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Review / *Derleme*

Vectors and Vector-Borne Diseases in Turkey

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Summary: In Turkey, arthropod-borne diseases such as human babesiosis, dirofilariasis, leishmaniasis, malaria, lymphatic filariasis, onchocerciasis, anthrax, bartonellosis, louse-borne relapsing fever, lyme disease, plague, trench fever, tularemia, epidemic typhus, tick-borne typhus, Crimean-Congo hemorrhagic fever, phlebovirus infections, tick-borne encephalitis and west nile virus in humans; animal trypanosomiasis, avian haemosporidiasis, babesiosis, canine hepatozoonosis, canine lesihmaniosis, dipetalonemiasis, dirofilariosis, habronemiasis, onchocerciasis, parafilariasis, setariasis, theileriosis, thelaziasis, anaplasmosis, ehrlichiosis, feline infectious anemia, akabane, bluetongue, bovine ephemeral fever, equine infectious anemia, louping ill, west nile virus, colony collapse disorders (CCD) were reported in domestic animals and *Wolbachia* endobacteria infection was also reported in mosquitos so far. On the other hand, aphids (Aphididae), leafhoppers (Cicadellidae), white flies (Aleyrodidae), beetles (Coleoptera), trips (Thysanoptera), gal mites (Eriophyidae), and nematodes are also very important vectors of plant diseases in Turkey. Some of the most harmful plant viruses in the world such as tristeza, plum pox virus, and tomato ringspot viruses are also transmitted by arthropod vectors. In recent years, in spite of changes in ecological balance caused by abandoning agricultural land, use of natural areas to farm, release of rabbits, preventing water flooding, leaving the fields uncultivated, migration from urban to rural areas, hunting of wild animals, the dramatic drop in the number of farm animals, global warming and the strengthening of wild life was probably responsible for the increase of tick populations. The construction of ponds and dams, changes in riverbeds, drying out of swamps and marshes, dense ad-hoc and haphazard construction, changes in picnicking habits, wild irrigation in agriculture, and the use of unsuitable control measures by local authorities, resulted in an increase of flies. This led to an increase in infected vector populations and vector-borne diseases and a decrease in the potential for economic development. In conclusion, it is very important to initiate and develop integrated control programs targeting arthropod vectors, disease agents of human, animal and plants and natural reservoirs. These diseases have been caused high economic losses in Turkey, and therefore they should be further investigated.

Key words: Animal, human, plant, Turkey, vectors, vector-borne diseases,.

Türkiye'de Vektörler ve Vektörlerle Bulaştırılan Hastalıklar

Özet: Türkiye'de insanlarda babesiosis, dirofilariasis, şark çıbanı, sıtma, lenfatik filariasis, onchocerciasis, şarbon, bartonellosis, bitle bulaşan dönemli ateş (louse-borne relapsing fever), lyme, veba, siper ateşi, tularemia, epidemik tifüs, tick-borne tifus, Kırım-Kongo kanamalı ateşi, phlebovirus enfeksiyonu, tick-borne encephalitis ve batı nil virusu; evcil hayvanlarda trypanasomiasis, kanatlı haemosporidiasisi, babesiosis, köpek hepatozoonosisi, köpek leishmaniosisi, dipetalonemiasis, dirofilariosis, yaz yarası, onchocerciasis, yaz kanaması, seteriasis, theileriosis, thelaziasis, anaplasmosis, ehrlichiosis, kedi enfeksiyöz anemisi, akabane, mavidil, üçgün hastalığı, loupingill, enfeksiyöz at anemisi, arıların colony collapse hastalığı (CCD) ve sivrisineklerde *Wolbachia* endobakteri enfeksiyonu şimdiye kadar rapor edilen artropod kaynaklı hastalıklardır. Diğer taraftan, Türkiye'de yaprak bitleri (Aphididae), yaprak zararlıları (Cicadellidae), beyazsinekler (Aleyrodidae), kın kanatlılar (Coleoptera), kirpik kanatlılar (Thysanoptera), gal akarları (Eriophyidae) ve nematodlar da bitki hastalıklarının önemli vektörleridirler. Tristeza, şarka, domates halkalı leke virüsleri gibi dünyadaki en zararlı bitki patojenlerinin de uygun vektörleri olmadan epidemi yapamadıkları bilinmektedir. Tarım alanlarının terk edilmesi, doğal alanların tarıma açılması, doğaya tavşan salınması, su taşkınlarının önlenmesi, yayla yasağı, av yasağı, tarlaların işlenmemesi, kırsal hayattan şehirlere göç, yırtıcı hayvanların öldürülmesi, çiftlik hayvanlarının sayısındaki dramatik düşüşe karşın yaban hayatının güçlenmesi ve küresel ısınma gibi son yıllarda ekolojik dengelerin değişmesine yol açan faktörler kene sayısında artışa yol açan olası nedenlerdir. Fizibilite yapılmadan gölet ve baraj inşası, nehir yataklarının değiştirilmesi, bataklık ve sazlıkların kurutulması, plansız ve gelişigüzel yoğun yapılaşma, piknik kültüründeki değişiklik, tarımda vahşi sulama, yerel yöneticilerin bilimsel yaklaşımdan yoksun, bilinçsiz vektör mücadelesi de sinek populasyonlarında artışa sebep olmuştur. Bu durum da vektör populasyonunda, vektörlerle bulaştırılan hastalıklarda artışa ve dolayısıyla ekonomik gelişmelerde azalmalara veya yavaşlamalara yol açmaktadır. Sonuç olarak, Türkiye'de insan, hayvan ve bitki sağlığını tehdit ederek ekonomik kayıplara yol açan vektörlere ve bu vektörlerin bulaştırdıkları hastalıklara karşı mücadele programları geliştirmek ve başlatmak, bu konuda daha ileri araştırmalar yapmak oldukça önemlidir.

Anahtar sözcükler: Bitki, hayvan, insan, Türkiye, vektörler, vektörlerle bulaşan hastalıklar.

Introduction

The majority of the described infections are vector-borne diseases and most of them are described as emerging, reemerging and zoonotic diseases in The World (92). In Turkey, several vector-borne diseases including equine infectious anemia have already been investigated until today. Currently, presence of these diseases such as human babesiosis, leishmaniasis, malaria, lymphatic filariasis, onchocerciasis, anthrax, bartonellosis, louse-borne relapsing fever, lyme disease, plague, trench fever, tularemia, epidemic typhus, tick-borne typhus, Crimean-Congo hemorrhagic fever, phlebovirus Infections, tick-borne encephalitis and West Nile Virus in humans; animal trypanosomiasis, avian haemosporidiasis, babesiosis, canine hepatozoonosis, canine leishmaniasis, dipetalonemiasis, dirofilariosis, habronemiasis, onchocerciasis, parafilariasis, setariasis, theileriosis, thelaziasis, anaplasmosis, ehrlichiosis, feline infectious anemia, akabane, bluetongue, bovine ephemeral fever, equine infectious anemia, louping ill and West Nile virus in domestic animals and colony collapse disorders (CCD) in honeybee, *Wolbachia* endobacteria infection in mosquitoes have been recorded in Turkey. On the other hand, Aphids (Aphididae), leafhoppers (Cicadellidae), white flies (Aleyrodidae), beetles (Coleoptera), trips (Thysanoptera), gal mites (Eriophyidae), and nematodes have been also described as important vectors of plant diseases in Turkey. Some of the most harmful plant viruses in the world such as Tristeza, plum pox virus, tomato ringspot viruses are transmitted by vectors. In this article it was aimed to review vector-borne diseases which have already been investigated and described in Turkey.

Human babesiosis (HB): HB is an infectious disease caused by protozoa of the genus *Babesia*. *Babesia* species are transmitted by ticks. *Babesia divergens* and *Babesia microti* are the most significant etiologic agents of human babesiosis cases in Europe and in U.S.A. respectively. In Turkey, the seropositivity of *B. microti*, *B. divergens* and *B. bovis* was reported as 6.23% (149), 8% (65) and 18% (106) in human populations respectively.

Leishmaniasis: Zoonotic visceral leishmaniasis (ZVL) caused by *Leishmania infantum* and cutaneous leishmaniasis (CL) caused by *L. tropica* and *L. infantum* were reported in Turkey. These diseases are notifiable diseases in Turkey since long time. The ZVL has been seen in Aegean and Mediterranean regions endemically and reported sporadically in other regions. It was reported from 38 provinces and the population under the risk has been estimated around 45 million. The official number of cases was reported between 50 and 60 annually but most cases are underreported. It is consistent with Mediterranean type and mostly seen in infants. *Leishmania* strains were isolated from human/dogs in different regions and identified as *L. infantum* MON-1 and MON-98 by multilocus enzyme electrophoresis (MLEE) also known as zymodeme analysis. Antimonials and Liposomal Amphotericin B are being used for the treatment as first choice (136, 142). CL was characterized by long-term nodulo-ulserative lesions healing spontaneously with scarring and the disease has been seen in southeastern and East Mediterranean Regions endemically/epidemically. It has been spreading from endemic regions to other regions because of the different epidemiological factors. CL with different clinical types was reported in 41 provinces but more than 90% of the total cases were concentrated in 5 provinces (Sanliurfa, Adana, Osmaniye, Mersin, Aydin) located in southeastern, east Mediterranean and western regions of Turkey. According to Ministry of Health's official records, 46.003 new cases were reported between 1990 and 2010. Among those cases, 96% of them were reported from Şanlıurfa, Adana, Osmaniye, Hatay, Diyarbakır, İçel and Kahramanmaraş provinces. Although 45% of the cases were notified from Şanlıurfa in the last 20 years, its ratio is currently decreasing while other regions' ratios have been showing an increasing trend. Antimonials (intralesional or systemic) are the first line drugs for treatment (70).

Human Malaria: In recent years, the number of malaria cases in Turkey and their active foci has decreased significantly. Although more than two million patients were treated in 1945, only four cases of *Plasmodium vivax* (relapsing cases) were reported in 2011. The first malaria control program was launched in 1925. Since 1971, the number of malaria cases in the Çukurova and Amikova plains began to increase, reaching epidemic proportions in 1976 and 1977, when 37,320 and 115,512 cases were reported, respectively. The situation deteriorated again, however, with over 34, 000 cases in 1980 and 66,673 in 1983. Between 1990 and 1996 years, the malaria situation remained critical. The cases peaked to 84,321 in 1994. The situation began to improve only in 1997, when case numbers were cut in half from the previous year. Incidence of the disease was increased particularly in areas where the Southeastern Anatolia Project (GAP) irrigation program was being implemented (14).

Lymphatic Filariasis (Elephantiasis): Elephantiasis is caused by the nematodes such as *Wuchereria bancrofti*, *Brugia malayi* and *B. timori*. The adults of these round worms lodge in the lymphatic system and disrupt the immune system of the host. They live for 6-8 years and, during their life time, produce so many of microfilariae circulating system of the host. The disease is transmitted by mosquitoes belonging to the genera *Culex*, *Anopheles* and *Aedes*. Currently, about 1.3 billion people are under the risk potential in several countries and approximately 65% of those live in the South-East Asia Region, 30% in the African Region, and the

remainder in other tropical areas according to WHO records. In Turkey, a case was recorded from an 11-year-old girl presented with swelling in both legs from Kozan in 2006 (35).

Anthrax: Anthrax is an infection of humans and other mammals caused by the bacterium *Bacillus anthracis*. Although the vast majority of human cases are related directly from infected carcasses or the handling of contaminated products from morbid animals, the transmission of the disease has been demonstrated with wide variety of tabanid and mosquito species, and with stable-flies (*Stomoxys* spp) (44). The disease has wide distribution in the World, and is also an endemic zoonosis in Turkey. A total of 967 (464 from animals and 503 from humans) anthrax cases were reported from Eastern Turkey between 1992 and 2004 years (146). On the other hand only human anthrax cases have been recorded as 926 in Turkey between 1990 and 2007 (42).

Bartonellosis: Bartonellosis is caused by different *Bartonella* species, and is usually transmitted by hematophagous insects, such as sandflies (*Lutzomyia* spp), fleas, and lice and also by animal scratches and bites (120). Although the reports about this disease are limited in Turkey, the seropositivity rate of *Bartonella henselae* was recorded as 18.6% in cats (33), 6% in human blood donors (195) and 16.9% in kidney transplant patients (111), 22.2% in cattle breeders and veterinarians (161) while the seroprevalence of *B. vinsonii* subsp. *berkhoffii* was recorded as 6.6% in dogs (34) in Turkey.

Louse-Borne Relapsing Fever: Louse-borne relapsing fever is a disease of human caused by spirochaetes, *Borrelia recurrentis*, and can be disseminated by war, famine and other disasters. It was reported that during the first half of the 20th century, there were at least 50 million people with the infection and 10 million of them died in Europe, the Middle East and northern Africa. After the 1st World War, the disease speared and the epidemics extended notably into Turkey and Persia in 1920-1921 (183). After the 2nd World War, the infection rose again into the Middle East and it has continuing potential for epidemic spread of the infection from its current foci in some parts of Africa (181).

Lyme Disease: The disease is caused by *Borrelia burgdorferi* and transmitted via ixodid ticks especially *Ixodes ricinus*. The distribution of the disease is correlated the prevalence of hard ticks. The vector tick mainly occurs in moist habitats like woodlands, urban parks and also pastures in maritime climates. In Turkey, the seroprevalence of *B. burgdorferi* was found 17% in human in rural area of Samsun province (18) and 23.2% in dogs and 6% in horses (25).

Plague (Black Death): The disease is zoonotic and transmitted from rodent to rodent and from rodent to man via biting of fleas. Man can also be infected by direct contact with infected animal tissues. Pneumonic plague can result from direct human to human transmission. The causative agent is the bacterium, *Yersinia pestis*. Urban plague describes the situation where plague circulating among wild rodents. The infection is maintained in the rat population by fleas, such as *Xenopsylla cheopis* (Asia, Africa Europe and the Americas), *Xenopsylla astia* (Shout-East Asia) and *Xnepsylla brasiliensis* (Africa, India and South America). Rarely, plague is spread directly from person to person by fleas, such as *Xenopsylla* species and so-called human flea, *Pulex irritans* (130). The first recorded appearance of the plague in Europe was at Messina, Sicily in Middle Ages (October, 1347). It was estimated that it arrived on trading ships that very likely came from the Black Sea, past Istanbul and through the Mediterranean. At that time, it was estimated that a quarter people of Europe killed from the Black Death. Within the last decade, human plague cases have been reported from countries in Africa, America and Asia. During the decade of the 1990s through 1996, there were 16,005 cases of plague and 1214 deaths (7.6%) reported to the World Health Organization (30). There is no official record about this disease in Turkey.

Trench Fever: The disease is caused by *Bartonellea Quintana,* and was first detected during the First World War and the Second World War years and then it disappeared. Later it has been reported in homeless people in Mexico, North America and Europe. The agent of the infection is transmitted by human body louse, *P. humanus* (73). The disease has not been reported from Turkey by this date.

Tularemia: Tularemia is also another important vector-borne zoonotic disease in Turkey. The pathogenic agent of the disease is Gram-negative and facultative intracellular bacterium *Francisella tularensis.* The transmission of the infection can be disseminated by contact with infected animals or blood-sucking vectors such as ticks, mosquitos, and flies. Although many human cases of tularemia have been reported each year in Turkey, there is no record that reflects the status of this disease in animals and as well in the vectors. This disease has been initially reemerged in 1988 in Marmara Region of Turkey. Then, the infection has been spread all over the Turkey. A total of 4824 human cases with tularemia were recorded by Ministry of Health in Turkey between 2005 and 2011 years (43). Tularemia outbreak was initially observed in 2005. First case was diagnosed at the Department of Infectious Disease, Erciyes University Hospital in 2005. The patient came to the hospital from Sariz town which is from east part and 120 km far from the center of Kayseri. Following years, the cases spread all villages located at the northeast, east and southeast part of Kayseri. Tularemia is still an endemic disease in Kayseri and around (108).

Epidemic Typhus (louse-borne typhus): Epidemic typhus is a louse-borne rickettsial disease caused by *Rickettsia prowazekii* in humans. In the past, reported epidemic typhus cases were associated with wars and also human disasters. It was estimated that over 20 million people were infected *R. prowazekii* after the First World War (1914-1918) and almost 20% of the infected people died in Eastern Europe from the infection. It was also estimated that 7 million people died from epidemic typhus after the Second World War (1939-1945) and typhus cases still occur in war-torn countries today (74). Only one epidemic typhus case was reported from Turkey (170). After that there is no information about presence of the infection in Turkey by this time.

Tick-borne Typhus (Mediterranean Spotted Fever, MSF): The disease is caused by *Richettsia conorii* and transmitted by dog tick *Rhipicephalus sanguineus*. Until today, a limited number tick typhus cases were reported from Turkey (127, 162, 186).

Crimean-Congo Hemorrhagic Fever (CCHF): CCHF is an acute viral and contagious infection in human (140). Wild and livestock animals serve as amplifiers for CCHF virus in field conditions. The infection is mainly transmitted by ixodid ticks especially *Hyalomma marginatum* in endemic areas. CCHF virus can also be transmitted to human through contact with the infected blood of viremic man and as well livestock animals. In Turkey, since 2002 about 6000 people became infected with the Crimean-Congo hemorrhagic fever and nearly 400 of them have died. Ticks like *H. marginatum,* which are common in Turkey, have been identified as the vectors of Crimean Congo hemorrhagic fever to humans and animals in Kayseri region. The disease is spreading throughout Turkey (180); however the conditions in Kayseri province and its surroundings are particularly favorable for its development and spread.

Phlebovirus Infections: Four serotypes of phleboviruses, sand fly Sicilian virus (SFSV), sand fly Cyprus virus (SFCV), sand fly Naples virus (SFNV), and Toscana virus (TOSV), have been circulating in the Mediterranean Basin including Turkey. Sand flies are the biological vector for phleboviruses and the virus can also be transmitted transovarially (39, 122). SFSV, SFNV, and other related viruses cause sand fly fever, also known as 'three-day fever' or 'pappataci fever' in human. TOSV also causes neurological disorders, such as meningitis, encephalitis and meningoencephalitis (39, 41). In Turkey, first reports were published in 1975 and 1976. The seroprevalence of SFSV was reported as 5.2% in Aegean region and 22% in Mediterranean region while SFNV was reported as 28.3% in Aegean region and 62% in Mediterranean Region (172). Later studies were also showed the activity of SFNV and TOSV in different areas (139, 163). Toscana virus exposure was also detected in blood donors in Central, North and South/Southeast Anatolia of Turkey (55) and its association with central nervous system infections (54). Recently, the outbreaks in 3 different areas (Izmir, Ankara and Adana provinces) were happened in Turkey and new phlebovirus, Sand fly Fever Turkey Virus, was described (32). In 2011, phlebovirus RNA was also detected in 3 *Phlebotomus major s.l.* female specimens collected from Ankara province and characterized as Sand fly Fever Turkey Viruses (56).

Tick-borne Encephalitis (TBE): Tick-borne encephalitis is most important tick-transmitted disease in man and occurs in Europe and Asia. The pathogenic agent of the disease is tick-borne encephalitis virus, a member of the genus *Flavivirus* in the family Flaviviridae. Although TBE reports are very limited, the seropositivity of the disease was found as 10.5% in southeastern (52) and 1.43% in Central Anatolia (179) in Turkey.

West Nile Virus (WNV): WNV infection has a worldwide distribution. The infection is mainly transmitted by mosquitoes. The virus has been isolated from several mosquito species. Especially *Culex* species have been found infected with the virus. In Turkey, a few seroepidemiological studies about WNV infection have been carried out in humans and also in animal. The results of serological investigations were reported as 0.99% (53) and 16% (141) in man and betveen 1-37.7% in domestic animals (143). Recently some molecular epidemiological studies have been also performed on WNV infection and the first case was detected in horse in Central Anatolia, Turkey (144). Additionally, the infection was also investigated in mosquitos using molecular techniques (141).

Trypanosomiasis (Animal Trypanosomiasis): The disease is caused by belonging to the genus *Trypanosoma*. Although some *Trypanosoma* species (e.g. *Try. equiperdum*) are transmitted directly between hosts, the transmission of the infection is possible by blood-sucking insects. The disease principally affects domestic livestock animals in Africa, and is associated with severe production losses (102). In Turkey, this disease has not been reported except one sub clinical case *Trypanosoma theileri* infection associated with *Theileria annulata* infection in cattle in Ankara (81) by this date.

Avian Haemosporidiasis (Avian malaria): The disease is a mosquito-borne protozoon infection of wild birds and fowl. The infections are caused by a complex of more than fifty species of *Plasmodium.* In addition to *Plasmodium* species, infections with *Haemoproteus* and *Leucocytozoon* are also responsible for the avian haemosporidian diseases. Species belonging to *Culicodies* and *Simulium* are the known vectors of the latest species, respectively. The occurrence of the infections is differed depend on host rage, geographical distribution, vector species and the virulence of the parasite. Avian haemosporidiasis begins when infective sporozoites are injected by a dipteran insect and are carried around the

body until they invade cells of the lymphoid-macrophage system in brain, spleen, kidney, lung and liver tissue where they undergo a phase of asexual multiplication (exoerythrocytic schizogony) resulting in the production of many uninucleate merozoites. The life cycle involves the sexual process and sporogony which occurs in the invertebrate host (vector) and the merogony and development of gametocytes which takes place in avian hosts (20, 75, 99, 134). Recently, presence of partial *cytb* gene of avian haemosporidian mt-DNA from *Culex pipens*, *Aedes vexans*, *Culex theileri* and *Culiseta annulata* collected from Kayseri province has been reported for the first time in Turkey. In addition among phylogenetically analyzed isolates, 11 lineages belonging to *Plasmodium* were characterized in four phylogenic groups whereas two lineages belonging to *Haemoproteus* were characterized in one phylogenic group in the same study. On the other hand *Cx. pipiens* was found be the major vector of avian *Plasmodium* in the study area (94). Regarding to *Haemoproteus* infections the first molecular detection and characterization of *Haemoproteus* spp. lineage in an owl from Mugla region was also reported in Turkey (192).

Babesiosis: Babesiosis [bovine babesiosis (BB, Redwater, tick fever), ovine babesiosis, equine babesiosis, canine babesiosis] is very important tick-borne disease of domesticated animals such as cattle, sheep, horses, dogs, and is caused by intraerytrocytic parasite of the genus *Babesia*. The main causative agents of BB are *Babesia bigemina* and *B. bovis* and the principle tick vectors of the disease are *Boophilus* species in tropical and subtropical climates, and the disease causes magnitude economical losses in livestock industry in the endemic areas. BB is also very important cattle disease, and causes great economic losses in Turkey as well as in the World (47). BB was first defined by microscopically in 1890 in Turkey (91). Following, some studies on BB were carried out by microscopic (50, 61, 77, 165), serological (36, 80, 85) and molecular studies (46-48, 90, 97, 187) in Turkey. The causative agents of BB were detected in ticks which were collected from cattle in Kayseri region (76). On the other hand some field studies were also performed on ovine babesiosis (37, 40, 83, 87, 156), equine babesiosis (82, 112) and canine babesiosis (96, 178).

Canine Hepatozoonosis: The disease is a tick-borne and protozoal disease of dogs. The causative agent is *Hepatozoon canis* which primarily infects haemolymphatic tissues and causes anemia and lethargy, and *Hepatozoon americanum* which localize in muscular tissues and leads to severe myositis and lameness in dogs. Old World canine hepatozoonosis caused by *H. canis* is transmitted by *Rhipicephalus sanguineus* whereas American canine hepatozoonosis caused by *H. americanum* is transmitted by *Amblyoma maculatum*. The transmission of the both infections to dogs occurs by oral ingestion of the infected ticks with the mature oocyts of protozoon parasites (23). *H. canis* was first detected in India in 1905 and then it has been reported from Europe, the Middle East, Africa and Far East while *H. americanum* was recorded from Texas in 1978 and since this date some cases associated with *H. americanum* have been reported from several states in U.S.A. In Turkey, *H. canis* infection was first detected in 1933 (174) and in last decade a few *H. canis* cases were also reported from several part of Turkey (104, 110, 166).

Canine Leishmaniasis (CanL): CanL is another serious vector-borne disease of domesticated dogs and wild canids. Dogs can be infected with several *Leishmania* species, but the most important clinical picture of canine leishmaniasis is viscerocutaneous leishmaniasis, caused by *Lesihmania infantum*. CanL mainly occurs in the Mediterranean Basin. The infection is also widespread in some countries in Shouth and Central America. The infection (all forms) is transmitted by sand flies in the endemic regions (17). The infection is also prevalent in dogs in Mediterranean and Agean Sea regions of Turkey. The epidemiology of leishmaniosis was first investigated in the Mediterranean Region (137). Following, some studies were also carried out for CanL using serological tests (38, 138) and molecular techniques (78, 131, 138) in various regions in Turkey.

Dipetalonemiasis (Acanthocheilonemiasis): Dipetalonemiasis is another arthtopod-borne and helmintic infection of humans and animals caused by genus *Dipetalonema*. Althgouh the disease is described as a rare disease, it has been recorded in some part of the World and recently a clinical dipetalonemiasis case in a dromedary camel in Pakistan was reported (129). In Turkey, *D. reconditum* was first reported in 1966 in dogs in various parts of Turkey (51). Afterwards, canine filariosis were investigaeted around Istanbul and the microfilariae of *D. reconditum* was detected as an agent of canine filariasis in the research area (173).

Dirofilariosis (Canine Heartworm): Dirofilariosis is another vector-borne disease of dogs, caused by most important nematod parasite *Dirofilaria immitis*, and has a worldwide distribution in tropical, subtropical and temperate zones. *D. immitis* is transmitted by mosquito species including genara of *Culex*, *Aedes*, *Ochlerotatus*, *Anopheles*, *Armigeres* and *Mansonia* (15, 31, 147). Transmission of dirofilariosis depends on the presence of sufficient numbers of infected, microfilaremic dogs, susceptible mosquitoes, and a suitable climate to permit extrinsic incubation of parasite in the mosquito vector (123). In Turkey, the canine heartworm is widespread and was reported from dogs in several provinces. The prevalence of disease has been reported between 0.2% and 30.0% from several regions of Turkey (27, 79, 189, 190). Currently, the risk potential of *D. immitis* as a

problem for Turkey was also investigated using molecular analyzing techniques in potential mosquito vectors in Central Anatolia, according the results of the research, *Ae. vexans* was determined as the main potential vector of *D. immitis* in Kayseri (191). On the other hand, some dirofilariasis cases were also reported as orbital dirofilariasis (24, 66, 167), premasseteric (117) and foot nodules (116) in man.

Habronemiasis (Summer Sores): Habronemiasis is a dipteran- borne nematode infection of horses, caused by *Habronema muscae*, *H. majus* (synonym *H. microstoma*) and *Draschia megastoma* (formerly *H. megastoma*) species. The disease causes gastric, pulmonary, cutaneous lesions called "summer sores" (118) and ophthalmic (185) habronemiasis forms in infected horses. The infection is ubiquitous and it was reported from several countries in The World and the prevalence of habronemiasis in horses was recorded as 0.8% according to the necropsy findings (8) in Turkey.

Onchocerciasis: Onchocerciasis *is very serious simulid-borne diease of* humans and animals which has three principal manifestations: subcutaneous nodule formation, dermatitis, and blindness. About 27 species of *Onchocerca* infect animals and onchocercal infections occur worldwide and very common in cattle, horses and donkeys. The accidental infection of humans by animal *Onchocerca* species (probably *O. gutturosa*) has been reported from North America, Europe and Japan (152). The causative agents of the diease are transmitted by black-flies of the genus *Simulium. Simulium* species feed on a variety of mammals and birds, and their painful bites cause considerable annoyance. The transmission of the disease associated with afflictions; first microfilariae ingested during feeding migrate to the flight muscles of the fly and moult twice over one week. They then migrate to the proboscis and develop into infective third-stage larvae which are transmitted to vertebrate hosts during feeding. In Turkey, one human onchocercosis case caused *O. caecutienus* was reported for first time in 1976 (196). Following, bovine onchocercosis caused *O. armillata* was recorded in the shoutern part of Turkey, and the prevalence of the disease was also reported as 86% in over 1 year old and 18% in under 1 year old cattle (9). Recently, ocular onchocercosis case in a human was repoted from Edirne province of Turkey and the nematode was identified as *O. lupi* based on its morphology and molecular phylogenetic analysis of partial *cox* 1 and 12S ribosomal DNA genes (155). Recently, the risk potential of simulid infestation as a vector for transmission of *Onchocerca* species to humans and also livestock animals in Central Kizilirmak basin (including along the river of Nevsehir area) in Turkey was also investigated using TaqMan probe bazed Real Time PCR assay. According the results of the study, 2 of the examined pools which were consisted from adult simuliid speciemens found to be positive for *Onchocerca* spp (98).

Parafilariasis (Summer Bleeding): Parafilariasis is another insect-borne infection of horses and cattle caused by nematods of the genus *Parafilaria*. The causative agents of the disease are *P. bovicola* and *P. multipapillosa* which live in subcutaneous tissues of infected animals and pierce the skin to relase eggs in blood. The vectors of the infections are muscid flies, *Musca autumnalis*, *M. lusoria* and *M. xanthomelis* and the biting dipteran *Haemotobia atripalpis.* The transmission of nematod parasites are disseminated by vector insects while feeding blood from the lesions. Vector flies ingest eggs of the parasites together with blood, then the eggs hatch, larvae invade the tissues of the infected fly and develop to third-stage larvae (L3). L3 move to the mounthparts of the fly and enter the host at the refeeding time on a lesion or on the orbit of another host. Parafilariasis has a widespread distrubion in the World (12). In Turkey, some clinical parafilariosis cases in cattle have been reported from Malatya area (169) until today.

Setariasis: Setariasis is a mosquito-borne disease of ungulates with the filarial worms of the genus *Setaria*. It was reported that, of the livestock bovids and horses are natural hosts for *S. digitata* and *S. equine*, respectively whereas sheep, goats and horses are abnormal hosts for *S. digitata*. *S. digitata* is considered to be non-pathogenic in natural hosts while the transmission of the infective stage larvae to abnormal hosts (e.g. sheep) causes severe neuropathological defects (184). The causative agents of the infections in abnormal hosts are transmitted by mosquito species beloning to the genera *Aedes*, *Anopheles*, *Armigeres* and *Culex* in different regions of the World. When the infected mosquito feeds, the infective larvae of the parasite actively pass down the proboscis to be deposited on the host's skin, and then enter the host through the puncture caused by the mosquito bite. The infections occur often in Far East and Asia. For example in China, the prevalence of the disease in sheep and goats was reported as many as 30-40% (184). In Turkey, several *S. equina* infections in horses were reported (8, 29, 67). Recently the prevalence of *S. equina* was recorded as 15% in equids in Ankara (135).

Theileriosis: Theileriosis is a tick-borne protozoan disease of ruminants, equids and felids. The causative agents of infection are *Theileria* species. The natural transport of the infection from an infected animal to other susceptible animal is possible with trans-stadial transmission, depending on gametocytes in the blood of infected animals being ingested by the larvae or nymphs of the particular species of two or three host ixodid ticks (150, 154). The disease occurs in two forms such as malign theileriosis and benign theileriosis in infected animals (95). The malignant theileriosis of cattle and

sheep causes morbidity and mortality in susceptible animals. European cattle breeds and their cross-bred are very susceptible to the malign bovine theileriosis and so considerable loss of productivity is seen due to infection in the endemic areas. Tropical theileriosis (Mediterranean coast fever, bovine malaria) is one of the malignant cattle theileriosis is caused *Theileria annulata.* The agent of the disease is transmitted by *Hyalomma* ticks (2, 159), and is widespread throughout Turkey (2, 21, 88, 158). The epidemiology of the disease has been also investigated deeply using microscopic (83), serologic (160), biochemical (22) and molecular (10, 45, 76, 97) methods in Turkey. The infection causes heavy damage to animals in the Develi, Yesilhisar and Incesu districts of Kayseri province as well as in the other endemic regions of Turkey (84, 86). In this region only, economic losses due to tropical theileriosis in cattle were estimated to be approximately USD 600,000 for two years (89). On the other hand ovine theileriosis was also researched by field observations and laboratory analysis (3, 11, 88, 93) but malign theileriosis of sheep has not been reported in Turkey up today. Meanwhile recently, a few molecular researches were also carried out on *Theileria equi* which causes equine theileriosis (112). Feline theileriosis has not been documented until today in Turkey.

Thelaziasis: Thelaziasis is a dipteran-borne and ocular infection of animals and humans, caused by spirurid nematods belonging to the genus *Thelazia* commonly known as eyeworms. The most pathogenic species of these eyeworms is *T. rhodesii* that infects cattle in many regions of The World (119). In Turkey, bovine thelaziasis caused by *T. rhodesii* reported as widespread and the prevalence of the parasite was reported as 22% (69) and 5.5% (171) in cattle and 1,2% in buffalo (68).

Anaplasmosis (Gall Sickness, Tropical Bovine Ehrlichiosis): Anaplasmosis or gall sickness is principally a tick-borne disease of cattle, sheep and wild ruminants that caused by intra-erythrocytic *Anaplasma* species. In addition the transmission of the disease is also possible iatrogenic and mechanical by blood sucking insects such as *Tabanus* spp. and *Stomoxys* spp. The disease has a worldwide distribution in tropical and sub tropical regions. Causative organisms of gall sickness are *Anaplasma marginale*, *A. centrale* and *A. caudatum* while the agent of anaplasmosis of leucocytes (Tropical Bovine Ehrlichiosis or mononuclear/agranulocytic anaplasmosis) is *Anaplasma (Ehrlichia) bovis*. *Anaplasma* species recently have been classified within the genogroup II of ehrlichial complex based on analyzing of 16S ribosomal RNA gene sequences (113, 153). In Turkey, bovine anaplasmosis cases have been reported clinically (145), microscopically (26), serologically (49) and molecularly (4). The molecular prevalence of causative agents of bovine anaplasmosis was detected in the ticks which were collected from the cattle in Black Sea Cost of Turkey (5, 6). On the other hand additionally, blood parasites of dogs were investigated to determine the prevalence with mocular techniques in Kayseri area. In the study, the prevalence of *A. phagocytophilum* was found to be 8% according to results detected by real time PCR analyses (96).

Ehrlichiosis: Ehrlichiosis is a tick-borne disease caused by *Ehrlichia* species in tribe Ehrlichieae. The causative agents of the disease are obligate intracellular Rickettsialles and infect granulocytes, agranulocytes or platelets of human, domesticated animals and also wild animals. Ehrlichiosis was recognized as a problem in the Old World before its presence in the New World was discovered. Dogs in Africa were to be found infected in 1930s, and tick-borne fever (TBF) was recognized in ruminants in Europe and the UK around 1950 (59). The causative agent of TBF, now known as *Ehrlichia phagocytophila*, was found to be transmitted by the tick *Ixodes ricinus*. Following the discovery of *E. chaffeensis* as a zoonotic agent, another human pathogen was recognized in North America. *Ehrlichia canis* is widely distributed in domestic dogs in The World, and is transmitted by *Rhipicephalus sanguineus,* called dog tick (153). In Turkey, limited studies were carried out for canine ehrlichiosis. In a study in Ankara, 12 dog blood samples were examined for *E. canis* infection using *E. canis*-specific PCR and three of them were found to be positive by PCR using *E. canis*-specific primers. One of the positive isolates (*E. canis* strain, Kutahya) was found identical to Venezuelan Dog Ehrlichia (VDE) and was closely related (99.9%) to strain of *E. canis*, Oklahoma (177). Following clinically first ehrlichiosis case was reported from a dog in Aydin province in 2007 (176). On the other hand the seroprevalence of *Anaplasma phagocytophilum* in humans was reported as 10.62% in Sinop and 5.77% in Tokat (64). In addition very soon the molecular prevalence of blood parasites of dogs in Kayseri region was investigated by highly specific TaqMan Real Time PCR technique for the first time. In the study, totally 224 (56.0%) out of the 400 dog blood samples were found to be infected with at least one parasite species in Kayseri province. *Ehrlichia canis* had the highest prevalence among with the rate of 15.0% according to results detected by real time PCR analyses. This rate was followed by *B. canis canis* (12%), *B. gibsoni* (9%), *A. phagocytophilum* (8%) and *N. caninum* (6%) (96).

Feline Infectious Anemia: Feline infectious anemia (FIA, haemobartonellosis) is one of most imported vector-borne diseases of cats. The infection is caused by *Mycoplasma haemofelis* when combined with feline leukemia virus. Cats become infected via biting of infected flea. Some clinical cases about the infection were reported in Turkey (19, 115, 175).

Akabane: Akabane (AKA) virus is a mosquito-borne and infects pregnant ruminants such as cattle, sheep and goats. The virus belongs to Bunyaviridae family and has a wide distribution in the World (125). In Turkey, the seroprevalence of AKA has been reported as 0.5% in sheep, 22% in cattle in Black Sea Region (Samsun, Sinop, Ordu, Amasya and Tokat provinces) (7), as 0.14% in cattle in Thrace (105) in Turkey.

Bluetongue Virus: Disease with bluetongue virus (BTV) is an insect-borne disease and causes non contagious infections in domestic ruminants particularly in sheep. The virus has worldwide distribution. Several bluetongue outbreaks were reported from Aegean, Mediterranean Sea and Thrace regions of Turkey between 1977 and 2000 years; BTV-4, BTV-9 and BTV-16 serotypes of Bluetongue virus were isolated; BTV-4 of them was attenuated and then used successfully as vaccine to control of the disease in vaccination programs in the country (58). In this period, some epidemiological investigations were also performed on seroprevalence of the disease and on the vector of the agent. The epidemiological studies showed that the vector of the BTV is *Clucoides imicola* (100); the seroprevalence of disease were recorded as 73.54% cattle in Thrace (105), 3% in sheep, 11% in cattle in Middle Black Sea Region (7) in Turkey.

Bovine Ephemeral Fever (BEF): Bovine ephemeral fever is another vector-borne disease of cattle and water buffalo. The infection is caused by BEF virus and occurs in virtually all of Africa, the Middle East and Asia. BEF epizootics occur in summer and autumn and have a strong association with recent rainfall and BEF virus has been isolated from a pool of *Culicoides* species in several countries (126). In Turkey, the seroprevalence of Ephemeral fever virus in cattle was reported between 2.5% and 15.3% in Thrace (105) and 13.5% in Middle Black Sea Region (7).

Equine Infectious Anemia (Swamp Fever, EIA): EIA is a viral infection of equids. The causative agent is a lentivirus, and transmitted by biting flies. Although a lot of seroepidemiological studies were carried out for EIA in the World, the seropositivity has not been reported in equids in Turkey until today (121).

Louping-ill (Infectious Encephalomyelitis of Sheep, LI): Ll is a tick-transmitted and acute viral disease of mainly sheep/goats, but it can be recognized rarely in cattle and horses. LI virus characteristically causes an encephalomyelitic disease of sheep. The occurrence of LI infection is closely related to the distribution of the primary vector tick, *Ixodes ricinus*. A specific acute encephalomyelitis was recognized in sheep in north western part (Gebze and Kırklareli areas) of Turkey and the isolated agent was defined as member of the Louping ill/Russian Spring Summer Virus complex and then the isolated virus was described as Turkish sheep encephalitis (TSE) virus and coded as TTE80 strain (71). Later TTE80 strain was also characterized as a subgroup in tick-borne viruses of Flaviviridae family by antigenic, pathogenic and molecular analyses (60).

Colony Collapse Disorders (CCD): Honey bees (*Apis mellifera*) are the most important insects both economically valuable and as a pollinators of agricultural crops worldwide. These economically valuable insects are affected from so many pathogens such as bacterium, virus, fungus, parasite and also some predators including man. The most of these pathogens cause severe diseases and very serious damages in honey bee colonies. CCD is associated several diseases. It was characterized with the severity and unusual colony declines in honeybee colonies, and was first described in 2006 in U.S.A. Recently, CCD was also reported as the main factor of the huge economic losses in beekeeping units all around the World (101). In Turkey, a few studies were carried out on the role of the viruses [e.g. Deformed Wing Virus (DWV)] which cause CCD and their transmission by "Varroa Mites", *Varroa destructor*. The vectoral role of *V. destructor* for DWV was determined in the honey bee colonies with CCD in Hatay. The vectoral role of varroa for deformed wing virus was determined in the CCD colonies of Hatay (132).

Wolbachia Endobacteria: *Wolbachia* Endobacteria is maternally inherited endosymbiont in so many kinds of insects (e.g. mosquito species), arachnids, crustaceans and some filarial nematod species such as *Dirofilaria* spp. It is estimated that 65% of insect species are infected with *Wolbachia*. In arthropods, *Wolbachia* is responsible for inducing a number of reproductive modifications that enable its spread and maintenance in natural populations (28). Recently considerable researches have been performed on *Wolbachia* that related to the interaction of *Wolbachia* and its host and impacts on parasite transmission (28). The results of the study have prompted researchers to propose strategies that utilize *Wolbachia* infections that limit parasite proliferation in the insect host to aid in the control of disease transmission and so an important step has been taken for *Wolbachia*-based control strategies, the release of *Wolbachia*-infected mosquitoes in a natural population with the ultimate goal of aiding in the control of mosquito-transmitted disease (28). In Turkey, a recent study was carried out to investigate the precence of *Wolbachia* Endobacteria in *Culex pipiens* specimens collected from Kayseri province of Turkey. The minimum infection rate of *Wolbachia* spp. in the totally analyzed 118 *C. pipens* specimens was determined as 5.08% in the study. Furtermore one of the isolates (WolKys1) was also determined in *Wolbachia* Group B and wPIP subgroup according to the phylogenetic analyses of the *Wolbachia* surface protein (wsp) gene (GenBank accession no: JX474753). In conclusion, this study reports the first molecular

detection and characterization of *Wolbachia* endobacteria in *C. pipiens* populations in Turkey (193).

Vector-borne diseases of plants: In addition, there are many harmful arthropods and nematodes causing loss in quality and quantity of crop production in Turkey. These organisms can directly and sometimes indirectly harm plants (103). Aphids (Aphididae), leafhoppers (Cicadellidae), whiteflies (Aleyrodidae), beetles (Coleoptera), trips (Thysanoptera), gal mites (Eriophyidae), fruit flies (Tephritidae), ash-gray leaf bugs (Piesmatidae), bees and ants (Apidae and Formicidae) and nematodes are important vectors of plant diseases. Some of the most harmful plant viruses in the world such as tristeza, plum pox virus, tomato ringspot viruses are transmitted by vectors (128). The study of vector behavior and their control are of paramount importance to diminish damage to crops. The citrus tristeza virus spread by aphids brings about epidemics worldwide, causing the death of millions of citrus trees. This virus is also of extreme importance for the economy of Turkey (13, 16, 57). Plant and animal viruses have some very different constraints regarding the transmission step. While animal hosts are mobile and often come into physical contact with each other plant hosts are immobile and close contact is rare. Furthermore, plant cells are surrounded by cell walls, thick, solid barriers, which a virus cannot penetrate unless a crack is created either by mechanical stress or by plant-feeding organisms. This apparently explains why nearly all plant viruses are exclusively vector transmitted in the real world, whereas many animal viruses rely partly or completely on non-vector transmission (114). As a consequence, a diverse range of specific and intricate interaction strategies has evolved, and these strategies have been the subject of considerable research efforts in the plant virus field. Over the last half century, the classification of these plant-virus-vector interactions has been frequently modified, complemented and updated (72, 107, 148, 168, 182). Vector transmission of animal viruses was originally thought to be of two possible sorts, either 'mechanical' or 'biological'. The former is generally associated with non-specific inoculation of viruses by contaminated mouthparts or body of the vector, while the latter applies to specific associations and requires that the virus can propagate within the vector. Although this simple dichotomy is still in use today (62, 124, 133), it may not reflect the actual diversity of strategies that viruses can develop, particularly for so-called 'mechanical' transmission. Because the classification system developed for the transmission of plant viruses is more detailed, it will be used in the rest of this chapter as a common system applying to both plant and animal viruses.

In recent years, in spite of changes in ecological balance caused by abandoning agricultural land, use of natural areas to farm, release of rabbits, preventing water flooding, leaving the fields uncultivated, migration from urban to rural areas, hunting of wild animals, the dramatic drop in the number of farm animals, climate change and the strengthening of wild life was probably responsible in the increase of tick populations (151, 164). The construction of ponds and dams, changes in riverbeds, drying out of swamps and marshes, dense ad-hoc and haphazard construction, changes in picnicking habits, wild irrigation in agriculture, and the use of unsuitable control measures by local authorities, resulted in an increase of flies (1, 109, 188, 194). This leds to an increase in infected vector populations, and also vector-borne diseases and a decrease in the potential for economic development (63, 157).

In conclusion, it is very significant to initiate and develop struggle programs against to vectors and vector-borne diseases which threaten human, animal and plant health and cause high economic losses in Turkey. Therefore they should be further investigated and monitorized regularly by using new and specific diagnostic tools.

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