

Possible windborne spread to Western Turkey of bluetongue virus in 1977 and of Akabane virus in 1979

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SUMMARY

An outbreak of bluetongue in sheep started in the Menderes valley, Aydin Province, Western Turkey, in October 1977. The severity of the disease indicated that it had not been there before but had been introduced into the area. Analysis showed that, while it was possible for the virus to have been brought into the area by movement of infected animals, there was also a period of south-easterly winds which could have carried infected midges from Cyprus, where bluetongue was present. During the night of 14–15 October 1977, south-easterly winds could have brought midges infected with bluetongue virus for the 15 h flight at a height possibly of 500 m and at temperatures of about 20 °C. A depression moving north-eastwards accompanied by rain may have affected the landing of midges in the Menderes valley on the morning of 15 October.

An outbreak of arthrogryposis–hydranencephaly in newly born calves occurred in March–May 1980, also in the Menderes valley, Aydin Province. The severity of the outbreak indicated that Akabane virus had not been in the area before but had been introduced in September–November the previous year. While infected animals could have brought the virus into the area, analysis based on the probable time of infection of pregnant dams showed that easterly winds at the end of September or beginning of October 1979 could have brought insects infected with Akabane virus into the Menderes valley from eastern Turkey or northern Syria.

These analyses illustrate the use of meteorological data to backtrack to possible sources and to identify the time of infection.

INTRODUCTION

In October 1977 there was an outbreak of bluetongue (serotype 4) in sheep near Aydin in the Menderes valley in western Turkey. The bluetongue outbreak in Aydin Province persisted until December, when the disease disappeared, to reappear in 1978 and 1979 in sheep in this and other provinces of western Turkey (Anon, 1980; Yonguç *et al.* 1982). Two months before the outbreak in 1977 a



bluetongue epidemic due to type 4 had commenced in Cyprus (Polydorou, 1978; Sellers *et al.* 1979).

In March 1980 a severe outbreak of what was subsequently shown to be Akabane disease was reported in Aydin Province, with calves showing arthrogryposis and hydranencephaly (Urman *et al.* 1979; Yonguç *et al.* 1982).

The sources of these infections, which both started in the same area, are obscure. Bluetongue and Akabane viruses are transmitted by biting midges of the genus *Culicoides*, and Akabane virus has been isolated from mosquitoes. It was therefore decided to see whether introduction of virus by infected insects carried on the wind could have been responsible for the outbreaks; in addition, other possible origins of the outbreaks were considered.

A location map of the areas described is shown in Fig. 1.

BLUETONGUE, 1977

Initial outbreak

The disease was first observed on 24 October 1977 in sheep of the Daglic breed in two villages near Aydin. The sheep had spent the summer in the hills above the

Menderes valley and had returned to the villages in the first week of October. In rapid succession, 17 other villages reported bluetongue; thus, disease was present in the Menderes valley throughout Aydin Province. The last cases occurred on 16 December 1977 (Anon, 1980). Virus was isolated from samples collected from sick sheep and shown to be bluetongue virus serotype 4 (Yonguç *et al.* 1982). In later work *Culicoides imicola* midges have been caught around Aydin (Jennings, Boorman & Ergun, 1983).

Analysis

Bluetongue virus serotype 4 has been shown to produce clinical disease in sheep 5–9 and 12 days after infection; in the majority, clinical signs were seen first on the sixth, seventh or eighth day (Goldsmid, Barzilai & Tadmor, 1975). A *Culicoides* midge can transmit virus to another host seven days after taking an infected blood meal and for the remainder of the life of the midge (Sellers *et al.* 1979).

Since bluetongue disease was first seen in the sheep on 24 October 1977, infected midges would have bitten sheep between 12 and 19 October. These midges would have taken an infected blood meal at some time between 5 and 12 October or before.

The nearest known source of bluetongue virus serotype 4 at that time was Cyprus. At the end of September 1977, in the northern part of the island, disease was present from Akanthou in the east to Kormakiti and Morphou in the west and in the southern part in Famagusta, Larnaca and Paphos districts and south of Morphou. Thus, apart from Karpasia, south and south-west of Nicosia and the higher parts of the Troodos mountains, there was widespread infection with infected *Culicoides* midges throughout the island (Mellor & Pitzolis, 1979; Sellers *et al.* 1979).

Other possible sources at that time were Egypt (Delta), Israel, Lebanon (Bekaa valley), Syria (Orontes valley) and the Adana and Gaziantep regions of Turkey. Apart from Egypt, these areas may have been the source of windborne infected midges carried to Cyprus in August 1977 (Sellers *et al.* 1979). No disease was reported in these countries except in sheep in Israel, but cattle, sheep and goats were probably silently infected.

Previous existence of bluetongue in Aydin Province

Before 1977 bluetongue had last been seen in Turkey near Antakya in 1947. No disease had been reported in any part of Turkey since then (Anon, 1980).

Bluetongue virus may persist in an area in the local animals or in the vector. In cattle, virus may be recovered from blood cells for 100 days after infection and transplacental transmission through to the newborn calf has been demonstrated (Leudke, Joehim & Jones, 1977). The virus may persist in adult *Culicoides* for the lifetime of the midge (53 days or more) (Nevill, 1971). The midges overwinter as larvae or adult midges, but transovarial transmission of bluetongue has not yet been demonstrated (Jones & Foster, 1971).

Conditions in western Turkey are suitable for the persistence of the virus. Further outbreaks of bluetongue occurred in 1978 and 1979 and virus was isolated in 1980 (Yonguç *et al.* 1982), indicating that overwintering had taken place, most probably in surviving adult midges and cattle.

However, if bluetongue had persisted in the area from before 1977, disease in sheep must have resulted from a change in virulence of the virus.

Bluetongue virus could have been introduced earlier in the year and circulated in the local cattle as an inapparent infection. Disease arose only after the return of the sheep to the valley at the beginning of October. However, it is difficult to explain why this did not also occur in other valleys of western Turkey where similar conditions prevail.

Introduction from elsewhere

Bluetongue may be introduced into an area by movement of animals or by carriage of infected culicoides in vehicles or on the wind.

Movement of animals

There is continual movement of animals in Turkey, sheep from eastern Turkey often appearing in Istanbul market after a week's journey.

Serological investigations in south-eastern Turkey (W. P. Taylor, L. Csontos & E. Worrall, unpublished results, 1980–2) and in Syria (W. P. Taylor & R. F. Sellers, unpublished results, 1978–83) have indicated the presence of precipitating antibody to bluetongue in these areas, with neutralizing antibody (as shown by the cluster technique – Gumm *et al.* 1984) to type 4. However, no serological evidence of type 4 infection was found between Adana Province and Aydin.

If bluetongue had been introduced by movement of animals from south-eastern Turkey or Syria, outbreaks might have been expected to occur in the other valleys of western Turkey.

Although there was an extensive outbreak in Cyprus there was no report of legal movement of cattle, sheep or goats from that island to the Turkish mainland.

Movement of Culicoides

Transport on vehicles. Transport of insects on vehicles, boats and aircraft has been put forward as a possibility for introduction of arboviral infection from one area to another. However, outbreaks might have been expected to occur in other valleys of western Turkey.

Wind carriage of infected Culicoides. In 1977 the nearest known source of bluetongue type 4 was in Cyprus.

Synoptic weather maps for the period 1 September to 18 October 1977 were examined for the possible occurrence of unusual south-easterly winds that could have carried infected midges from Cyprus to the Menderes Valley. Only two possible spells were found: 3–4 September and 14–15 October. All other days had usual winds from between north-west and north-east, except for a few that had west or south-west winds. Although the first spell (3–4 September) had directions suitable for transporting midges, speeds were low and transport times would have been several days. Moreover, the timing was not very consistent with disease reports and extent of infection in Cyprus. In contrast, the second spell was much more favourable. Any midges that were transported must have arrived before about 09.00 GMT on 15 October, for the wind over the Menderes valley then veered from south-south-east to west. If midges had left Cyprus at dusk the previous day, a maximum of 15 h flying time would have been available, requiring an average displacement speed of about 40 km/h. Available records suggest that winds in the lowest 500 m of the atmosphere off south-western Cyprus were 110–130°/25–30 km/h. Over the south-western corner of Turkey the wind direction was about 160° and speed about 20–30 km/h. Thus there is reasonable evidence for

winds blowing along a track curving over the sea from about 120° near Cyprus to about 160° over the Menderes valley, but these winds seem to have been too slow to have transported midges in the time available. However, some acceleration of the wind can be expected to have taken place over the sea due to diversion by the 300 m high mountains of western Antalya Province. The magnitude of any such diversion is not easy to estimate, but speeds of 40–50 km/h may well have been present over much of the latter half of the track. Surface winds reached 30 km/h at exposed coastal stations and are likely to have been stronger by 10–20 km/h at heights around 500 m. Air temperatures near the sea surface were 23–25 °C but over land they fell to 17–20 °C by dawn. At 500 m above sea level, the air temperature was probably fairly uniform at about 20 °C.

It therefore seems likely that winds could have taken midges from Cyprus to the Menderes valley on the night of 14–15 October 1977 and on no other during the previous month or more. An earlier departure from Cyprus would have led to a more curved track and to a flight time perhaps twice as long. It is interesting that midges would have arrived in the Menderes valley at about the same time as a depression that had moved north-eastwards from near Benghazi, Libya, at midnight on 13 October. This depression was accompanied by widespread rain over western Turkey, which may have affected the landing of midges in the Menderes valley.

It was thus possible for bluetongue type 4 to have been brought to Aydin by midges carried on the wind. There was a good source of virus in Cyprus, suitable winds en route and a susceptible population in Aydin. The route lay mainly over the sea, but there is no clear evidence of infection of any land in between. Antibodies were found in blood collected in 1980 from sheep on Rhodes, but the time of infection on that island is not known (Dragonas, 1981).

AKABANE DISEASE, 1980

Disease

Akabane disease is an epidemic virus disease in which abortions, mummified fetuses, premature birth, still-birth, arthrogryposis and hydranencephaly occur in cattle, sheep and goats. The disease is caused by Akabane virus, a member of the Simbu group of Bunyaviridae. It is transmitted by *Culicoides* midges and mosquitoes (Inaba & Matumoto, 1981).

History of outbreak

In Aydin (March 1980) births of calves with arthrogryposis, hydranencephaly, mandibular defects and reduction in size were first observed (Urman *et al.* 1979). This persisted into April, when the numbers of calves with arthrogryposis increased and difficulties in salivation were also seen. Fewer cases were seen in May but none in June or for the rest of 1980 or in 1981. In May 1980 serological investigations carried out on bloods collected in the area showed antibodies to Akabane virus in adult cattle and calves and in precolostral serum from one calf (Yonguç *et al.* 1982). Thus the most likely cause of the arthrogryposis–hydranencephaly (AG/HE) clinical syndrome was Akabane virus, although the virus was not isolated (W. P. Taylor & L. Csontos, unpublished).

Akabane disease in the eastern Mediterranean

An epidemic of Akabane disease occurred in cattle, sheep and goats in Israel in 1969–70 (Shimshony, 1980). Otherwise, before the outbreak at Aydin in March 1980 there was no report of epidemics in the eastern Mediterranean. Sellers & Herniman (1981) found evidence of antibodies to Akabane virus in sheep that had been present in the Famagusta area of Cyprus in 1969 and suggested that virus could have been brought by infected *Culicoides* on the wind from Israel at that time. No disease was seen, since the majority of sheep and goats had already produced young or were in the last third of pregnancy, and numbers of cattle on Cyprus were few.

Subsequent serological surveys from 1979 onwards (K. A. J. Herniman, W. P. Taylor & I. D. Gumm, unpublished; A. Shimshony & E. Barzilai, personal communication, 1984) have shown the presence of antibodies in ruminants in Cyprus, eastern Turkey, Syria, Jordan and Israel.

*Analysis**Time of infection*

Pregnant cattle inoculated experimentally with Akabane virus on the 92nd to 96th day of gestation gave rise to calves showing the AG/HE syndrome (Kurogi *et al.* 1977). Study of the monthly numbers of reported cases in 1972–3 in Japan (Inaba & Matumoto, 1981) indicates that the peak of the AG/HE cases occurred in January, six months after the possible month of infection – July. By analogy, this means that, with the peak of infection in Turkey in April and with cases in March and May, the most likely month of infection would be October, with the last part of September and early November also being possibilities.

Source of infection

Previous existence in Aydin Province. The AG/HE syndrome had not previously been reported in Aydin Province. However, a non-virulent strain of Akabane virus might not have been apparent. Maintenance of virus in the province would have been in animals or in midges or mosquitoes. The duration of viraemia in animals is short, and transplacental transmission of virus through to the newborn animal has not been found (Kurogi *et al.* 1977). Although transovarial transmission has not been demonstrated with Akabane virus, it has been shown with other bunyaviruses and in *Aedes*, *Culex* and *Anopheles* mosquitoes. Nevertheless, the involvement in 1980 of so many pregnant cattle indicates that virus was not circulating in the area for two or more years; otherwise, the pregnant cattle would have been infected as calves and the transfer of Akabane virus across the placenta at the time of viraemia, with subsequent malformation, would not have occurred. In addition, if transovarial transmission had occurred, infection might have been expected earlier in the year once conditions had become warmer for the development from egg to adult mosquito.

Introduction from outside the area

Akabane virus could have been introduced into the area by movement of animals or by carriage of infected midges or mosquitoes in vehicles or on the wind. As with

bluetongue, Akabane disease might have been expected to occur in other valleys of western Turkey if movement of infected animals or carriage of insects on vehicles had been concerned.

Wind carriage of infected midges or mosquitoes

The period between mid-September and mid-November 1979 was examined to see if the weather was suitable for the transport of infected insects from other parts of the eastern Mediterranean. Throughout the two-month period, winds over the Menderes valley were mainly from between west and north-east. Towards the end of the period, winds were more variable in direction. On three occasions the winds were from the east.

There was a period of east and north-east winds from 27 to 30 September. On 8–9 October and 4–5 November easterlies covered Turkey, because on these two occasions vigorous anticyclones moved eastwards just north of the Black Sea. During 4–5 November temperatures were about 15 °C at sea level. However, in November it is likely that only two cycles of at least 14 days of insect–cattle infection could have taken place before the customary falling off in insect numbers at the beginning of December. With the two earlier occasions, there could have been four or five cycles of infection.

If carriage on the wind of insects infected with Akabane virus was responsible for the outbreaks, then 8–9 October was probably the most likely time, since it fits in most closely with the sequence of the AG/HE syndrome around Aydin from March 1980. The possible source of virus would be eastern Turkey or northern Syria. Serological tests on sentinel cattle, sheep or goats did not show the presence of antibodies to Akabane virus in Cyprus between 1977 and 1980 (K. A. J. Herniman & R. F. Sellers, unpublished results).

DISCUSSION

The climate in Turkey, Cyprus, Syria, Israel and Jordan is Mediterranean, with a warm, dry summer and a cold, wet winter. The warmth during the summer together with the moisture provided through rivers, irrigation or natural springs permits the breeding and multiplication of insects. In Cyprus and Israel, populations of midges start to increase in April, reach a peak in May and then maintain a high level until a further peak is reached in late September or early October. With the advent of winter in November and December populations fall, but immature stages and adults are present in low numbers from January to March (Braverman & Galun, 1973; Sellers, 1975). July and August are dry months and only occasionally does rain fall in September. Rain falls in October, November and December. Rain therefore has not the importance given to it in other parts of the world where arboviruses occur, e.g. in West Africa, southern Africa, Australia and Texas, where rain occurs during the summer. Of the severe outbreaks of bluetongue in Cyprus – 1939, 1943, 1946, 1950, 1951, 1961 and 1965 (Sellers, 1975) – those of 1939 and 1977 started in August (no rain) and that of 1965 in September (no rain); October 1943 and October 1946 were no wetter than normal; there was higher than normal rainfall in October 1951 and 1960 and lower than normal in 1950. Rain later in the year may lead to an increase in breeding sites and, if the weather

remains warm, the number of flying insects increases and further spread of disease may occur.

Transovarial transmission with bluetongue or Akabane virus has not yet been demonstrated. If it had happened in Turkey in 1977 or 1979, one would have expected the initial infection to have occurred in April or May after the spring rise in temperature, when immature *Culicoides* stages or mosquito eggs would have developed and the infected adults bitten the animals. September and October would be too late in the season. If transovarial transmission had occurred in those months, infection would have come from immature stages or eggs laid in June before the dry months of July and August. However, in the Aydin valley the river and extensive irrigation provide suitable breeding sites throughout the months with little or no rain. In 1977 the rainfall in September was higher than normal, that in October lower; in 1979 there was no rain in September and rainfall in October was lower than normal.

Bluetongue overwintered in western Turkey until 1980 (Yonguç *et al.* 1982), probably in adult midges as in South Africa and Israel (Nevill, 1971). Akabane may also overwinter in other parts of the eastern Mediterranean in surviving insects or transovarially, but exactly how is not known.

During the outbreak of bluetongue in Aydin from October to December 1977, 201 of the 404 sheep affected died, indicating the severity of the disease (Anon, 1980). Similarly, from March to May 1980 the outbreak of AG/HE in new born calves involved many animals and was severe (Yonguç *et al.* 1982). Such reports suggest that neither bluetongue nor Akabane virus was endemic in the area, since overt outbreaks of bluetongue and of arthrogryposis-hydranencephaly usually occur in fringe areas towards the edge of the distribution of the vector (Della-Porta, Murray & Cybinski, 1976; Sellers, 1983) and result from the movement of animals or vectors into the area.

Undoubtedly, both bluetongue and Akabane viruses could have been introduced into Aydin Province by movement of cattle, sheep or goats. However, without clear records of movement it is difficult to prove or disprove introduction of virus in that way.

Meteorological data collected regularly in the area are available for analysis. Such data can be used to show the presence or absence of suitable winds that could carry infected *Culicoides* or mosquitoes. In the past such an analysis has been used to show the possibility and the impossibility of the spread of African horse sickness by infected *Culicoides* on the wind, e.g. (possible) from Turkey to Cyprus in 1960 and Morocco to Spain in 1966, and (impossible) Sudan to Egypt in 1926 and 1943 and Egypt to Palestine in 1944 (Sellers, Pedgley & Tucker, 1977). In this way one method of introduction at least can be shown to be feasible or not and taken into account in determining the origin of an outbreak.

Analysis of the 1977 outbreak showed that bluetongue could have been introduced by infected *Culicoides* carried on the wind from Cyprus on the night of 14–15 October, 1977. There was an extensive source of infection in Cyprus at that time and the air temperature, distance and wind conditions were within those found for other instances of wind spread of bluetongue and other midge-borne diseases (see Sellers, 1980). The evidence is circumstantial and falls within the example of back tracking from later developments (Pedgley, 1982).

The analysis of the AG/HE syndrome in Aydin from March to May 1980 was more difficult. Instead of timings based on virus incubation periods in the animals and in insects, account had to be taken of the likely time of infection of the cow with Akabane virus during pregnancy to produce the AG/HE syndrome. This enabled a period to be selected for examination in greater detail, and the most likely times of wind carriage of infected insects were the end of September and the beginning of October 1979. The most likely source of infection with Akabane virus would be eastern Turkey or northern Syria, where antibodies in ruminants have been found.

Despite the severe AG/HE epidemic in Aydin from March to May 1980, the areas of the likely source of Akabane virus showed little or no evidence of disease. Where bluetongue is concerned, lack of clinical disease can be ascribed to differences in susceptibility between sheep in Cyprus and western Turkey and sheep in eastern Turkey, Syria and Israel. The AG/HE epidemic in Israel in 1969–70 indicated that cattle in that area at that time were highly susceptible, and subsequent serological tests in the region have shown that many animals have no antibody to Akabane virus. However, no outbreak has been reported since 1970. It may be that in the source areas animals are becoming infected in the latter part of pregnancy, as may have happened in Cyprus (Sellers & Herniman, 1981). It may also be that the weight of infection in the Menderes valley might have been greater, brought about by the concentrating of insects as a result of windshift in the valley (Pedgley, 1982).

It would appear from these and other investigations on bluetongue, African horse sickness and Akabane disease in the area (W. P. Taylor, K. A. J. Herniman, I. D. Gumm, L. Owen & R. F. Sellers – unpublished results) that there are two circulations involving movement of infected animals and carriage of infected insects on the wind. One circulation includes the Euphrates and Tigris valleys in Iraq, eastern Turkey and northern Syria; the other includes Israel, the Jordan valley, the Orontes valley, Antakya and Adana. On occasions there is extension of these circulations into Cyprus and western Turkey, mainly through carriage of infected insects on the wind. In 1977 bluetongue occurred in the west of Cyprus for the first time since 1951. The combination of disease not normally found in that part of the island and of unusual south-easterly winds could have led to the outbreak of bluetongue in western Turkey.

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