Air streams and the introduction of animal diseases borne on *Culicoides* (Diptera, Ceratopogonidae) into Israel *

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**Summary:** The role of air streams and climatic conditions in the transport of biting midges (*Culicoides* spp.), the vectors of bluetongue and Akabane viruses, is known from other parts of the world. Knowledge of such climatic systems may enable predictions to be made on the occurrence of these diseases and may also assist in drawing up vaccination and control programmes. In this study, data on temperature, relative humidity, wind speed and direction have been analysed for the years 1964, 1966, 1969 and 1988, at altitudes of 0.5 km, 1 km and 1.5 km. The authors examine the relationship between these parameters and outbreaks of bluetongue and Akabane.

The results show that outbreaks of bluetongue and most seroconversions did not occur before the season of the Persian trough air-stream system. This was despite the fact that the vector *C. imicola* was present in March and April, i.e. before this air-stream system began. Circumstantial evidence to indicate the introduction of infected midges by wind is stronger than the evidence against such an introduction. In addition, the amount of precipitation in the spring seasons of 1968 to 1986 could not be positively correlated to the number of bluetongue outbreaks.

These results indicate that cooperation among the countries in the region of the Persian trough air system could provide an early warning system against wind-borne infected vectors. An outbreak of bluetongue in one country would be a warning to the next country along this route.

**KEYWORDS:** Air streams – Akabane – Bluetongue – Culicoides – Israel.

**INTRODUCTION**

When the traditional means by which animal diseases are spread, such as animal movement (legal and illegal) and carriage of vectors by vehicles (cars, trains, ships and aeroplanes), cannot be blamed for an incursion, other possible routes of penetration should be investigated.

Circumstantial evidence of the spread by wind of *Culicoides*-borne animal diseases, such as bluetongue (BT), African horse sickness (AHS), Akabane, ephemeral fever

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EF and epizootic haemorrhagic disease of deer (EHD), has been presented previously (23, 30, 32, 33, 34). In these cases, wind streams from the infected source area could have brought infected midges over distances of up to 700 km to the new areas. It was also shown that temperature and other conditions were likely to be important, e.g. air temperatures of 15-20°C at night or 20-40°C by day and flight duration of up to 20 h. The assumptions of wind carriage were also based on the fact that midges have been reported from altitudes of 170 m to 4,000 m above ground level (2, 12, 13, 18, 21), as well as on such cases as the reinvasion of Simulium damnosum, carried over 300 km to the Volta River after a control operation (11, 22), and capture of Culicoides of the schultzei group on a ship on the East China sea (43).

In Israel, most outbreaks of BT occur between July and December (39). Among the explanations offered recently for the apparent overwintering of BT virus (BTV) in the Mediterranean area (3, 41), was the possibility that overwintering might occur outside the endemic area, at the delta of the Euphrates and Tigris rivers, with reintroductions occurring through infected midges moving across the Persian trough in summer. According to Sellers (29), Israel and the rest of the Mediterranean area belong to zone ‘C’, where pathogens may be introduced by infected vectors on warm winds, and where persistence of pathogens may occur if conditions are right.

The fertile crescent between the Euphrates and Tigris rivers is considered to be the most probable source of infected midges for Israel (9, 31). As most BT cases in Israel occur between July and November, when the dominant wind is the Persian trough (Etesian), this is likely to be the wind which is principally responsible for carrying infected midges (16, 17, 20).

The major BTV and Akabane virus vector in the Mediterranean area is Culicoides imicola (1, 6, 7). This species is on the wing from dusk till dawn (4, 25). It is suggested that, during flying activity, part of the midge population may be carried by active flight and convection to upper levels of the atmosphere, where they are transported by air streams over long distances. These insects land when the air streams decrease and this can occur at any hour of the day. Climatic parameters considered appropriate for the survival of midges in the carrying wind are a temperature of 15°C-35°C, relative humidity above 25% and wind velocity of up to 10 m/sec (35 km/h) (30, 31, 32, 33). Owing to the political situation in the Middle East from 1948 to 1983, it can be assumed that no livestock movement or transportation took place from neighbouring countries to Israel during these years and vice versa. Thus, another route of penetration, e.g. wind, has been suspected as the means of invasion of Culicoides-borne diseases into Israel. Tracing BT outbreaks in Israel and their relationship to a certain wind event seems more complicated than in neighbouring countries, as sheep have been routinely vaccinated against the common types of BTV in Israel since 1964 (2, 4, 8, 10). These campaigns have tended to inhibit or mask the natural spread of the disease and prevent accurate determination of the date and location of the first outbreak. Therefore, more weight should be placed on serological data from cattle, as this species is not vaccinated against BTV. Another difficulty is that hardly any reports are available on the circulation of BTV and Akabane virus in neighbouring countries. Despite these problems, this study was conducted to find whether wind direction could be related to outbreaks of BT and Akabane in Israel. Such a positive link between wind regime in summer and outbreaks of Culicoides-borne diseases could be used as an early warning system. This might also indicate when and where to start vaccination of the host species and control of the vectors, to prevent further spread of the disease.
MATERIALS AND METHODS

Weather parameters, i.e. wind velocity and direction, temperature (°C) and relative humidity (%), were recorded at altitudes of 0.5 km, 1 km and 1.5 km for a period of 15 to 30 days prior to an outbreak of BT. This represents the minimum time period from transmission of the BT virus from an infected host in the source area to infection of a susceptible animal in Israel. This time includes an incubation period of eight days in sheep and seven days in midges (30, 31).

_Culicoides_ spp. breed in humid and semi-humid habitats, therefore the amount of rainfall in spring in Mediterranean climates might have an impact on the population size of BT vectors. In order to check this assumption, the authors compared the number of BT outbreaks in Israel with the amount of precipitation in spring (from March to April) between 1968 and 1986. The data were taken from six meteorological stations located in six typical regions in which the disease occurs in Israel (39). The stations were located in Tirat Zevi (Bet Shean Valley), Nazareth (Lower Galilee), Even Izhaq (Coastal Plain), Bet Dagan (Coastal Plain), Negba (southern Coastal Plain) and Jericho or En Geve (Jordan Valley).

To identify the time of year in which transportation of insects is feasible, an analysis of temperature, relative humidity and wind at altitudes of 1 km, 1.5 km and, by extrapolation, for an altitude of 0.5 km was conducted. For the years in which outbreaks of BT and Akabane occurred in Israel, an analysis of temperature, relative humidity and wind (direction and velocity) was carried out at the appropriate altitudes. These parameters were measured at Bet Dagan by radiosonde during the day (1300 h) and at night (0100 h). Data were recorded at air pressures of 850 millibars (Mb) at an altitude of 1.5 km, 900 Mb at 1 km, 1,000 Mb at 120 m and also in a meteorological shade at a height of 2 m above the ground. On the basis of the distribution of temperature and relative humidity values at the above altitudes, an estimate was obtained for these values at an altitude of 0.5 km. Measurements of the velocity and direction of wind at the various altitudes were also made by PILOT (a hydrogen balloon sent into the atmosphere and monitored from meteorological stations by an optical theodolite) near the suspected focus of outbreak of these diseases. To determine the source area of the diseases, use was made of the altitude data in synoptic maps at the 850 Mb level in the years of the disease outbreaks in Israel, and of yearly data from meteorological stations in Lebanon, Syria, Iraq, Turkey, Cyprus and Egypt (35).

Serological data from BT in cattle do not exist for the years 1964, 1966 and 1969. A small-scale serological survey for BTV antibodies started in 1976, and only by 1988 was the survey finally designed to include ten localities, representing different natural ecological regions (10). In these surveys, sera from the same herds are checked for BTV-specific antibodies at the beginning of the season, i.e. June, and also in December, at the end of the BT season. These serological data can only indicate the beginning of BTV activity and cannot pinpoint the exact date of an outbreak.

RESULTS

Analysis of meteorological parameters associated with the breeding and transportation of midges

Comparison of the amount of rainfall in the spring with the annual number of outbreaks of BT (which is circumstantially related to vector density) showed no correlation between these factors (\( r = -0.41 \)). A negative correlation was even
detected, i.e. in the years 1968, 1969 and 1976, when a large number of outbreaks occurred (more than 20), the amount of rainfall in the spring (March and April) was small and ranged between 50 mm and 100 mm. In most years with few outbreaks (one to three) of the disease (such as 1971), the amount of rainfall in the spring ranged from 100 mm to 170 mm, which is not always the general rule. In years such as 1986, with a low amount of rainfall in the spring, e.g. approximately 40 mm, there were only small numbers of BT outbreaks.

Analysis of the yearly temperature data at an altitude of 1.5 km, collected in meteorological stations in Israel and neighbouring countries to a radius of 700 km, demonstrates that the duration of the suitable season for wind transportation of midges ranges from four to six months (Table I). In Israel, as well as further south in Egypt and to the east in Iraq, the suitable season for insect transportation – in which the average temperature at noon is between 15°C and 28°C – continues for about six months (from May to October). In Cyprus, to the north-west of Israel, and in southern Turkey, Lebanon and Syria, located north of Israel, the suitable season for insect transportation, with an average noon temperature ranging from 15°C to 23°C, continues for four months (June to September). By contrast, in mid-Turkey (Ankara), the period in which the temperature is suitable for insect transportation lasts for only two months (July to August). A detailed record of temperatures at noon in neighbouring countries is relevant for insect transportation as, at a height of 1.5 km, differences between daytime and night temperatures are less than 1°C. The average temperature between May and October (the hot months) at an altitude of 1 km is higher by 2°C to 3°C from that at 1.5 km. The average temperature during March to November at an altitude of 0.5 km is about 15°C and is suitable for insect transportation. Monthly analysis of BT outbreaks in the years 1968 to 1986 indicates that 70% of the outbreaks occurred from October to November and 90% from July to November (39). This means that there is compatibility between the time of disease outbreak and temperature values above 15°C at altitudes of 0.5 to 1.5 km. At low altitude, the relative humidity values are high and more suitable for midge transportation. For instance, at an altitude of 0.5 km, the average relative humidity is higher by 5% to 10% during the day and 15% to 20% at night, than the relative humidity value at an altitude of 1 km. The differences in average relative humidity between altitudes of 0.5 km and 1.5 km are even greater. It was found that during the daytime, at an altitude of 0.5 km, the average relative humidity values are higher by 15% to 20% than the values at an altitude of 1.5 km. At night the difference is 35% to 40%. The relative humidity values at an altitude of 1.5 km are especially low from May to October (the hot months).

For instance, in these months, during the day at the meteorological station at Bet Dagan (Coastal Plain), daily average relative humidity values of 55% to 65% were recorded. At an altitude of 1 km, during the day, the average relative humidity dropped to 45% to 50%, whereas at an altitude of 1.5 km, a relative humidity of 25% to 35% was recorded. Relative humidity values at night for 1 km in altitude are higher than the corresponding daytime values by 5% to 10%, and higher than the daytime values at an altitude of 1.5 km by almost 5%.

The Persian trough is active in the Middle East from mid-June to mid-September. The trough spreads from Iran through Turkey to the north-eastern Mediterranean Sea, causing the westerly and north-westerly winds which dominate at this period. In Bet Dagan, in the months of June to August, the frequency of winds from the west, north-west and north is 80% to 90%.
**TABLE I**

*Average temperature (°C) at noon at an altitude of 1.5 km (850 millibars) at various meteorological stations in the Middle East from 1957 to 1966*

(35)

<table>
<thead>
<tr>
<th>Country</th>
<th>Meteorological station</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May *</th>
<th>June *</th>
<th>July *</th>
<th>August *</th>
<th>September *</th>
<th>October *</th>
<th>November</th>
<th>December</th>
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<td>5.4</td>
<td>8.5</td>
<td>12.2</td>
<td>15.8</td>
<td>19.6</td>
<td>20.8</td>
<td>21.7</td>
<td>18.4</td>
<td>16.0</td>
<td>12.0</td>
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<td>Beirut</td>
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<td>4.4</td>
<td>6.5</td>
<td>10.1</td>
<td>14.4</td>
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<td>20.2</td>
<td>20.7</td>
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<td>14.3</td>
<td>11.2</td>
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<td>13.2</td>
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* 15°C is considered as the lowest temperature still permitting insect transportation.
Analysis of bluetongue outbreaks related to the meteorological conditions at altitudes of 1 km and 1.5 km

The possible association between weather conditions at the source area and the routes of the Persian and Red Sea troughs with outbreaks of BT in Israel was investigated. The analysis was conducted for the years 1964, 1966 and 1988, in which BT outbreaks occurred in the hot months, when the eastern Mediterranean area was dominated by the Persian trough and winds from north and north-west directions were active in Israel. In those years, the outbreaks occurred when winds from the section between 260°W to 20°N were identified. An analysis was made of instances where the average temperature was above 15°C, the relative humidity above 25% and the wind velocity up to 10 m/sec (35 km/h). These parameters were also used by previous authors (30, 32, 33). As wind velocity does not reach such values at the above altitudes in Israel, one can assume that wind velocity is not a constraint. Weather data from a period of up to thirty days before the BT outbreak were analysed. At this time in Israel, sometimes the Red Sea trough prevails; therefore a similar analysis was conducted for the south and south-west (150°SE-250°W) air streams. The first BT case was reported from Adirim (Yizreel Valley) on 23 June 1964, when a severe outbreak in susceptible unvaccinated sheep occurred. The data were analysed for the period between 11 May and 9 June, which is the last marginal date for BT infection. In these thirty days during the daytime, at an altitude of 1 km, four instances in which suitable conditions existed for the transportation of midges from the north-western section, and three instances at an altitude of 1.5 km, were recorded (no observations were carried out at night). On 4 June 1964, a maximum wind speed of 7 m/sec (26 km/h) was recorded, when, at an altitude of 1 km, a northern wind (330°NW) prevailed, with an average temperature of 20°C and 33% relative humidity. At this velocity, the air stream can cover approximately 500 km in 20 hours. During the same period, from south to west, five instances at an altitude of 1 km and four instances at an altitude of 1.5 km were recorded in which suitable conditions for the carriage of midges prevailed. An air stream with a velocity of 8-9 m/sec (30-32 km/h), which is considered high, was recorded on 8 June 1964 at an altitude of 1 km to 1.5 km from the direction 230°SW-250°W with an average air temperature of 15°C to 17°C and 27% to 48% relative humidity. In such conditions the air stream can move over 600 km in 20 hours.

The precise date of the outbreak of BT in September 1966 was not recorded, therefore this outbreak was assumed to have occurred on 15 September. If this assumption is correct, the time of infection was in August, the principal season for the Persian trough. In 10 to 15 instances, at an altitude of 1 km, the weather conditions were suitable for insect carriage, according to observations of 0100 h at night and 1300 h during the daytime, and in six instances, suitable conditions for insect carriage prevailed at an altitude of 1.5 km, during all observation hours.

In these instances, the maximum velocity of 9 m/sec (32 km/h) was recorded on 29 August 1966, at an altitude of 1 km, when the air stream was from the direction of 330°NW, with an average temperature of 26°C and relative humidity of 26%. This means that the air stream could travel more than 600 km in 20 hours. In the southern to western air streams, the maximum velocity was 7 m/sec (24 km/h). On 12 August 1966, at an altitude of 1 km, the direction of the air stream was 200°S, the average air temperature 22°C and relative humidity 50%.
The third outbreak of BT occurred early on 6 July 1988 at Mehola in the Jordan Valley, i.e. the infection had started two weeks previously, before 22 June. Therefore, an analysis of one month, between 23 May and 21 June, was conducted. During this period, seven instances of prevailing northern to western air streams were recorded, in which weather conditions were suitable for carriage of insects at an altitude of 1 km, and ten instances were recorded at an altitude of 1.5 km. The fastest air stream was recorded on 9 June 1988, when wind velocity reached 6 m/sec (20 km/h) in the day. Such an air stream can travel approximately 400 km in 20 hours. The average temperature of the air stream from the direction of 340°N was 22°C and the relative humidity 28%. In the southerly to westerly air streams, the highest velocity, which was recorded on 21 June 1988, was 7 m/sec (26 km/h). The direction of the stream was from 250°W, the temperature was 23°C and the relative humidity was 40%. Serological data from cattle at Neve Etan, situated 13 km north to Mehola, showed that 17.4% of the sentinel herd were already seroconverted in July (29). This finding indicates that infected Culicoides vectors arrived in Mehola by a northern air stream.

Analysis of the Akabane outbreak in 1969

According to Shimshony (37), infection in sheep could occur between October and December 1969. The meteorological data concerning the month before the crucial date were screened and it was found that most air streams in September were hot and dry, and unsuitable for the carriage of insects. The relative humidity values during September were below the 25% threshold. At an altitude of 1.5 km during the day, there were only seven instances in which conditions were suitable for the carriage of insects from the north-west, and two cases in which conditions were suitable for carriage of insects from the south-east. At 1 km in altitude, there were thirteen days where conditions were suitable for carriage from the north-west and seven days with suitable conditions for carriage of insects from the east. The most rapid air stream with suitable conditions for insect carriage occurred on 9 September 1969, when, at an altitude of 1.5 km, the average temperature was 17°C, relative humidity was 31%, wind direction was 260°W and wind velocity was 8 m/sec (30 km/h). At night, between 8 and 9 September 1969, wind velocity was 10 m/sec (35 km/h), i.e. the western-south-western air stream was capable of carrying insects during those 20 hours, covering a distance of 600 km to 700 km. The source of this air stream was the Red Sea trough, originating in North Africa. In October, when the Persian trough air stream activity ceased, the number of instances suitable for insect carriage was reduced. Only three cases of suitable western air streams at 1.5 km in altitude were recorded in October. From the east, there were seven cases of suitable conditions for insect carriage (as in September). At an altitude of 1 km, there were 14 days in which suitable conditions prevailed in the northwest air streams and 4 days in which suitable conditions prevailed in the eastern air streams. On 5 October 1969, at an altitude of 1 km, the temperature rose by 4°C, reaching 22°C, while relative humidity was 28%, wind direction was 310°NW and wind velocity was 4 m/sec (15 km/h). The fastest south-eastern air stream occurred on 10 October 1969, when the temperature was 22°C, the relative humidity 31%, the wind direction 160°S and the wind velocity was 5 m/sec (18 km/h). From the end of October, the temperature at 1.5 km in altitude dropped below the threshold of 15°C. As there were no reports of the presence of Akabane virus in the countries where the air streams originated, these air streams cannot be considered with certainty to have transported the infected insects.
DISCUSSION

The study of Walker and Davies in Kenya suggested a positive association between the amount of rainfall in summer, the population density of midges and the number of BT outbreaks (44). Shimshony tried to demonstrate such an association in Israel (36), but, as in this country the rainfall season is restricted to the winter, when temperatures are unfavourable, Braverman and Galun suggested considering only the amount of spring rainfall, a favourable season for Culicoides spp. breeding, in relation to BT outbreaks (5). The data on spring rainfall were examined in this study and no proof could be found for an association with the number of BT outbreaks in this season. Temperature and relative humidity data at altitudes of up to 1 km showed that this altitude is the most suitable for Culicoides spp. survival during a long carriage, and that this is the most probable altitude for insect transportation. This study indicates only a circumstantial association, with regard to time, between synoptic events two weeks to one month before the occurrence of the disease and/or infection, and outbreaks of BT. In regard to the years under analysis, 1964, 1966, 1969 and 1988, no data were found about outbreaks of the disease along the route of the Persian trough, i.e. Iraq, Turkey, Syria and Lebanon, nor along the Red Sea trough route, i.e. Egypt, Jordan and North Africa. The dates of BT outbreaks in sheep in Israel are not reliable as, since 1964, after a large outbreak (39), routine vaccination of most herds of susceptible breeds in Israel was introduced. The best parameter for following the activity of BTV is seroconversion in sentinel cattle, as these animals are not susceptible to the disease and are therefore not vaccinated. Such monthly serological data are not available for the years 1964, 1966 and 1969. In regard to 1988, serological data are available only for July, August and December.

This means that the dates of the onset of BT outbreaks are not necessarily correct and, as a result, the synoptic conditions that prevailed two weeks before are not necessarily pertinent. The results obtained do not enable one to decide whether there is an association between prevailing winds and BT and Akabane outbreaks in Israel. In order to assess the possibility of such an association, supporting and conflicting evidence will be described.

Evidence supporting transportation of bluetongue and Akabane vectors to Israel by winds

In most years, Culicoides spp. are found in Israel during the entire year and the temperature and relative humidity conditions are suitable for survival of this insect at the appropriate altitude for at least six months. Nevertheless, there is only a positive association between the period of the Persian trough and the occurrence of BT outbreaks. Despite the fact that a large local population of Culicoides spp. exists in the spring, outbreaks of BT are concentrated between June and December, and isolation of the virus from this vector was successful only from the beginning of June. In neighbouring Cyprus, it was also found that in 18 of 24 years in which BT outbreaks occurred, the source could be explained only as airborne penetration (29).

Serological surveys conducted from 1988 to 1991, on ten dairy farms in various ecological regions in Israel, showed a low frequency of BT antibodies in June, but a very high frequency in December. These reports (10), as well as previous studies, indicate that BT activity coincides with that of the Persian trough.
According to Taylor (40), two wind systems exist in the Middle East but only one, the Persian trough (Fig. 1), is principally involved in the carriage of infected midges to Israel. Sporadic instances in the interim seasons and during the Persian trough season could be associated with the meteorological system of the Red Sea trough (Fig. 2).
Previous studies have proved an association between wind systems and the migration of midges infected with BT, Akabane, African horse sickness, ephemeral fever and epizootic haemorrhagic disease of deer (23, 30, 32, 34).

Insects including *Culicoides* spp. were sampled at various altitudes above ground and mid-sea, and the phenomenon of insect carriage by air streams had already been proven (12, 15, 21).

*Culicoides imicola* in Israel show a preference for high-elevation flight, which makes this species adaptable to carriage by air streams (8). It is therefore feasible that dispersal by wind is an integral part of the biology of *C. imicola*, as it is for the related insect, *C. brevitarsis* (24).

The fact that various types of BT virus, such as serotypes 10 and 16, appear only once every few years, probably indicates that they are not endemic and are transported by infected *Culicoides* spp. Moreover, the fact that there were some years in which even the common virus types 2, 4 and 6 did not occur supports even more strongly the assumption of vector carriage by wind.

There has been no report from Israel of outbreaks of BT which could be related to imported infected animals.

Thus far, there is no evidence in Israel for the existence of BTV in the period between February and May. No transovarial transmission of the virus in midges has been shown; consequently, such an overwintering mechanism has a very low probability (19, 27).

In Mediterranean countries, such as Spain and Portugal, in which the *C. imicola* vector exists, BT disease is thus far very rare, probably because these countries are not encompassed by a synoptic system that brings air streams from regions infected with the disease.

The fact that no association was found between high precipitations, which encourage breeding of *Culicoides* spp., and the number of BT outbreaks (5), might indicate that the source of the disease is outside Israel and that the infected vector is transported by air streams. It might be assumed that, after penetration of the virus, local infections are caused by the local *Culicoides* vectors for a limited time.

The fact that, in most years, there are more outbreaks of BT in the northern part of Israel and progressively lower numbers of outbreaks in the central and southern parts is probably not due to the existence of more susceptible animals in the northern part (5, 38), but to the landing of infected *Culicoides* spp., drifted by the Persian trough, first to the northern part and then to other parts of the country.

### Evidence against transportation of bluetongue and Akabane vectors to Israel by winds

An additional eleven types of BTV, which have not been identified in Israel, are known in the Middle East through serological surveys. This contrasts with the five virus types (four principal types) which have been isolated in Israel many times (14, 40, 42).

There is no confirmed information on the activity of BTV types in the suspected source regions (the Euphrates and Tigris rivers in Iraq).

Only an association in relation to time could be shown between wind regimes and outbreaks of *Culicoides* spp.-borne diseases. No isolation of the pathogen from high-altitude airborne *Culicoides* spp. has been recorded.
Even during an outbreak of BT, the natural rate of infected *Culicoides* spp. is very low. This means that, in order to cause a focal infection, a large population of *Culicoides* is needed. No report on the population density of *Culicoides* spp. at suitable altitudes for transportation has so far been reported.

Overwintering of the endemic types of BTV can theoretically take place in cattle and *Culicoides* spp. alone. Thus, the renewal of BTV activity each year is not dependent on transportation of infected *Culicoides* spp. (3, 26).

It was established that African horse sickness, another *Culicoides*-borne disease, spread through Spain in 1988 to 1989 and through Portugal in 1989 as a result of importation of infected animals and probably not because of airborne infected *Culicoides* (28).

CONCLUSIONS

An altitude of up to 1 km is the most appropriate altitude, as regards temperature and relative humidity, for the survival of *Culicoides* spp. in transportation of long duration.

In regard to two of the years of BT outbreaks analysed, i.e. 1964 and 1966, only a time-based association could be proven, i.e. between appropriate wind regimes, two weeks before the outbreak, and the incidence of BT. For 1988, in addition to an appropriate air stream, there is also supporting serological evidence.

In Israel, BT outbreaks and most seroconversions occur after the beginning of the Persian trough air-stream season, and not after the first appearance of the vector *C. imicola*. Therefore, there is a great probability that at least some BTV types are carried to Israel by airborne infected *Culicoides* spp.

The most probable air stream for the carriage of BT-infected *Culicoides* spp. to Israel is the Persian trough.

Vaccination should be conducted towards the onset of the Persian trough air stream and not necessarily before the first appearance of the vector *C. imicola*.

No association was found between the amount of spring rainfall and the number of BT outbreaks in Israel.

In order to reach a high level of confidence, future research should not be based on BT outbreaks in sheep, but should rely on the extensive seroconversion in cattle. Such a serological survey should be commenced each year before the Persian trough season, i.e. before June.

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Résumé : Le rôle des courants aériens et des conditions climatiques dans le déplacement des moucherons piqueurs (Culicoides spp.), vecteurs des virus de la fièvre catarrhale du mouton et de la maladie d’Akabane, a été établi dans d’autres régions du monde. La connaissance de ces phénomènes climatiques pourrait permettre de faire des prévisions sur la fréquence de ces maladies et apporter une aide précieuse pour la mise au point de programmes de vaccination et de contrôle. Après analyse des données relatives à la température, à l’hygrométrie relative, à la vitesse et à la direction des vents pour les années 1964, 1966, 1969 et 1988, à des altitudes de 0,5 km, 1 km et 1,5 km, les auteurs étudient la relation entre ces paramètres et les foyers de fièvre catarrhale du mouton et de la maladie d’Akabane.

Les résultats de cette étude montrent que les foyers de fièvre catarrhale du mouton et les anticorps n’étaient généralement pas observés avant que ne s’installe le système dépressionnaire persique, et ce, malgré la présence du vecteur C. imicola de mars à avril, c’est-à-dire avant cette installation. Les preuves circonstancielles de l’introduction par les vents de moucherons porteurs de virus sont mieux établies que les preuves inverses. De plus, on n’a pu démontrer de corrélation entre le volume des précipitations printanières, de 1968 à 1986 et le nombre de foyers de fièvre catarrhale du mouton.

Ces résultats montrent qu’une coopération entre les pays situés dans la région du système dépressionnaire persique pourrait permettre la mise en place d’un système d’alerte précoce contre les vecteurs infectés, transportés par les vents. L’apparition d’un foyer de fièvre catarrhale du mouton dans un pays servirait d’alerte pour le prochain situé sur la route des vents.


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Resumen: El papel del viento y del clima en el transporte de cítifes picadores (Culicoides spp.), vectores de la lengua azul y del virus de la enfermedad de Akabane, se había descrito ya en otras partes del mundo. El conocimiento de tales sistemas climáticos puede permitir la realización de predicciones sobre la aparición de estas enfermedades, y puede contribuir asimismo al diseño de programas de vacunación y de control. En este estudio se analizan la temperatura, la humedad relativa y la velocidad y dirección del viento registradas en los años 1964, 1966, 1969 y 1988, a altitudes de 0,5 km, 1 km y 1,5 km. Los autores examinan la relación existente entre estos parámetros y los brotes de lengua azul y de enfermedad de Akabane.

Los resultados demuestran que los brotes de lengua azul y gran parte de las seroconversiones no se produjeron antes de la estación de depresión del
sistema de vientos del Pérsico. Y ello a pesar de que el vector C. imicola estaba presente de marzo a abril, es decir antes del comienzo de la citada depresión. Las evidencias circunstanciales a favor de la introducción por el viento de insectos infectados son más fuertes que las pruebas en contra. Por otra parte, no pudo establecerse una correlación cierta entre el volumen de precipitaciones caídas durante las primaveras de 1968 a 1986 y el número de brotes de lengua azul.

Estos resultados sugieren que la cooperación entre los países de la región atravesados por el sistema de depresión eólica del Pérsico permitiría la creación de un sistema de alarma precoz contra los vectores infectados e introducidos por el viento. Un brote de lengua azul en un país constituiría la señal de alarma para el país siguiente en la ruta de los vientos.


**REFERENCES**


