diamer	83	60	72.28	61.95	81.10	2.24	0.003
	Gilgit	142	118	83.10	76.26	88.60	2.58	0.000
Astor	90	29	32.22	23.19	42.38	-	-	

livestock population of the study area was found to be 75.03% (610/813) with a higher ($P>0.05$) tick distribution in KPK than in GB. Only adult ticks of *Hyalomma anatolicum* and *Rhipicephalus microplus* were present on the screened livestock population. Animals/livestock species wise prevalence of ticks were 81.47% in sheep, 77.91% in cattle, 72.05% in goats and 58.49% in buffaloes. Similarly, animal numbers found positive for ticks species were 309 and 301 with *Hyalomma* and *Rhipicephalus* spp. respectively. A total of 18907 adult ticks were collected from the four livestock species in the study areas. Higher number of ticks were collected from sheep (7590), followed in order by goats (6622), cattle (4004), and buffaloes (691). Distribution of ticks collected from the screened livestock species is given in Table 2. Tick distribution was found highest ($P<0.05$) in the Mansehra district followed by the Haripur, Batagram, Shangala, Kohistan, Diamer, Gilgit and Astor districts. Host age and sex

Table 2. Tick Abundance in Screened Livestock Species of Gilgit Baltistan and Khyber Pakhtunkhwa, Pakistan

Sr. No. 1, 2, 3, 4	Livestock species	Range of tick Burden		Average
		Minimum	Maximum	
	Sheep	6	145	40.16
	Cattle	25	125	31.53
	Goats	19	130	25.18
	Buffaloes	10	60	22.29

were not found to be statistically associated ($P>0.05$) with the tick distribution in the study districts. Table 1 details the distribution of ticks by individual variables. Table 3 depicts the distribution of the two species of hard ticks infesting livestock in the various districts of KPK and GB.

DISCUSSION

The prevalence of tick infestation in ruminants

Table 3. Tick species-based distribution of hard ticks (Ixodidae) on different livestock hosts in the various districts of Khyber Pakhtunkhwa and Gilgit Baltistan, Pakistan

Variables	Levels	Animals Screened	Tick Positive	Prevalence (%)	Confidence interval 95%		Odds Ratio	P-value
					Lower limit	Upper limit		
Manshera	<i>Hyalomma</i>	162	71	43.83	36.33	51.54	1.16	0.440
	<i>Rhipicephalus</i>	162	61	42.96	30.44	45.30	-	-
Haripur	<i>Rhipicephalus</i>	104	48	46.15	36.74	55.78	1.17	0.571
	<i>Hyalomma</i>	104	41	39.42	30.38	49.05	-	-
Batagram	<i>Hyalomma</i>	95	40	42.11	32.49	52.20	1.08	0.737
	<i>Rhipicephalus</i>	95	37	38.95	29.54	49.02	-	-
Shangala	<i>Hyalomma</i>	72	31	43.06	32.00	54.66	1.24	0.481
	<i>Rhipicephalus</i>	72	25	34.72	24.42	46.23	-	-
Kohistan	<i>Rhipicephalus</i>	65	25	38.46	27.26	50.67	1.04	0.934
	<i>Hyalomma</i>	65	24	36.92	25.88	49.11	-	-
Diamer	<i>Hyalomma</i>	83	33	39.76	29.67	50.56	1.22	0.500
	<i>Rhipicephalus</i>	83	27	32.53	23.12	43.14	-	-
Gilgit	<i>Rhipicephalus</i>	142	64	45.07	37.03	53.31	1.19	0.413
	<i>Hyalomma</i>	142	54	38.03	30.32	46.22	-	-
Astor	<i>Hyalomma</i>	90	15	16.67	10.01	25.44	1.07	0.922
	<i>Rhipicephalus</i>	90	14	15.56	09.14	24.16	-	-

is much higher in the developing countries of Asia (Siddiqi and Jan, 1986; Khan et al., 1993; Sajid et al., 2007, 2008, 2009, 2011; Yi-Lun et al., 2011; Iqbal et al., 2013; Ali et al., 2013; Sultana et al., 2015) and Africa (Walker and Koney, 1999; Walker, 2003), where control measures are infrequently applied, than in Australia (Springell, 1974; Kamau, 2011), Europe (Papadopoulos et al., 1996; Hostis and Seegers, 2002) and the Americas (Guimaraes et al., 2001; Lohmeyer et al., 2011). Extensive research studies have been conducted on the prevalence of the tick fauna and associated risk factors in various districts of Pakistan. Seven tick species have been reported from sixteen districts of Pakistan, with a prevalence ranging from 6.99% to 86.50% in the bovine and caprine populations of various study areas during 1971 to 2015 (Iqbal et al., 1971; Khan et al., 1993; Zaman, 1997; Kakar and Kakarsulemankhel, 2008; Sajid et al., 2008; Durrani and Shakoori, 2009; Irshad et al., 2010; Perveen, 2011; Atif et al., 2012; Ali et al., 2013; Iqbal et al., 2013; Tasawar et al., 2014; Mustafa et al., 2014; Sultana et al., 2015). However, the northern areas of the country have been ignored due to harsh climate and the very difficult assess to small holder animal farmers in the remote hilly villages. This is the first attempt to con-

duct such a study in these areas. The two tick species, i.e. *H. anatolicum* and *R. microplus*, which were identified from the screened livestock population along the Karakoram highway, have also been reported earlier from other parts of the country (Ali, 1988; Khan et al., 1993, 1996; Wahid et al., 2004; Durrani, 2008; Sajid et al., 2008; Irshad et al., 2010; Atif et al., 2012; Iqbal et al., 2013; 2014; Mustafa et al., 2014; Tasawar et al., 2014). These two tick species have also been reported to infested deer, equine, swine, canine and humans. Further, these two ticks have been reported as vectors of viral, bacterial, rickettsial and protozoal diseases of man and animals, including: Crimean-Congo hemorrhagic fever, babesiosis, theliriosis, Q fever, trypanosomiasis and ehrlichiosis (Morzaria et al., 1986; Jongejan and Uilenberg, 1994; Chinikar et al. 2009) as well as for *Staphylococcus* spp., *Coxiella burnetti*, tick-borne encephalitis virus, and *Ehrlichia* spp. (Yang et al., 1993; Anbalagan et al., 2014).

Prevalence of these species of ticks has already been reported in wide range of farm animals from the hilly and plain areas of Malaysia (Mariana et al., 2008). The results of present study indicate a relatively higher prevalence of ticks in the livestock populations of the plain and hilly areas of Pakistan as compared to

earlier studies conducted in other parts of the country in which the prevalence ranged from 14% to 54.76% (Iqbal et al., 1971; Sajid et al., 2007, 2008; Ramzan et al., 2008; Sajid et al., 2009; Irshad et al., 2010; Sajid et al., 2011; Atif et al., 2012; Iqbal et al., 2013).

The key factors which favour the growth and development of ticks in particular region are: temperature, humidity, rainfall (Greenfield et al., 2011), vegetation (Gray, 2002), host availability, season, habitat (Teel et al., 1996), altitude (Jouda et al., 2004; Burri et al., 2007; Cadenas et al., 2007), breed, age, sex, stage of lactation, gestation period, nutritional status of the animal (Swai et al., 2005; Alonso et al., 2007; Yacob et al., 2008), body condition (Rony et al., 2010), method of application of acaricides (Bianchi et al., 2003) and husbandry practices (Sajid et al., 2011). In addition, tick survival and activity are dependent on many factors, primarily, humidity and moisture contents. To this end, mat depth (depth of soft soil which is usually measured by ruler) is another important factor which helps to maintain a better microclimatic condition suitable for tick survival, as more depth of mat retains more water (Milne, 1948) and provides more niches for ticks. Removal of mat layer/thickness causes desiccation of ticks thus reducing tick abundance. In addition to this, a humidity of above 80% is essential for tick survival and levels below this have a detrimental effect on tick survival (Macleod, 1934, 1935; Milne, 1948). It is therefore believable that humidity is an important determinant of tick survival. Humidity also has a profound effect on tick activity, primarily controlling the amount of time a tick can spend questing (Greenfield, 2011). Tick growth and development is temperature dependent and tick activity is greatly affected by changes in temperature. It has been reported that at temperatures $<7^{\circ}\text{C}$, ticks remain inactive, only venturing out of the mat and up the vegetation to quest for a host when temperatures increase (Macleod, 1939). Further, an increase in temperature not only causes an increase in the distribution of ticks but is also linked to the encroachment of ticks into higher altitudes not previously colonized by ticks (Danielov *et al.*, 2008). The increase and decrease in temperature is also associated with tick diapause and shift in nymph and adult activity. It is reported that lower temperatures ($16.0\text{--}20.9^{\circ}\text{C}$) significantly reduced the number of ticks recovered during dragging. Increase and decrease in temperature, soil moisture and cloud coverage can also affect tick questing. Studies have shown that higher humidity is not favorable for ticks, as they

become prone to over saturation, thus limiting their activities (Lee, 1946; Milne, 1948; Arthur, 1962). Gray (2002) reported that vegetation structure plays a large role in the presence and the absence of ticks. Ticks are often recorded in woodland habitats, as these provide a dense shrub layer; habitat with bracken, however, will also provide a suitable habitat. Vegetation height is also important factor which affects tick prevalence as higher heights are associated with a decrease in tick abundance. It is reported that the tick abundance is higher at 151-300mm high vegetation. Presence and absence of host in an area also affect occurrence of ticks. So, presence of ticks is not static as it depends on a number of factors.

The reasons of high prevalence of ticks in the livestock population nurtured along the Karakoram highway of Pakistan could be due to different factors. Geography and climate of the area are among those factors which are linked with variables such as: temperature, rainfall, humidity, vegetation, landscape and altitude and the role of these factors leading to a higher abundance of ticks has been reported (Estrada-Pena, 2003). Recently, it has been reported that the height of the study area from the sea level has negative correlation with the tick distribution and abundance (Qviller *et al.*, 2013). Probably, at the higher altitudes, environmental temperature does maintain the optimum range required for the growth and development of ticks (Perret *et al.*, 2000; Jouda *et al.*, 2004; Randolph, 2004). Further, at higher altitudes the micro climatic conditions diminish the body reserves of the ticks, which ultimately lead to delayed embryogenesis (Daniel, 1993). During the past decade, increases in the climatic temperature might have resulted in the higher abundance of ticks even at higher altitudes (Burri *et al.*, 2007; Cadenas *et al.*, 2007). Climate alteration is a believable justification for changes in the distribution and severity of tick infestation at higher altitude (Coulson *et al.*, 2009). In other words, environmental changes favour settlement of ticks at higher altitude where they had not colonized earlier (Danielova *et al.*, 2008). Vegetation and forest make another microclimatic component of the area that have significant role in higher distribution of ticks as it provides covering layer for lodging of ticks (Gray, 2002). Hilly areas of GB and KPK are densely shielded by shrubs, bushes and forests which provide appropriate resources for the exophilic questing behaviour of ticks.

Season plays vital role in the tick distribution as has been reported from all over the globe with highest prev-

alence in summer (Singh and Singh, 1999; Hussian and Kumar, 1991; Vatsya et al., 2008; Haque et al., 2011). In Pakistan too, summer season has been reported most favorable for the growth, propagation and infestation of ticks on the livestock population from various regions of the country (Sajid et al., 2007; Durrani and Shakoori, 2009; Sajid et al., 2009, 2011; Atif et al., 2012; Iqbal et al., 2013) Current point prevalence was determined in the summer when the weather conditions are hot and humid which favour tick growth and development (Gosh et al., 2007). Probably, nomadism also contributes towards higher distribution of tick infestation in the area as in our country animal keepers/farmers from the warmer areas of Punjab, Sindh and KPK migrate with their livestock in summer season to the hilly areas like GB where temperature is much lower during summer season. This activity favours successful transmission of ticks from the immigrant livestock to the indigenous animals of the area.

Husbandry practices are also correlated with tick abundance and distribution. In this context, mixed grazing of different animal species on the same pasture and/or mixed housing provides maximum opportunity to ticks to infest a large population at one time. In Pakistan, animal sheds are made of bricks and stones with mud which provides cracks and crevices that is suitable for the nidicolous questing behaviour of ticks (Soulsby, 1982). Lack of awareness about the treatment of infested animals and lack of veterinary facilities are also noteworthy reasons for the higher tick infestation

in these areas. Most of the interviewed farmers were illiterate and had a misconception that ticks do not impact on animal health and production. On the basis of the results of the present study, some recommendations for farmers and researchers are: (a) prophylactic treatment of the livestock populace must be administered at the start of warm season (March-April) (b) young and female animals need extra care (c) dairy and livestock development organizations must plan an awareness campaign in these areas to explain the possible threats of ticks and tick-borne diseases to the livestock. The present study is the first report of the successful adaptation and settlement of ticks at the high altitudes of northern Pakistan.

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REFERENCES

- Agarwal P, Gupta AR (2010) Management of ectoparasites of livestock. Department of Medicine, QUAT- Bhubaneswar, Orissa, India.
- Ali W F (1988) Incidence and chemotherapy of ectoparasites of cattle, sheep, goat and poultry in Northern Areas. M.Sc. Thesis, Department of Parasitology, College of Veterinary Sciences, Lahore, Pakistan.
- Ali Z, Maqbool A, Muhammad K, Khan MS, Younis M (2013) Prevalence of *Theileria annulata* infected hard ticks of cattle and buffalo in Punjab, Pakistan. *J Anim Plant Sci* 23:20-26.
- Alons DMA, López SBJ Leme de Magalhaes LAC, Rodríguez VRI (2007) Infestación natural de hembras de *Boophilus microplus* Canestrini, 1887 (Acari: Ixodidae) en dos genotipos de bovinos en el trópico húmedo de Veracruz, México. *Veterinaria México* 38:503-509.
- Anbalagan S, Vimalanathan AP, Mani K, Muthukalingan K (2014) The midgut bacterial flora of the hard tick *Hyalomma anatolicum* (Acari: Ixodidae) from South India as determined by molecular analyses. *Turkish J Vet Anim Sci* 38:520-525.
- Anonymous (2011) Pakistan Metrological Department, Lahore, Pakistan.
- Arthur DR (1962) Ticks and disease. London Pergamon Press. pp 445.
- Atif FA, Khan MS, Iqbal HJ, Ali Z, Ullah S (2012) Prevalence of cattle tick infestation in three districts of the Punjab, Pakistan. *Pak J Sci* 64:49-53.
- Bell-Sakyi L, Koney EB, Dogbey O, Walker AR (2004) Incidence and prevalence of tick-borne haemoparasites in domestic ruminants in Ghana. *Vet Parasitol* 124:25-42.
- Bianchi MW, Barre N, Messad S (2003) Factors related to cattle infestation level and resistance to acaricides in *Boophilus microplus* tick populations in New Caledonia. *Vet Parasitol* 112:75-89.
- Bilkis MF, Mondal MMH, Rony SA, Islam MA, Begum N (2011) Host determinant based prevalence of ticks and lice in cattle (*Bos indicus*) at Bogra district of Bangladesh. *Progress Agric* 22: 65-73.
- Burks CS, Stewart RJ, Needham GR, Lee RE (1996) The role of direct chilling injury and inoculative freezing in cold tolerance of *Amblyomma americanum*, *Dermacentor variabilis* and *Ixodes scapularis*. *Physiol Entomol* 21:44-50.
- Burri C, Cadenas FM, Douet V, Moret J, Gem L (2007). *Ixodes ricinus* density and infection prevalence of *Borrelia burgdorferi* sensu lato along a north-facing altitudinal gradient in the Rhone valley Switzerland. *Vector Borne Zoonotic Dis* 7:50-58.
- Cadenas FM, Rais O, Jouda F, Douet V, Humair, PF, Moret J, Gem L (2007) Phenology of *Ixodes ricinus* and infection with *Borrelia burgdorferi* sensu lato along and north- and south-altitudinal gradient on Chaumont mountain, Switzerland. *J Med Entomol*. 44: 683-693.

- Chinikar EMS, Saber E, Fahimeh BA, Amir MAT, Sahar K (2012) Seroepidemiological survey of Crimean-Congo hemorrhagic fever among sheep in Mazandaran Province, Northern Iran. *Vector Borne Zoonotic Disease* 12:739-742.
- Clark DD (1995) Lower temperature limits for activity of several Ixodid ticks (Acari: Ixodidae): effects of body size and rate of temperature change. *J Med Entomol* 32: 449-52.
- Coulson SJ, Lorentzen E, Strøm H, Gabrielsen GW (2009) The parasitic tick *Ixodes uriae* (Acari: Ixodidae) on seabirds from Spitsbergen Svalbard. *Polar Res* 28:399-402.
- Dale C, Moran NA (2006) Molecular interactions between bacterial symbionts and their hosts. *Cell* 126:453-465.
- Daniel M (1993) In Xuence of the microclimate on the vertical distribution of the tick *Ixodes ricinus* (L.) in Central Europe. *Acarologia* 34:105-113
- Danielova V, Schwarzova L, Materna J, Daniela M, Metelkad L, Holubovaa J, Kriz B (2008) Tick-borne encephalitis virus expansion to higher altitudes correlated with climate warming. *Int J Med Microbiol* 298:68-72.
- Drummond RO (1983) Tick-borne livestock diseases and their vectors, chemical control of ticks. *World Animal Review* 36:28-33.
- Durrani AZ, Shakoori AR, Kamal N (2008) Bionomics of *Hyalomma* ticks in three districts of Punjab, Pakistan. *Anim Poul Sci* 18:121-124.
- Durrani HZ (1992) A study on the taxonomy and bionomics of genus *Haemaphysalis* in domestic animals. M.Sc. Thesis, College of Veterinary Sciences, Lahore, Pakistan.
- Elghali AA, Hassan SM (2012) Ticks infesting animals in the Sudan and southern Sudan: Past and current status. *Onderpost J Vet Res* 79:1-6.
- Estrada-Peña A (2003) The relationships between habitat topology, critical scales of connectivity and tick abundance *Ixodes ricinus* in a heterogeneous landscape in northern Spain. *Ecography* 26:661-671.
- FAO (1998) <http://www.fao.org/ag/AGA/AGAH/PD/pages/tick01.htm>.
- Gaisuddin M, Haq MM, Sarkar NR, Rahman M L (1994) Seasonal incidence of Ixodid ticks grown in pasture of Bangladesh. *A J A S* 7:197-200.
- Garcia Z (2003) Integrated control of *Boophilus microplus* in cattle. In: Proc. 11th Int. Congr. Int. Society for Animal Hygiene, Mexico City, Mexico.
- Gosh S, Bansal, GC, Gupta SC, Ray D, Khan MQ, Irshad H, Shahiduzzaman M, Seitzer U, Ahmed JS (2007) Status of tick distribution in Bangladesh, India and Pakistan. *Parasitol Res* 101: 207-216.
- Gray JS (2002) Biology of *Ixodes* species ticks in relation to tick-borne zoonoses. *Wien. Klin. Wochenschr.* 114: 473-478.
- Greenfield BPI (2011) Environmental parameters affecting tick (*Ixodes ricinus*) distribution during the summer season in Richmond Park, London. *Bioscience Horizons* 4: 140-148.
- Guimaraes JH, Tucci EC, Barros-Battesti, DM (2001) Ectoparasitos de importancia veterinaria. Editora Pleiade, Sao Paulo. 213.
- Haque M, Jyoti J, Singh NK, Rath SS, Ghosh S (2011) Epidemiology and seasonal dynamics of ixodid ticks of dairy animals of Punjab state, India. *Indian J Anim Sci* 81: 661-664.
- Harrow ID, Gratton KAF, Evans N (1991) Neurobiology of arthropod parasites. *Parasitol* 102:559-569.
- Hostis, LM, H Seegers (2002) Tick-borne parasitic diseases in cattle current knowledge and prospective risk analysis related to the ongoing evolution in French cattle farming systems. *Vet Res* 33:599-611.
- Hussain IS, Gyanchandani AK (1991) Prevalence of ticks (Ixodidae) of cows at Umerkot and its adjoining areas, in the Province of Sindh. *Pak J Zool* 11: 225-229.
- Iqbal A, Sajid MS, Khan MN, Khan MK (2013) Frequency distribution of hard ticks (Acari: Ixodidae) infesting bubaline population of district Toba Tek Singh, Punjab, Pakistan. *Parasitol Res* 112:535-541.
- Iqbal A, Sohail MS, Khan MN, Muhammad G (2014) Epizootiology of ectoparasitic fauna infesting selected domestic cattle population of Punjab, Pakistan. *Int J Agri & Biol.* 16: 443-446.
- Iqbal M (1971) Studies on ectoparasites of livestock with special emphasis on the incidence, economic losses and chemotherapy. M.Sc. Thesis, Department of Veterinary Parasitology, Faculty Veterinary Sciences, University of Agriculture Faisalabad, Pakistan.
- Irshad N, Qayyum M, Hussain M, Qasim MK (2010) Prevalence of tick infestation and theileriosis in sheep and goats. *Pak Vet J* 30:178-180.
- Jongejan F, Uilenberg G (1994) Ticks and control methods. In: *Ectoparasites of Animals and Control Methods*. Blancou, J. (ed.), Scientific and Technical Review, Office Internationale des Epizooties (OIE), Paris, France, 13: 1201-1226.
- Jongejan F, Uilenberg G (2004) The global importance of ticks. *Parasitol* 129: 3-14.
- Jouda F, Perret J, Gern L (2004) *Ixodes ricinus* density, and distribution and prevalence of *Borrelia burgdorferi sensulato* infection along an altitudinal gradient. *J Med Entomol* 41:162-169.
- Kabir MHB, Mondal MMH, Eliyas M, Mannan MA, Hashem MA, Debnath NC, Miaz OF, Mohiuddin C, Kashem MA, Islam MR, Elahi MF (2011) An epidemiological survey on investigation of tick infestation in cattle at Chittagong District, Bangladesh. *African J Microbiol Res* 5:346-352.
- Kakar MN, Kakarsulemankhel JK (2008) Prevalence of endo (trematodes) and ectoparasites in cows and buffaloes of Quetta, Pakistan. *Pak Vet J* 28:34-36.
- Kamau J, de Vos AJ, Playford M, Salim B, Kinyanjui B, Sugimoto C (2011) Emergence of new types of *Theileria orientalis* in Australian cattle and possible cause of theileriosis outbreaks. *Parasites & Vectors* 4:1-10.
- Khan MH (1994) Infestation of ticks on cattle and buffaloes in Bareilly, Uttar Pradesh. *J Vet Parasitol.* 8:71-76.
- Khan MH (1996) Studies on *Hyalomma kumari Sharifi* on goats. *Vet. Parasitol* 10:165-169.
- Khan MI (1993) Taxonomical study of ticks of genus *Rhipicephalus* and their relation to the incidence of haemoparasites and comparative efficacy of different acaricides on ticks in sheep and goats in Kaghan valley. MSc Thesis. College of Veterinary Sciences, Lahore, Pakistan.
- Khan MN, Hayat CS, Iqbal Z, Hayat B, Naseem A (1993) Prevalence of ticks on livestock in Faisalabad, Pakistan. *Pak Vet J* 13:182-184.
- Kikuchi Y, Hosokawa T, Fukatsu T (2007) Insect-microbe mutualism without vertical transmission. a stinkbug acquires a beneficial gut symbiont from the environment every generation. *Appl Environ Microbiol* 73:4308-4316.
- Kirby AD, Smith AA, Benton TG, Hudson PJ (2004) Rising burden of immature sheep ticks (*Ixodes ricinus*) on red grouse (*Lagopus lagopus scoticus*) chicks in the Scottish uplands. *Med Vet Entomol* 18:67-70.
- Lee RE, Baust JG (1987) Cold-hardiness in the Antarctic tick, *Ixodes uriae*. *Physiol Zool* 60: 499-506.
- Lees A D (1946) Water balance in *Ixodes ricinus* and certain other species of ticks. *Parasitology* 37:1:1-20.
- Lohmeyer KH, Pound JM, May MA, Kammlah DM, Davey RB (2011) Distribution of *Rhipicephalus (Boophilus) microplus* and *Rhipicephalus (Boophilus) annulatus* (Acari: Ixodidae) infestations detected in the United States along the Texas/Mexico border. *J Med Entomol* 48:770-774.
- MacLeod J (1934) *Ixodes ricinus* in relation to its physical environment, the influence of climate on development. *Parasitology* 26: 282-305.
- MacLeod J (1935) *Ixodes ricinus* in relation to its physical environment. *Parasitology* 27:489-500.
- Macleod J (1939) The seasonal and annual incidence of the sheep tick *Ixodes ricinus* in Britain. *Bull Entomol Res* 30:103-18.
- Manan A, Khan Z, Ahmed B (2007) Prevalence and identification of Ixodid tick genera in frontier region Peshawar. *J Agri Bio Sci* 2:19-61.
- Mariana A, Zuraidawati Z, Ho TM, Kulaimi BM, Saleh I, Shukor MN (2008) Ticks (Ixodidae) and other ectoparasites in Ulu Muda Forest Reserve, Kedah, Malaysia. *Southeast Asian J Trop Med Public Health* 39:496-506.
- McMichael AJ, Woodruff RE, Hales S (2006) Climate change and human health: present and future risks. *Lancet* 367: 859-869.
- Milne A (1948) The ecology of the sheep tick, *Ixodes ricinus* microhabitat economy of the adult tick. *Parasitol* 40:14-34.
- Morzaria SP, Latif AA, Jongejan F, Walker AR (1986) Transmission of a Trypanosoma species to cattle by the tick *Hyalomma anatolicum anatolicum*. *Vet Parasitol* 19:13-21.
- Mustafa I, Kamran RA, Marghoob S, Ahmed I, Aleem R, Sadaf J, Hira M, Shabbir RG, Abdul G, Tahir M, Muhammad A, Mobushir RK, Saira A, Inayat UM, Abu BMR,

- Muhammad AA, Mazhar Q, Ayesha W, Haroon A (2014) Seasonal activity of tick infestation in goats and buffalo of Punjab Province (District Sargodha), Pakistan. *Kafkas Univ Vet Fak Derg* 20:655-662.
- Niyonzema A, Kiltz HH (1986) Control of ticks and tick-borne diseases in Burundi. In proceeding of Australian Centre for International Agriculture Research: pp16-24.
- Otim CP (2000) Advance in disease control: ticks and tick borne diseases. Uganda. *J Agr Sci* 5:79-85.
- Pais R, Lohs C, Wu Y, Wang J, Aksoy S (2008) The obligate mutualist *Wigglesworthia glossinidia* influences reproduction, digestion, and immunity processes of its host, the tsetse fly. *Appl Environ Microbiol.* 74:5965-5974.
- Papadopoulos B, Morel PC, Aeschlimann A (1996). Ticks of domestic animals in the Macedonia region of Greece. *Vet Parasitol* 63: 25-40.
- Patz JA, Campbell-Lendrum D, Holloway T, Foley JA (2005) Impact of regional climate change on human health. *Nature* 438: 310-317.
- Patz JA, Olson SH, Uejio CK, Gibbs HK (2008) Disease emergence from climate and land use change. *Med Clin. North America* 92:1473-1491.
- Perret JL, Guigoz E, Rais O, Gern L (2000) Influence of saturation deficit and temperature on *Ixodes ricinus* tick questing activity in a Lyme borreliosis-endemic area (Switzerland). *Parasitol Res* 86:554-557.
- Perveen F (2011) Distribution and identification of ixodid tick species on livestock in northern Pakistan. *J Agric Sci Tech* 1:73-80.
- Peter RJ, Van DB, Penzhorn PBL, Sharp B (2005) Tick, fly, and mosquito control. Lessons from the past, solutions for the future. *Vet Parasitol* 132: 205-215.
- Petney TN, Kolonin GV, Robbins RG (2007) Southeast Asian ticks (Acari: Ixodida): a historical perspective. *Parasitol Res* 101: 201-205.
- Qviller L, Risnes-Olsen N, Bærum KM, Meisingset EL, Loe LE, Ytrehus B, Viljugrein H, Mysterud A (2013) Landscape level variation in tick abundance relative to seasonal migration in red deer. *Plos One* 8:71299-7205.
- Ramzan M, Khan MS, Avais M, Khan JA, Pervez K, Shahzad W (2008) Prevalence of ectoparasites and comparative efficacy of different drugs against tick infestation in cattle. *Pak J Anim Pl Sci* 18:216-305.
- Randolph, S.E., 2004. Tick ecology: processes and patterns behind the epidemiological risk posed by ixodid ticks as vectors. *Parasitol* 129:1-29.
- Razmi GR, Ramoon M (2012) A study of tick fauna in Tando Ureh National Park Khorasan Razavi Province, Iran. *Acarina* 20:62-65.
- Reye AL, Olatunbosun G (2012) Arinola, Judith M. Hübschen and Claude P. Muller Pathogen prevalence in ticks collected from the vegetation and livestock in Nigeria. *Appl Environ Microbiol* 78: 2562.
- Rodríguez VRI, Domínguez AJL (1998) Grupos entomológicos de importancia veterinaria en Yucatán, México. *Revista de Biomedicina.* 9:26-37.
- Rony SA, Mondal MMH, Begum N, Islam MA, Affroze S (2010) Epidemiology of ectoparasitic infestations in cattle at Bhawal forest area, Gazipur. *Bangl J Vet Med.* 8: 27-33.
- Sajid MS, Iqbal A, Khan MN, Muhammad G, Siddique RM., Iqbal, Z, Khan MK, Siddique F (2013) Descriptive epidemiology of insects infesting domestic sheep (*Ovis aries*) of district Toba Tek Singh, Punjab, Pakistan. *Pak J Agri Sci* 50:117-122.
- Sajid MS, Iqbal Z, Khan MN, Muhammad G (2008) Point prevalence of hard ticks infesting domestic ruminants of lower Punjab, Pakistan. *Intl J Agric Biol* 10:349-351.
- Sajid MS, Iqbal Z, Khan MN, Muhammad G (2009). *In vitro* and *in vivo* efficacies of ivermectin and cypermethrin against the cattle tick *Hyalomma anatolicum anatolicum* (Acari: Ixodidae). *Parasitol Res.* 105:1133-1138.
- Sajid MS, Iqbal Z, Khan MN, Muhammad G, Iqbal MU (2007) Effect of *Hyalomma* ticks (Acari: Ixodidae) on milk production of dairy buffaloes (*Bos bubalus bubalis*) of Punjab Pakistan. *Italian J Anim Sci.* 6:939-941.
- Sajid, M.S., Iqbal, Z., Khan, M.N., Muhammad, G., Needham, G., Khan, M.K., 2011. Prevalence, associated determinants, and *in vivo* chemotherapeutic control of hard ticks (Acari: Ixodidae) infesting domestic goats (*Capra hircus*) of lower Punjab, Pakistan. *Parasitol Res* 3:601-609.
- SAS (2010) SAS/STAT User Guides version 6.12. SAS Inst Inc, Cary, NC, USA.
- Scharlemann JPW, Johnson PJ, Smith AA, Macdonald DW, Randolph SE (2008) Trends in ixodid tick abundance and distribution in Great Britain. *Med Vet Entomol* 22: 238-247.
- Schork MA, Remington RD (2010) Statistics with applications to the Biological and Health Sciences. 3rd edition Lexington KY: USA.
- Schulze TL, Jordan RA, Hung RW (2001) Effects of selected meteorological factors on diurnal questing of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae). *J Med Entomol.* 38:318-324.
- Siddiqi MN, Jan AH (1986) Ixodid ticks of N.W.F.P. Pakistan. *Pakistan Vet J* 6:124-6.
- Singh AP, Singh A (1999) Seasonal dynamics of ixodid ticks infesting the crossbred cattle of Ludhiana district. *Indian Vet J* 76:167-168.
- Singh H, Jyoti J, Haque M, Singh NK, Rath, SS (2012) Molecular detection of *Anaplasma marginale* infection in carrier cattle. *Ticks Tick-Borne Dis* 3:55-58.
- Singh NK, Rath, SS (2013) Epidemiology of ixodid ticks in cattle population of various agro-climatic zones of Punjab, India. *Asian Pac J Trop Med* 6:947-951.
- Sonenshine DE (1993) Biology of Ticks, Vols I and II. Oxford University Press, UK.
- Soulsby EJJ (1982) Helminths, Arthropods and Protozoa of Domesticated Animals, 7th Ed, Elsevier, New Delhi, India.
- Springell PH (1974) The cattle tick in relation to animal production in Australia. *Wild Anim Rev* 10:19-23.
- Swai ES, Mbise AN, Kessy V, Kaaya E, Sanka P, Loomu PM (2005) Farm constraints, cattle disease perception and tick management practices in pastoral Maasai community-Ngorongoro, Tanzania. *Livstock Res Rural Dev* 17:17.
- Teel PD, Marin SL, Grant WE (1996) Simulation of host parasite landscape interactions: influence of season and habitat on cattle fever tick (*Boophilus* sp.) population dynamics. *Ecol Model* 84:19-30.
- Thrusfield M (2007) Veterinary Epidemiology, 3rd Ed, Blackwell Science, London, pp: 231-232.
- Tiki B, Addis M (2011) Distribution of ixodid ticks on cattle in and around Holeta town, Ethiopia. *Global Vet* 7:527-531.
- Vandyk JK, Bartholomew DM, Rowley WA, Platt KB (1996) Survival of *Ixodes scapularis* (Acari: Ixodidae) exposed to cold. *J Med Entomol* 33: 6-10.
- Vatsya S, Yadav CL, Kumar RR, Garg R (2008) Prevalence of ixodid ticks on bovines in foothills of Uttarakhand state: a preliminary report. *Indian J Anim Sci* 78: 40-42.
- Vesco U, Knap N, Labruna MB, Avsic-Zupanc T, Estrada-Pena A, Guglielmone AA, Bechara GH, Gueye A, Lakos A, Grindatto A, Conte V, De Meneghi D (2011) An integrated database on ticks and tick-borne zoonoses in the tropics and subtropics with special reference to developing and emerging countries. *Exp Appl Acarol* 54: 65-83.
- Wahid R, Iqbal A K, Ayaz H Q, H Shujaat (2004) Prevalence of different species of ixodidae (hard ticks) in Rawalpindi and Islamabad. *Pak J Med Res* 43: 22-34.
- Walker AR, Koney E B M (1999) Distribution of ticks infesting domestic ruminants in Ghana. *Bull Entomol Res* 89:473-479.
- Walker AR (2003) Ticks of domestic animals in Africa: a guide to identification of species. Bioscience Reports, Edinburgh, Scotland.
- Walker AR, Bouattour A, Camicas JL, Estrada-Pena A, Horak IG, Latif AA, Pegram RG, Preston PM (2007) Ticks of domestic animals in Africa, Bioscience reports. Edinburgh, UK.
- Walker JB, Keirans JE, Horak IG (2000) The Genus *Rhipicephalus* (Acari, Ixodidae). In: Fauna of the Ixodid ticks of the World (Acari: Ixodidae), Moscow 2009. G.V. Kolonin, (Ed.). A Guide to the Brown Ticks of the World, Cambridge Univ. Press, pp: 643.
- Yacob HT, Atakltly H, Kumsa B (2008) Major ectoparasites of cattle in and around Mekelle, northern Ethiopia. *Entomol Res* 38:126-130.
- Yang LP, Zhang TS, Yuan XP, Zi DY (1993) Two strain of Russian Spring-Summer Encephalitis virus isolated from *Boophilus microplus* and *Hipposideros armiger* in Yunan province. *Chin J Zoonoses* 9:22-3.
- Yi-Lun TSAI, Jacky Peng-Wen C, Shu-Kai C, Jui-Chun HSIEH, Shih-Te C (2011) Survey of species of ticks infesting cattle in Taiwan. *Taiwan Vet J* 37:74-82.
- Zahida T, Sumaira N, Mushtaq HL (2014) The prevalence of ixodid ticks on buffaloes at private animal farm Bibipur, Multan. *Global Vet* 12: 154-157.
- Zaman AK (1997) Prevalence and chemotherapy of ticks among cattle in various refugee camps at Hangu area. MSc. Thesis, NWFP. Agri. Univ., Peshawar, Pakistan.