# History of Foot-and-mouth disease in North African countries

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Foot-and-mouth disease,
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**Summary**
Foot-and-mouth disease (FMD) is a highly infectious and contagious transboundary viral disease of domesticated and wild cloven-hoofed animals. Wide prevalence of FMD in Asia and Africa associated with huge economic losses to livestock farming and industry prompted global concern. The present review summarizes the state of the art research in epidemiology, diagnosis, and surveillance of FMD in the North African countries. Even if the situation varies across the North African states, FMD is still a key factor affecting livestock production in this part of the world. Historically, 4 serotypes have circulated in North Africa (O, A, SAT2, and C) with type O being the most prevalent serotype, followed by serotype A. However, the rapid spread of SAT2 lineages from Libya to Egypt in 2012 and the O lineages from Libya to Tunisia, Algeria, and Morocco between 2014 and 2015 demonstrated the need for a robust surveillance system to detect and respond effectively to exotic infections. Emergence and re-emergence of FMD virus genotypes/lineages have been detected engendering the need to replace vaccine strains quite frequently.

## Storia dell'afta epizootica nei Paesi del Nord Africa

**Parole chiave**
Afta epizootica,
FMD,
Nord Africa,
Epidemia,
Sierotipo,
Vaccino.

**Riassunto**
L'afta epizootica (FMD) è una malattia transfontaliera altamente infettiva e contagiosa che colpisce animali biungulati domestici e selvaggi. La sua diffusione in Asia e in Africa, associata a enormi perdite economiche nel settore agricolo e zootecnico, ha causato profonda preoccupazione. La presente review riassume lo stato dell'arte epidemiologico, diagnostico e di sorveglianza dell'afta epizootica nei paesi dell'Africa settentrionale. La FMD incide in maniera determinante sulla produzione di bestiame negli Stati del Nord Africa. Storicamente, hanno circolato in Nord Africa 4 sierotipi (O, A, SAT2 e C); il serotipo O è il più diffuso seguito dal serotipo A. Tuttavia, la rapida diffusione nel 2012 del lineage SAT2 dalla Libia all'Egitto e di quello O dalla Libia a Tunisia, Algeria e Marocco tra il 2014 e il 2015, ha dimostrato la necessità di un sistema di sorveglianza solido per rilevare e rispondere efficacemente alle infezioni esotiche. L'emergenza e la riemergenza di genotipi/lineages della FMD osservate negli ultimi anni hanno costretto l'utilizzo, nelle campagne vaccinali, di stipiti virali diversi.

## Introduction

Foot-and-mouth disease (FMD) is endemic in some North African countries. Its aetiological agent, the foot-and-mouth disease virus (FMDV; family *Picornaviridae*, genus: *Aphthovirus*), causes a highly contagious disease of ruminants and swine. Seven immunologically distinct serotypes [O, A, C, Asia 1, Southern African Territories (SAT)1, SAT2 and SAT3] have been identified so far.

Serotypes O, A, SAT1, and SAT2 predominate in most of the African countries (Rweyemamu *et al.* 2008). Vaccination or recovery from infection with one serotype will not protect against subsequent infection with another serotype (Belsham 2005). Control of FMD is difficult due to the emergence of new strains (Domingo *et al.* 2005). Phylogenetic analyses of the VP1-coding region have been used to define genotypes in defined geographic areas

(topotypes) for each of the FMDV serotypes (Knowles and Samuel 2003).

Outbreaks of FMD continuously threaten the livestock industries in countries that are free of FMDV (with or without vaccination). Millions of animals are sacrificed every year worldwide under FMDV eradication programs (Di Nardo *et al.* 2011). However, surveillance programs and molecular epidemiological studies help us to detect the introduction of new variants and possible source of spread of the disease into a community or region (Knowles and Samuel 2003, Rweyemamu *et al.* 2008). To implement effective control program against FMD, it is essential to have information on the pattern of outbreaks, the circulating viruses involved, and eventually determine – through regular vaccine matching – the ability of the current vaccine candidates to confer immune-protection. Regular monitoring of the circulating FMDV strains for possible genetic and antigenic variations is essential for understanding the dynamics of the virus, using appropriate vaccine at any given, implementing appropriate and adequate control strategies (Patonet *et al.* 2009, Volsoo *et al.* 2004).

The North African region includes Morocco, Algeria, Tunisia, Libya and Egypt. By virtue of its geographical location and its borders with the Middle East and Sahel countries, North African countries are vulnerable to several transboundary diseases, including FMD. Currently, the livestock population susceptible and at risk to FMD in the North African countries is approximately 100 million heads (cattle, sheep/goats and pigs) and the epidemiological situation and control measures applied by these nations need to be harmonized (OIE 2017).

Even if the situation in North African states is not strictly the same, given the epidemiological specificities each countries, FMD is still one of the main constraints affecting livestock production in this part of the world, causing a significant drain on the budgets of the national veterinary services and on livestock owners in the region. Foot-and-mouth disease is mostly endemic in all the Middle East and North Africa region (MENA) and despite the use of modern and effective vaccines, devastating epidemics occur periodically in the area. They usually originate in neighbouring regions – West Asia, East, and West Africa (Sub Sahara area) – and spread rapidly across national and regional borders (Yehia and Primot 2009).

This review describes the geography and time disposition of outbreaks, control strategies towards free status, and re-introduction of the disease into North African states until 2015. The role of cross border movements in the incidence of the disease, the serotyped and genotyped isolates from the various countries are also taken into consideration.

Data available in research papers and reports of international organisations and databases [Pirbright World Reference Laboratory (WRLFMD)[1], OIE[2], and FAO[3]] have also been considered to describe the FMD situation in the area.

## *History of FMD epidemics in North Africa before 1999*

### Outbreaks reported before 1999

Historically, 4 serotypes have circulated in North Africa (O, A, SAT2, and C) with type O being the most prevalent serotype, followed by serotype A. Serotype C and SAT2 have been reported in Tunisia and Egypt, respectively (Table I). Prior to 1999, the last reported outbreaks in North African countries were (WRLFMD 2017) in: Algeria (December 1990, serotype O); Morocco (September 1992, serotype O); Libya (January 1994, serotype O); Tunisia (August 1994, serotype O); and Egypt (April 1997 serotype O).

### Control strategies before 1999

In 1993 and 1994, the Algerian government planned an annual vaccination only for cattle using a monovalent type O vaccine. However, the vaccination program was discontinued due to the political situation at that time. The same strategy was adopted in Morocco in the same years, where annual vaccination of cattle was performed up to December 1997 with a monovalent type O vaccine. Tunisia had also vaccinated susceptible animal populations annually since 1989, small ruminant populations were vaccinated with a monovalent type O, while cattle received a trivalent (O, A, C types) vaccine (FAO 1999). No information about the vaccination program has been for Libya, probably this is because of scanty information about animal heath situation and the available control programs, (FAO 1999).

In Egypt, the disease has been reported since 1950s, when the disease was detected for the first time upon an outbreak caused by strain SAT2. The most sever outbreak in Egypt took place in February 1987; when the disease affected 63,430 cattle and buffaloes; 11,178 sheep and goats; and 230 swine, with mortality rate reaching 4%, 2%, and 100%, respectively (FAO 1999). Furthermore, in March

[1] Pirbright Institute World Reference Laboratory for Foot-and-Mouth Disease by the Food and Agriculture Organization (FAO) - Reference laboratory for FMD by the Office International des Epizooties (OIE). www.wrlfmd.org.

[2] World Organisation for Animal Health(OIE) http://www.oie.int/.

[3] Food and Agriculture Organization (FAO) http://www.fao.int/.


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**Table I.** *History of Foot and mouth disease (FMD) serotypes in North Africa before 1999 (WRLFMD 2016).*

| Country | Year | FMD serotype |
|---|---|---|
| Algeria | 1966-1990 | O |
| | 1977 | A |
| Libya | 1959, 1962, 1967-1968, 1972, 1981-1983, 1988-1989, 1994 | O |
| | 1979 | A |
| Morocco | 1991-1992 | O |
| | 1952, 1977, 1983 | A |
| Egypt | 1951, 1958, 1961-1962, 1964-1977, 1978-1982, 1987, 1989-1994, 1997 | O |
| | 1950 | SAT2 |
| | 1952 (or 1953?), 1956, 1958, 1972 | A |
| Tunisia | 1970, 1975, 1989-1990, 1994 | O |
| | 1979, 1982 | A |
| | 1965, 1967, 1969 | C |

1993, an outbreak took place in 11 governorates, 20 foci, involving 2,027 cattle and 1,827 buffaloes, were reported. As a result, since 1987 vaccination against FMD (serotype O) in Egypt is obligatory and free of charge (FAO 1999).

## *The 1999 epidemic*

### Situation report in 1999

The livestock population at risk for FMD in North African countries in 1999 was approximately 78 million heads, because most of these livestock were not vaccinated against any of the FMD serotype. On the 20th and 21st February 1999, 2 cases of Foot-and-mouth disease (FMD) were suspected in cattle in Algiers district, Algeria. The vesicular material was collected aseptically and sent to the Pirbright World Reference Laboratory (WRLFMD) for analysis. FAO was regularly informed once the serotypes had been confirmed as type O (FAO 1999). Sequence analysis of the virus revealed a genetically different type O virus from the strains that were circulating at the time in the MENA. The sequenced analysis showed that the Algerian viruses (O/ALG/1/99) belonged to the West-African topotype with 99% similarity to a strain isolated in Côte d'Ivoire (O/CIV/8/99) and Guinea (O/GNA/6/99) in 1999 (Samuel *et al.* 1999, Samuel and Knowles 2001).

These data confirmed the suspicion about the origin of the disease. Indeed, zebu cattle had been introduced illegally across the Algeria Southern frontiers in February 1999. At the time of capture, these zebu cattle did not present any clinical signs of FMD (Samuel *et al.* 1999, Samuel and Knowles 2001). However, their presence demonstrated that transboundary animal movements took place on the Southern frontier with Niger and Mali, which are endemic for FMD. From the beginning of the epizootic up to the 22th June 1999, 179 outbreaks were recorded in 36 districts out of 48. On the 22nd February 1999, cases of FMD were also detected in Souk-Ahras district (50 km from the Tunisian border) and in Tlemcen (58 km from the Moroccan border) (FAO 1999).

In Morocco, the first case of foot-and-mouth disease was suspected on the 25th June 1999, in the district of Oujda, five days after its declaration in Algeria. Clinical signs and lesions typical of Foot-and-mouth disease were observed (FAO 1999). The WRLFMD confirmed the presence of the serotype O (O/MOR/1/99 and O/MOR/2/99) which was genetically very similar (99%) to the virus that had appeared in Algeria. Furthermore, approximately two weeks later the disease was reported in the Khouribga and Beni Mellal district (600 km from the Oujda outbreak), highlighting the contagious nature of the disease, covering wide geo-graphic areas and infecting susceptible animals in affected flocks (Samuel *et al.* 1999, Samuel and Knowles 2001, WRLFMD 2017).

In Tunisia, on the 1st March, 1999, an FMD outbreak was detected in Nabeul district, despite the launch of a vaccination campaign of cattle, sheep, and goats to prevent the FMDV introduction from the Algerian border. The FMDV from all susceptible animals was confirmed by the WRLFMD. The strain involved was identified as serotype O (O/TUN/1/99 and O/TUN/5/99) genetically very similar to the virus that detected in 1999 in Algeria and Morocco (Samuel *et al.* 1999, Samuel and Knowles 2001, WRLFMD 2017). There was no outbreak recorded during this epidemic in Libya and Egypt (OIE 2017).

### Control strategies in 1999

In 1999, an appeal for vigilance was launched throughout the national territories in Algeria, Tunisia, and Morocco with active surveillance in all farms, all veterinary professionals were mobilized, and biosafety measures observed. Media were used to sensitize and disseminate information on the benefits of farmer's participation in disease prevention and control program to protect their livestock. In the affected farms, all cattle were euthanized and their owners compensated, along with intensification of surveillance on a 10Km radius from the area of the outbreak. The vaccine used for this campaign contained the O Manisa, as prescribed by WRLFMD (FAO 1999, Thomson 2002).

In Algeria, during the first week of the epizootic, ring vaccination was carried out around the outbreak

locations and subsequently generalized to the entire national herd, including small ruminants along the frontier on the East of the country following the appearance of cases of FMD in sheep in Tunisia. A total of 1,4 million cattle was vaccinated and 160,551 received a booster vaccination after 1 month. Furthermore, 600,000 sheep and 34,733 goats were also vaccinated around the outbreak area.

In Morocco, over 2,500,000 cattle were vaccinated against FMD since the beginning of the outbreaks; while in Tunisia, 193,686 out of 313, 960 cattle and 1,083,628 out of 2,102,000 small ruminants were vaccinated (FAO 1999, Thomson 2002).

## *FMD epidemic from 2000 to 2013*

### Situation report between 2000 and 2013

In Libya, several outbreaks of FMD have been reported between 2000-2013. The first wave of the outbreak in 2003 was caused by SAT2 strain of the virus, which was eventually self-limiting and never spread across international borders. Serotype A, topotype Asia lineage Iran-05, was detected in 2009. In 2011, another outbreak was reported. In this case, O serotype, topotype ME-SA, lineage PanAsia-2 of the FMDV was detected (WRLFMD 2017).

Libya officially confirmed outbreaks due to FMDV serotype SAT2 to the OIE on 27 February 2012, in association with newly introduced feedlot cattle in Benghazi, in the Eastern Province of the country. The results of genotyping of this FMDV strain indicated that the serotype was similar to the one that prompted a previous FMD outbreak in Sudan in 2007 and SAT2 viruses identified in Nigeria in 2007. In addition to SAT2, serotype O was also confirmed from samples collected in January 2012 (WRLFMD 2017).

Due to the political instability in Libya, information about the incidence of the disease became scarce. Control measures (including vaccination) were implemented, particularly after the introduction of new strains of serotype SAT2 in 2012. A sero-surveillance was implemented by the Istituto Zooprofilattico Sperimentale di Brescia, Italy, OIE's Reference Laboratory (IZSLER) (Hall *et al.* 2013).

In Egypt, outbreaks due to serotype O occurred in 2000 and 2006. These outbreaks were self-limiting and never spread across international borders (WRLFMD 2017). Other serotypes have not been reported since 1972 (OIE 2017). In January 2006, clinical cases of FMD were detected on a cattle farm in Ismailia, Northeastern Egypt. Samples were submitted to WRLFMD for laboratory confirmation and FMDV type (A) was identified as A/Egy/2006. This strain has more than 90% nucleotide identity with A/KEN/98, A/ETH/92, and A/KEN/05, and all topotypes are closely related. Its introduction in Egypt from East Africa was probably made through trading of live cattle from Ethiopia (via sea-route) (WRLFMD 2017). By April 6, 2006, 34 FMD outbreaks in 8 districts have been reported affecting more than 7,500 animals. Most (96.7%) of clinical FMD cases involved cattle; 411 cattle (mainly calves) reportedly died (OIE 2017).

In 2009, another outbreak with a serotype A was reported. The identified strain spread in 2006 and evolved until 2009 (WRLFMD 2017) and was closely related to A/EGY/06 (95.5% nucleotide identity), thus, confirming the persistence of African type A virus in Egypt

In February 2012, despite a nationwide vaccination campaign conducted in January 2012, a great number of FMD events were reported throughout Egypt. The analysis of the epidemiological situation and laboratory findings suggested that exotic FMDV serotypes or strains might have been responsible for the pattern of outbreaks. Actions were agreed to clarify the situation which confirmed the presence of SAT2 and other serotypes among the samples from outbreaks. The number of suspected cases grew at a rate of 5,000 per day, while the number of deaths reached 500 head per day (OIE 2017). The mortality rate was increased especially among calves and in small farms, since SAT2 was newly introduced to Egypt and there was no herd immunity or previous vaccination efforts. Losses of older cattle was significant. Foot-and-mouth-disease impacts both cattle and buffalo populations, although the effects are normally more severe on cattle. The disease was already detected in 25 of 27 governorates in Egypt. Regionally, SAT2 outbreaks were reported in Libya in 2009 and in 2012 (OIE 2017),

Algeria, Morocco, and Tunisia reported no cases of FMD since the 1999 major episodes (OIE 2017, WRLFMD 2017).

### Control strategies between 2000 and 2013

The disease is endemic in Libya and Egypt, the introduction and spread of FMDV to other North African countries free or without cases is therefore an important risk that needs to be addressed (Knowles *et al.* 2007, OIE 2017, WRLFMD 2017).

In Egypt, a locally produced bivalent FMDV vaccine, containing both O1 and A / Egypt/2006 isolates, was released in mid-May 2006 for the first time. Following the SAT2 outbreaks of 2012, the authorities add a SAT2 strain to the vaccine (OIE 2017).

In Algeria and Morocco, after the 1999 epidemic, yearly FMD vaccination (cattle only) with the

O Manisa strain was conducted. In Tunisia, the vaccination covered cattle, sheep, and goats (OIE 2017). Following the Egypt FMD outbreaks, Tunisia added respectively SAT2 and the A22 strains to the FMD vaccine. Algeria also added A22 strain to the FMD vaccine (Ahmed el al. 2012). Since 2007, Morocco has stopped FMD vaccination following several sero-epidemiological surveys conducted on cattle and small ruminants, which confirmed the absence of FMDV circulation. The country prepared an FMD contingency plan, relying on epidemio-surveillance, and has constituted a vaccine antigen bank to be used in case of emergency.

In 2011, Algeria, Morocco, and Tunisia commenced working together deploying a regional approach for the FMD control. In October 2011, these 3 countries submitted their dossiers to OIE to be assessed by the FMD *ad hoc* group and the Scientific Commission of the OIE before presentation to the General Assembly in May 2012. This work was fully consistent with the FAO/OIE FMD Progressive Control Pathway (PCP-FMD) and had the goal to achieve the OIE official status of FMD-free with vaccination (for Algeria and Tunisia) and without (for Morocco). In May 2012, Algeria, Morocco, and Tunisia were recognised by the OIE as Member Countries with endorsed official control programme for FMD, in accordance with the Chapter 8.5 of the Terrestrial Animal Health Code (OIE 2012, OIE 2013).

Algeria and Tunisia carry out annual vaccination campaigns (Algeria: O Manisa + A22. Tunisia: O Manisa + O-Tunisia99 + A22 + SAT2 Eritrea), while Morocco stopped vaccination in 2007 (OIE 2012, OIE 2013). National laboratories in North Africa are fully associated and participate actively in the European network of FMD reference laboratories, as they part take in the annual ring trials and attend technical meetings for capacity-building and cooperation (OIE 2012, OIE 2013).

## The 2014-2015 epidemics

Overall, the livestock population susceptible and at risk for FMD in North Africa was approximately 100 million heads. The epidemiological situation of FMD in North African countries and the control measures applied in the region were not uniform (Table II) (OIE 2017).

### Situation report in 2014-2015

On 24 April, 2 cows with clinical signs suggestive of FMD were reported in Nabeul district, Tunisia (OIE 2017). Both real time Polymerase Chain Reaction (PCR) and phylogenetic analysis were performed by the national laboratory (IRVT) and then confirmed by IZSLER. O/ME-SA/Ind 2001d was the identified topotype. This topotype is closely related (99%) at nucleotidic level to viruses isolates from Libya (LIB/2/2013) and Saudi Arabia (SAU/3/2013) (WRLFMD 2017). According to OIE report, the source of the outbreak was due to the illegal movement of animals from Libya (OIE 2017). In May 2014, 32 new outbreaks had been reported in domestic sheep, goats, and cattle, in 11 districts. In June, new cases were declared in Jendouba districts 50 km to the West border of the country with Algeria (OIE 2017).

On the 23rd of July 2014, a FMD outbreak was detected in Setif district at the East of the Algeria, 260 km from the border with Tunisia. The first outbreak occurred on a fattening cattle farm, the source of the outbreak was due to the illegal introduction of animals from Tunisia. Clinical signs of the disease included fever, blisters, lameness, and mammary lesions (OIE 2017). Samples were submitted to the IZSLER, Brescia, Italy. The isolated virus was O/ME-SA/Ind-2001d lineage with nucleotide identity of 99.69% and 99.37% to field strains O/TUN/1031/2014 and O/TUN/1054/2014, respectively, isolated during the 2014 FMD outbreaks in Tunisia (WRLFMD 2017). Outbreaks were reported in 6 districts during the last week of April. In the first week of May, 35 new outbreaks were reported in 13 new districts. By the end of August, more than 350 outbreaks had been recorded in 33 different districts. Cases were subsequently declared in Oran districts 160 km from the West border of the country with Morocco. All the cases recorded were from cattle and there were no clinical, serological signs of FMD in small ruminants. However, in March 2015, 12 FMD outbreaks involving sheep re-emerged in El Bayadh and El Oued districts. These were the first cases reported in Algeria after 5 months (OIE 2017).

In 2014, despite the vaccination effort, several outbreaks were recorded in Egypt caused by serotypes O, A, and SAT2. As for Libya, due to the political situation, information about FMD was scarce (OIE 2017, WRLFMD 2017).

**Table II.** *Livestock populations in North Africa in 2014 and Foot and mouth disease (FMD) vaccine serotypes used (OIE 2016).*

| Species | Cattle | Sheep | Goats | FMD vaccine serotype used |
|---|---|---|---|---|
| **Libya** | 150,000 | 5,100,000 | 1,200,000 | O/A/SAT2 from 2013 (cattle) |
| **Tunisia** | 600,000 | 6,600,000 | 1,500,000 | O/A/SAT2 (cattle), O/SAT2 (small ruminants) |
| **Algeria** | 2,008,000 | 26,000,000 | 5,000,000 | O/A (cattle) |
| **Morocco** | 2,800,000 | 20,000,000 | 5,000,000 | O Stopped since 2007 |
| **Egypt** | 5,700,000 | 1,800,000 | 1,000,000 | O/A/SAT2 (cattle and small ruminants) |

### Control strategies between 2014 and 2015

Following the FMD epidemic in Tunisia in April 2014, several measures were implemented in both Tunisia and Algeria (OIE 2017):

- crisis cell centres at national and regional levels were instituted;
- disinfection of vehicles leaving affected or suspected district;
- vaccination points of susceptible species at the entrance of livestock markets;
- peri-focal vaccination in 5 km radius;
- epidemiological investigation to determine the origin of the infection;
- closing of livestock markets, ban on movement of animals within the infected districts.

Currently animals' treatment is not conducted. In Algeria, in the affected farms, all cattle infected were euthanized and their owners compensated. Further control measures are: stamping out, screening, vaccination in response to outbreaks, disinfection of infected premises/establishments. Vaccination campaigns have been conducted throughout Algeria and Tunisia. The vaccination was carried out with the same vaccine (O BFS received as a donation from the UE) used in Libya. In Algeria, the campaign rate by June 2014 was 85% in cattle (O Manisa, A22); although small ruminants were completely naïve (OIE 2017, WRLFMD 2017).

A summary of vaccine matching data generated at the WRLFMD for representative member countries for the O/ME-SA/Ind2001d lineage that shows results for 22-field virus samples also contains data for viruses from Algeria and Tunisia. In general, 3 vaccine antigens (O/TUR/5/09, O-3039, and O/TAW/98) are matched against these viruses, while the *in vitro* test indicates a poorer match for O-Manisa and O-BFS, the vaccine strains used in Algeria and Tunisia. Arguably, this may be the reason why the FMD epidemic occurred in Tunisia and Algeria despite the vaccination efforts applied by the 2 countries. In August 2014, the vaccine strain O/TUR/5/09 was used in Algeria, which allowed the control and resolution of the episodes (WRLFMD 2017).

Following the FMD epidemic in Algeria in July 2014, in Marocco several measures were applied such as:

- a vigilance committee was put in place;
- strengthening surveillance mainly at the borders;
- high alert for any suspicious case.

In August 2014, a preventive vaccination campaign on cattle (strain O/TUR/5/09) was conducted. The campaign had two phases. In the first phase, regions at the border with Algeria (East of Morocco – about 1,000,000 heads) were targeted; on September 7, 2014, a total of 84% of the targeted population was vaccinated. In the second phase, the vaccine was administered in the rest of the territory (about 1,700,000 heads). As a result, no FMD case was declared in Morocco until the end of October 2015, when 6 outbreaks were recorded in Sidi Bennour, a province in the centre of Morocco. The origin of the infection was unknown (OIE 2017). However, the situation was immediately resolved (OIE 2017). The virus isolated was identified as O/ME-SA/Ind-2001d lineage, with 98% nucleotide similarity to the Tunisian and the Algerian field strains isolated during the outbreaks in 2014 (OIE 2017, WRLFMD 2017).

## *The 2017 epidemics*

### Situation report in 2017

At the end of March 2017, FMD outbreaks in domestic cattle have been reported in the West (Relizane district), Centre (Medea district), and East (Bordj Bou-Arréridj district) of Algeria (OIE 2017). Clinical signs and lesions typical of FMD were observed including fever, blisters, lameness, and mammary lesions (WRLFMD 2017). Samples were forwarded to the IZSLER, sequence analysis of the virus revealed a genetically different type A virus from the strains that were circulating in neighbouring Libya at the time (Asia/ Iran-05BAR-08) (WRLFMD 2017). The origin of the infection was unknown. Although, the phylogenic analysis showed that the Algerian viruses belonged to the African topotype lineage G-IV with 98.4% nucleotide identity to field strains isolated in Nigeria in 2015 (WRLFMD 2017).

### Control strategies in 2017

Several sanitary measures have been implemented following the FMD epidemic in Algeria in March 2017. Nonetheless, without effective vaccination several outbreaks have been recorded in other districts in Algeria from April to June. Furthermore, on the 28$^{th}$ of April 2017, the presence of serotype A was recorded in Tunisia. The origin of the infection is unknown and the phylogenic analysis was not preformed (WRLFMD 2017). The vaccine strain recommended by WRLFMD (A/ERI/98) was used at the end of July (WRLFMD 2017).

## *Discussion*

Three FMD serotypes (O, A, and SAT2) and 6 lineages

(Table III) have been introduced into North Africa from West Africa and Middle East. However, Algeria, Tunisia, Morocco, and Egypt have contingency plans and funding for immediate procurement of vaccines; while Libya has not such a plan. This puts Libya neighbouring countries at a constant risk, given the free movement of animals across its borders (WRLFMD 2017). The livestock population in Algeria and Morocco is highly susceptible to SAT2, and effective vaccines are only used in Tunisia. In Libya, the routine implementation of vaccination program has been severely affected by civil unrest and changes in government leadership and policies. It is expected that serotype SAT2 will spread widely and may affect a high proportion of livestock in the region until limited by natural immunity or imposition of effective biosecurity measures and vaccination programmes at a regional level (Ahmed *et al.* 2012, Hall *et al.* 2013, Ryan *et al.* 2015).

The rapid spread of SAT2 and other exotic FMDV in Libya and Egypt demonstrates the need for robust surveillance systems to detect and respond effectively to exotic infections in an endemic FMD region. It also shows the relevance of collecting virological information concerning FMDV epidemics in the Sahel countries to the immediate South of the Sahara or in Eastern regions. Uncontrolled movements of ruminants in North Africa occur by land transport. This remains a major constraint for border control services; the flow of uncontrolled movements of animals across the border that occurs along the East-West axis between North African countries is difficult to estimate and depends on several factors (price changes, religious festivities, etc.). Furthermore, political unrest in Libya increased the potential risk of spreading diseases into neighbouring countries, especially Egypt, Tunisia, and Algeria.

**Table III.** *Foot and mouth disease virus (FMDV) lineage in the North-African countries 2011-2016 (WRLFMD 2016)*

| FMDV lineage | Year and country occurrence |
|---|---|
| O/ME-SA/PanAsia-2 | Egypt (2014), Libya (2011 and 2012) |
| A/ASIA/Iran-05 | Libya (2009), Egypt (2012,2013 and 2014) |
| O/ME-SA/Ind-2001 | Libya (2013), Tunisia (2014), Algeria (2014), Morocco (2015) |
| SAT2 topotype VII | Egypt (2012 and 2014), Libya (2012) and Mauritania (2015) |
| A/AFRICA/G-IV | Egypt (2014) |
| O/EA-3 | Egypt (2013 and 2014) |

In conclusion, control and prevention measures for FMD, like other trans-boundary animal diseases, include: surveillance, animal movement control, vaccination, quarantine, humane culling, and just compensation. Countries in which FMD is endemic within MENA need to monitor intensively the pattern of FMD and investigate outbreaks thoroughly using syndromic surveillance for patterns, such as mortalities in young stock or among well-vaccinated animals, as well as adequate and rapid strain typing of FMD at OIE or FAO Reference Centres to ensure that exotic serotypes are detected.

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