INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 11, No. 6, p. 193-200, 2017

RESEARCH PAPER OPEN ACCESS

A new vegetation history documented by pollen analysis and C14 dating in the alder of Ain Khiar - El Kala wet complex, Algeria

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Key words: Alder of Ain Khiar, Vegetation dynamic, Vegetation history, Pollen anlaysis

http://dx.doi.org/10.12692/ijb/11.6.193-200 Article published on December 30, 2017

Abstract

In order to trace the history of local and regional vegetation a pollen sequence of 260 cm of depth was extracted from alder-peatland of Ain-Khiar in the wet complex of El Kala which is situated in north–east of Algeria and considered as one of the most important wetlands in Mediterranean. A pollen diagram obtained from the study of the core which has been supported by tow A.M.S. radiocarbon dates. 66 taxa have been identified as following: local vegetation as hygrophilous and aquatic taxa which is dominated by Alnus, Cyperaceae and Juncaceae; regional vegetation as mesophilic taxa which is dominated by *Quercus*, *Erica arborea* and *Myrtus*; herbaceous taxa dominate the area which are represented by Poaceae, Apiaceae and Fabaceae and anthropogenic activity indices taxa as *Eucalyptus* and *Cupressus*. At the beginning of the record of 500 years, towards 420 ± 69 BP (1530 ± 69 AD) a cork oak forest and mesophilic vegetation were dominant at the Medieval Warm (MWP) Period as declared as in Mediterranean region by other authors, during the Little Ice Age (LIA) period the cork oak forest was replaced by the alder and hygrophilous vegetation, this landscape is kept till nowadays. Anthropogenic activity characterizes the modern epoch around 141 ± 97 BP (1809 ± 97 AD), by reforestation of *Eucalyptus* in sub-humid area and using *Cupressus* as a protective barrier for agricultural land in the surrounding area. These climate changes have been reported in the northern hemisphere as well as the Mediterranean by other authors.

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Introduction

Today, climate change studies are a great challenge to control and overcome its consequences on human population as well as on environment. Paleo-botanical and Paleo-climatic studies are the most reliable ways for understanding these changes and explaining past events through the study of vegetation dynamics mainly in peatlands, which are the record of vegetation and climate history.

In Algeria peatlands represent 1% of total area, which located on the north-east of the country. The alder-peatland of Ain-Khiar, situated in Wet Complex of El-Kala, is the subject of this study, following the works of Youbi and Benslama 2015 and Benslama 2010. Two A.M.S. radiocarbon analyzes revealed dates of about 500 BP, were applied In order to: retrace the vegetation history and understand its dynamics, and conditions that influenced these dynamics. Therefore make the link between this study and previous studies at the local level in Algeria and in the Mediterranean region.

Materials and methods

Geographical situation

El Kala region is one of the richest from the biodiversity area from the north-eastern of Algeria, has been protected by the establishment of a national park of approximately 80 000 ha since 1983 and has been registered as a biosphere reserve by UNESCO since 1990. The region is bounded on the east by Tunisian borders, on the north by the Mediterranean sea, on the west by Cap Rosa, on the south by the foothills of El-Ghorra mountains (Benslama *et al.*, 2010).

The wet complex of El-Kala contains several sites distributed from the east of oued Mafragh (longitude E7°50') to the west of Kef Segleb (long 8°30'), several of them have evolved into peat bogs to form the largest area of peatlands active in Algeria about 1000 ha (Benslama, 2002).

Our study is based on the Alder of Ain-Khiar, site RAMSAR since 2003 (36°480'.62"N, 8°18'58.50"E°), Located at 24-30 meters of altitude, about 170 ha constitutes the area which 20ha are peatland. It is bordered to the north by the sand dunes, to the south by Oued El Kebir and the agricultural plains of El Tarf city, to the east by the watershed of Oubeïra Lake and to the west by a degraded oak forest, receives water flood oued El-Kebir in winter to turn into the swampy area.

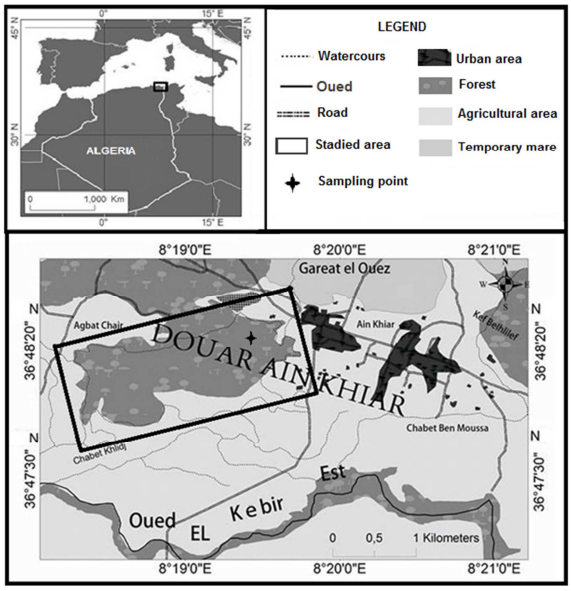

Fig. 1. Geographical situation of the studied area - Alder Ain Khiar.

Current local climate

The El-Kala region is located in the sub-humid Mediterranean climate (De Belair, 1990), with a mild summer with average temperatures of 31°C, The lowest temperatures are recorded in altitudes during the winter; February is the coldest month with 18°C while the month of August is the hottest. Annual precipitation is more than 700mm; prevailing winds are from the north-west resulting in 70% atmospheric humidity. This climate is particularly favorable to the development of forest vegetation which occupies 72.75% of the total area, 9% of agricultural land and 18% of lakes, marshes, and riparian areas.

Current vegetation

According to Thomas (1975), Aouadi (1989), De Belair (1990), Benslama *et al.* (2010) and Belouahem (2012) the vegetation cover is largely dominated by cork oak forest with an undergrowth of *Erica arborea* and *Myrtus communis*, while the dune formations are occupied by *Quercus coccifera*, the alders represent a small and fragile ecosystem of the region characterized by wetland vegetation:

- *Heliophytic vegetation: Alnus glutinosa, Salix pedicillata, Erica scoparia, Rubus ulmifolius, Vitis vinifera, Athyrium filix-femina, Osmunda regalis, Laurus nobilis,*

- *Hygrophilous vegetation: Ormenis mixta, Mentha rotundifolia, Trifolium maritimum,*

- *Amphibious vegetation: Scirpus acutus, Phragmites australis, Typha latifolia, Juncus capitatus,*

-*Aquatic vegetation: Nymphea alba, Callitriche pallustris, Ranunculus aquatilis, Polygonum salcifolium, Salvinia natans*

These alders are currently degraded and have a strong regression.

Sampling

Russian corer used for sampling, coring was carried out alternately in tow parallel holes. Cores were placed immediately in plastic gutters and packed in plastic bags to prevent them from breaking and drying. Then they were transported immediately to the laboratory and stored in the shade at ambient temperature (Reille, 1990). A core of 260cm length was taken. It was the subject of a morphological description and sampling for pollen analysis, total of 52 samples (each 5cm of the carrot) were treated to carry out pollen analyzes following (Eerdman, 1960); (Faegri and Iversen, 1989) method, based on a series of treatment with: NaOH (20%), HF (70%), HCl (10%), CH3COOH, acetolysis and finally Conservation of pollen material in glycerin. Pollen and spores identification was made under optical microscopy using the pollen and spores atlas of references (HJ Beug, 2004); (Reille, 1992); (Reille, 1996); (Reille, 1998).

Pollen diagram

The determination of pollen grains and spores carried out under an optical microscope. These pollen grains and spores were identified using a reference collection and pollen atlas of references (HJ Beug, 2004); (Reille, 1992); (Reille, 1996); (Reille, 1998). The numbers are expressed in relative frequencies in relation to the total pollen sum and Plotted graphically using TILIA and TG View (Grim, 1991).

Chronology

For ^{14}C dating, two peat samples were selected, the dating analyzes were carried out in Poznan radiocarbon laboratory, POLAND by the AMS spectrometry method, the dates obtained are calibrated on the site www.calpal -online.de and shown in the table below.

Table 1. AMS Radiocarbon dating of the cores taken at Alder Ain Khiar.

Dated samples levels cm	Lab cod	Dated material	Non calibrated ^{14}C (Yr BP)	calibrated ^{14}C (Yr BP)	calibrated ^{14}C (Yr AD)
20-25 cm	Poz-79132	Peat	85 ± 30 BP	141± 97 BP	1809± 97 AD
120-125 cm	Poz-79262	Sandy peat	380 ± 30 BP	420 ± 69 BP	1530 ± 69 AD

Results

1. Morphological description of Alder Ain Khiar core

Depth	Description
0-60 cm	Black, fibrous, presence of recognizable organic debris (leaves, branches, roots ...), very wet.
60-97cm	Brown, fibrous presence of sand pellets, presence of recognizable organic debris (roots, leaves ...) and pieces of charcoal, very wet.
97-120 cm	Gray-brown, clayey sand, massive, continuous, absence of organic debris, wet, metal smell.
120-135 cm	Black, sandy-fibrous, presence of recognizable organic debris (roots, leaves, branches, wood ..., very wet.
135-155 cm	Brown, fibro-sandy presence of recognizable organic debris (roots, leaves, branches, wood ..., very wet.
155-160 cm	Gray, sandy, massive and continuous, absence of organic debris, very humid.
160-200 cm	Yellow-gray, sandy clay, massive and continuous, absence of organic debris, wet, metal smell.
180-200 cm	Yellow, sandy clay, massive and continuous, absence of organic debris, wet, metal smell.
200-210 cm	Gray-yellow, sandy clay, massive, presence of organic debris (small roots), very wet, metal smell.
210-235 cm	Dark yellow, clayey-sandy, massive, presence of organic debris (small roots), very wet, metal smell.
235-255 cm	Yellow, sandy clay, massive, presence of organic debris (small roots), wet, metal smell.
255-260 cm	Gray, sandy clay, massive, presence of organic debris (small roots), wet, metal smell.

After pollen extraction, 66 spectra were established for alder Ain Khiar, based on a minimum of 300 counts. Aquatic taxa and Pteridophyteae were excluded from the total pollen sum, which reveals 3 pollen zones. The radiocarbon dates were integrated in the diagram as well as the stratigraphic description as shown in Fig. 2.

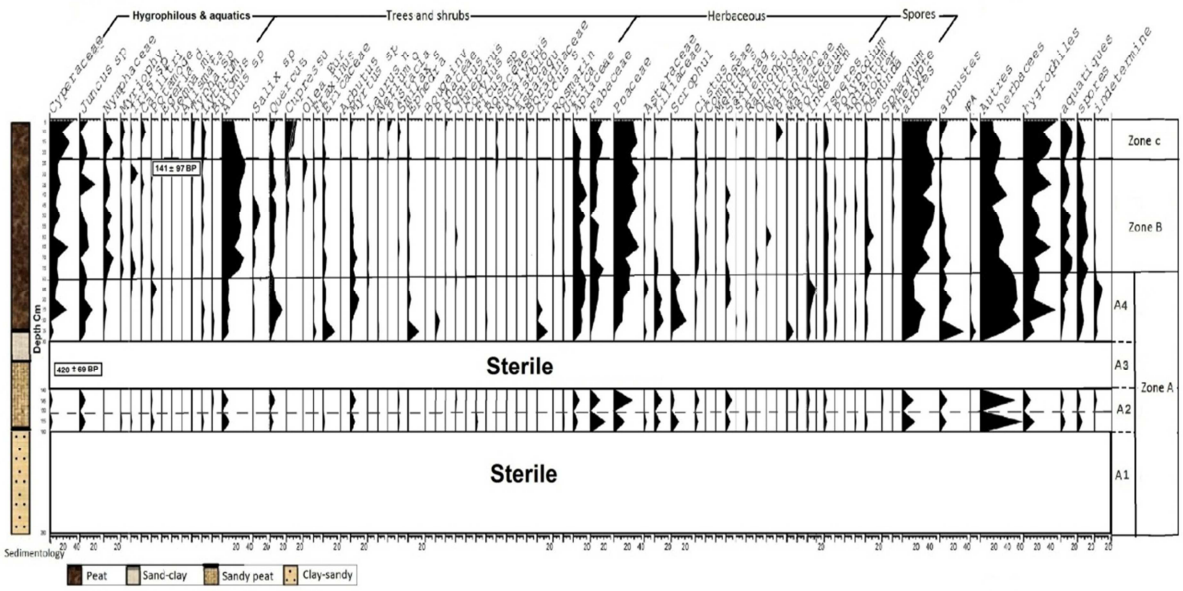

Fig. 2. Pollen diagram of Alder Ain Khiar.

2. Interpretation pollen zones defined from Alder Ain Khiar core

Site	Pollen zone		Depth cm	Significatif Taxa	Interpretation
Alder Ain Khiar	C		-25 to 0 cm	Hygrophilous and anthropization indices taxa	- Reduced tree inputs, Increase of shrubs and hygrophilous, appearance of exotic taxa anthropization indices IPA, *Eucalyptus, Plantago sp*.
	B		-25 to 80 cm	*Alnus- Quercus- Erica arborea Myrtus*- herbaceous Hygrophilous, Aquatic taxa and Spores	- A maximum input of *Alnus* (>30%) - Decline and disappearance of some mesophiles: *Quercus, Myrtus* et *Erica* and indeterminate taxa. - Maximum input for hygrophilous and aquatic taxa.
	A	A4	-80 to 110 cm	*Alnus- Quercus- Erica arborea Myrtus*- herbaceous Hygrophilous, Aquatic taxa.	- Maximum expression of herbaceous plants (> 50%), *Alnus* recedes (<20%) and maximum expression of *Quercus* and shrubs with *Myrtus* dominance up to 95 cm, then *Erica* dominance up to 105 cm. - Rarity of the aquatic and stop of supply of *Myriophyllum*. - Maximum input of indeterminate.
		A3	-110 to140 cm	Sterile	- Mixture of pure and mineral (sand, clay and silt) which interrupt the counting, impossible to reach 300 grains of pollen, it is considered sterile. - There is a continuity of vegetation of the sub-zones A2-A4.
		A2	-140 to 160 cm	*Alnus- Quercus- Myrtus*, herbaceous Hygrophilous, Aquatic taxa and spores.	- Maximum input of herbaceous plants (>50%), low input for trees not exceeding 10%, - Beginning of undetermined taxa appearance.
		A1	-160 to 260 cm	Sterile	- Soil texture (sandy clay) is not suitable for pollen grain conservation.

Discussion

Ain-Khiar alder occupy an inter-dune depression where vegetation cover forms a degraded alder and hygrophilous plants grouping on very wet peatland where *Osmunda regalis* grows up, forming a carpet exceeding 120 cm in height.

On regional plant the cork oak forest at *Erica arborea* and *Myrtus communis* occupies the sandstone flans, while *Quercus coccifera* matorral and its procession occupies the dunes, Garaat El Ouez represents the lake habitat closest to the site, the forest of *Eucalyptus* and the agricultural plain of El-Taref represent the artificial environment surrounding the area.

Sampling within the alder revealed a sediment layer (260 cm long), consisting of alternate black and brown sandy peat with gray - yellow clay sands at the base forming. The layer described in other regions around the site by other authors (Benslama, 1999); (Benslama, 2002); (Youbi and Benslama, 2015).

The sand pellets presence in peat sediments shows that the site is influenced by sand movements where the alder is located at the foothill of the dunes despite the dense vegetation cover described by Belouahem (2012).

The pollen analysis confirms local and regional diversity richness, the identification of more than 60 pollen types belonging to tree, shrubs, herbaceous and aquatic taxa.

Three principal pollen zones well described in the diagram are divided as follows:

Pollen zone A

Sub-zone A1 (-260 to -160) cm: The clay, sandy-clay texture of the sequence could be explained by the movements of the clays due to the floods of the Oued El-Kebir to the south of the alder and the dune sand movements to the north, this influence being due to the Low level of the site by forming a wet depression. This sub-zone does not contain pollen grains.

Sub-zone A2 (-160 to -140) cm: The beginning of vegetation installation while herbaceous dominance. This zone followed by pollen sub-zone A3 (-140 to -110) cm

Sub-zone A3 (-140 to -110) cm: Characterized by sandy-fibrous texture causing the pollen grains infiltrating explained by the continuation of same vegetation described in the Sub-zone A4 (-110 to -80) cm.

Sub-zone A4 (-110 to -80) cm: At the local level with a modest presence of *Alnus* and hygrophilous taxa (Cyperaceae), indicates that the site is a wet grassland and the low presence of aquatic taxa suggests that the stretch water (Grâat El Ouez 45m above sea level) has a relation with the alder Ain Khiar by the small water streams which allow the water transport of aquatic pollens from Garâat El Ouez to the alder.

At the regional level the dominance of herbaceous and heliophytic taxa (Fabaceae, Liliaceae, Asteraceae and Poaceae) indicates a drying area around the site, *Myrtus*, and Cistaceae cover the surroundings of the site, presence of a cork oak forest according to Bentiba and Reille (1982) *Quercus suber* is a modest pollinator and its presence does not exceed 20% Within a cork oak forest.

At this level the ^{14}C dating of (1530 ± 69) A.D, which can be said towards the end of the Medieval Warm Period known between (900-1300) A.D (Lamb, 1965); (Pfister *et al*., 1998) in pollen zone A, characterized by the dominance of mesophiles and heliophytes taxa.

Pollen zone B

Remote of mesophiles and disappearance of some heliophytes taxa and undetermined very strong extension of *Alnus* associated with *Osmunda* and hydrophilic and aquatic indicates the beginning of a wetter period, the beginning of the Little Ice Age (1500-1850) AD (Mann, 2002), This epoch signaled in Europe Italy (Calo *et al*., 2013), France (Jalut *et al*., 2000), Spain (Jalut *et al*., 2000); (Martin-Puertas *et al*., 2010) and also in Algeria (Youbi and Benslama, 2015).

Pollen zone C

The beginning of the modern epoch, confirmed by ^{14}C dating (1809 ± 97) AD, in this period the anthropization indices appear, they are represented by the *Eucalyptus*. The extension of the *Eucalyptus* culture in Mediterranean region began in the early XIXth century to explode in the XXth century. These were carried out in swamps or wet areas. (Riedacker, 1973) in Quezel *et al.*, 1990).

Eucalyptus was introduced into Algeria between 1854 and 1860; several species have performed well in the sub-humid and semi-arid areas of the country (FAO, 1982).

Eucalyptus, areas invasive and eliminate any type of competition, the irrational extraction of suber and using alder wood in that period, may have been the cause of their decline. *Cupressus* appearance at that period, which is native to Asia, was for construct protecting barriers of agricultural land.

● *Chronology and vegetation dynamics*

According to the obtained results, we try to understand the chronology of vegetation dynamics in alder Ain-Khiar during the last millennium. We refer to previous works at the local and regional level of: (Bentiba and Reille, 1982); (Benslama, 2010); (Youbi and Benslama, 2015) and others.

● *At the Medieval Warm Period (MWP):* (900-1300) A.D

At the local level, the timid presence of *Alnus* association and Cyperaceae indicates the presence of wet grassland, due to the mild climate notices at that time (Martin-Puertas *et al.*, 2010); (Calo *et al.*, 2013), spores fluctuations low aquatic taxa presence due to site's situation and relationship with Garaat El Ouez the closest permanent stretch of water according to Benslama (2010).

According to Reille *et al.* (1997) because of increased temperatures in the northern hemisphere and in Mediterranean corresponds to the Medieval Warm Period; there was an extension of the cork oak forest at the west of the Mediterranean, at low altitudes in El Kala region, while mesophiles (*Quercus suber, Erica arborea* and *Myrtus*) association with heliophytic herbaceous (Fabaceae, Liliaceae, Asteraceae and Poaceae) marks its maximum presence at regional level of alder Ain-Khiar, that is not the Case in the high altitudes occupied by herbaceous carpet according to Youbi and Benslama (2015). The Medieval Warm Period may have lasted for long time in this region than in northern hemisphere, according to C14 dating (1530 ± 69) A.D and described vegetation.

● *At the Little Ice Age Period (LIA) :* (1500-1850) A.D

In Europe this epoch is colder and wetter (Jalut *et al.*, 2000); (Martin-Puertas *et al.*, 2010); (Julia *et al.*, 2007).

Hygrophilous taxa (*Alnus*, Cyperaceae, Juncaceae, and Nemphaceae) represent their maximum extension, mesophiles taxa remoting (*Quercus suber, Erica arborea* and *Myrtus*) and other mesophiles taxa (undetermined taxa) disappearance.

● *From the late 19th century to present days:* (1809-± 97) AD

The anthropogenic activity characterizes this epoch, *Eucalyptus* reforestation between (1854-1860) in Algerian sub-humid areas, according the FAO (1982), also the appearance of *Cupressus*, a tree used as protective barrier of Agricultural land around the site, the landscape retains its appearance despite the decline of all of local and regional vegetation.

Conclusion

The palaeo-palynological study of the peat sequence (260 Cm) of depth extracted from the alder Ain-Khiar allowed us to reconstruct the vegetation history in the last 500 years, on a thick layer of clay sands, this story began with the dominance of oak forest and mesophilic vegetation, accompanied by the presence of *Alnus* and other hygrophilous during the Medieval Warm Period (MWP) (900-1300) A.D, epoch mentioned in the Mediterranean by several authors, as well as the Little Ice Age Period (LIA) (1500-1850) A.D which is characterized by the dominance of *Alnus* and other hygrophilous and the decline of the oak forest with other mesophiles and also the disappearance of some of them, the landscape keeps this appearance from the Little Ice Age Period (LIA) till nowadays. Anthropogenic activities characterize the modern epoch mainly by the reforestation of *Eucalyptus* and *Cupressus*. This work is an attempt to reconstruct the vegetation history in the wet complex of El-Kala, north-east of Algeria. Further works need to be taken into account for better understanding the climatic variations in the Mediterranean region and the vegetation dynamics associated with these changes.

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