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Aspergillus in Algerian studies

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Devant le jury composé de :

M. MAHAMEDI A. E.	MAA	Univ. de Ghardaïa	Président
M. DJELLID Y.	MAA	Univ. de Ghardaïa	Examinateur
M. BOURAS N.	Professeur	Univ. de Ghardaïa	Promoteur

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Dedication

I dedicate this work

To my dear Mama: Ousdik Fatma

The one who did the impossible for the sake of my success and my brothers and did not skimp on me with anything, and whose her prayers followed me since childhood.

To my dear Papa: Baala Ahmed
Who always helped me climb the ladder of success.

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To my dear aunts: Messoda, Djema
To all my friends and family

Saliha

ملخص

يعتبر جنس الرشاشيات (*Aspegellus*) مهمًا للغاية نظرًا لتواجدها في العديد من الأماكن المهمة وانتشارها على نطاق واسع، حيث يمكن أن تتواجد في الأكل ، في الوسط الذي نعيش فيه وحتى في جسم الانسان ،وقد حظيت هذه الكائنات باهتمام الكثير من العلماء والباحثين حول العالم.

الهدف من هذه الدراسة هو جمع كل الأنواع والأقسام التي وجدت في الجزائر من هذا الجنس من خلال الدراسات المتاحة وكذا التعرف على تصنيفها ومورفولوجيتها.

من خلال البحث عن هذا الجنس في الجزائر ، تمكنا من إحصاء 12 قسمًا من مجموع 25 قسم موجودا في الدراسات العلمية، و 33 نوعًا من أصل 150حيث تم توثيق المعلومات المتعلقة بالعينات الموجودة في هذه المذكرة، ووضع مجموعة من المفاتيح التي تساعد على التعرف عليها , وتجدر الإشارة إلى أن هذا النوع من البحث مؤقت ، حيث إن الدراسات التصنيفية تتغير باستمرار والابحاث حول هذا الجنس لاتزال مستمرة في الجزائر .عدد العينات المدروسة يعتبر بعيدا نوعا ما عن الأعداد الكلية ، الشيئ الذي يتطلب دراسة أعمق حول إمكانية وجود أقسام و أنواع أكثر في مناطق أخرى في الجزائر من خلال ابحاث اوسع و دراسات ادق تساهم في اثراء المعلومات حول هذا الجنس .

الكلمات المفتاحية: ، جنس، قسم، الجزائر، نوع ،*Aspergillus*.

Résumé

Le genre *Aspergillus* est très important en raison de sa présence dans de nombreux endroits importants et de sa large diffusion, où il se trouve dans la nourriture, le milieu dans lequel nous vivons et même dans le corps humain, et de nombreux scientifiques du monde se sont intéressés à son étude.

Le but de cette étude est de savoir toutes les espèces et groupes trouvées en Algérie de ce genre à travers les études disponibles et d'identifier leur classification et leur morphologie.

En prospectant ce genre en Algérie, nous avons pu obtenir 12 des 25 sections existantes dans la littérature scientifique et 33 espèces sur 150 où les informations relatives aux échantillons de cette memoire ont été documentées, et un ensemble de clés qui aident pour les identifier ont été documentés. Ce type de recherche est temporaire, car les études taxonomiques sont en constante évolution et les recherches algériennes sur ce genre sont en cours. Le nombre d'échantillons étudiés est loin des nombres totaux, ce qui nécessite une étude plus approfondie de la possibilité de leur existence.

Mots clés :, Algérie, espéce, section, genre, , *Aspergillus*

Abstract

Aspergillus is a very important genus due to its presence in many important places and its widespread distribution, where it can be found in food, medium in which we live, and even in the human body. All of these features of this genus have attracted the interest of researchers around the world.

The aim of this study is to detect all the species and sections found in Algeria of this genus through the available studies and to identify their classification and morphology.

By decting this genus in Algeria, we were able to identify 12 of the 25 existing sections in Scientific literature, and 33 species out of 150 where the information related to the samples in this memory has been recognized, and a set of keys that help to identify them have been documented. This type of research is temporary, as taxonomic studies are constantly changing and Algerian research on this genus is ongoing. The number of studied samples is far from the real numbers, which requires a deeper study about the possibility of their existence.

Key words:, Algeria, genus, section, species, *Aspergillus*.

SUMMARY

List of abbreviations

***A*: *Aspergillus*.**

UHPLC-MS/MS: Ultra Performance Liquid Chromatography-Mass Spectroscopy.

LEGO: Lemon Grass Essential.

AFS: Aflatoxine.

AFB1: Aflatoxine B1

AFB2: Aflatoxine B2

AFG1: Aflatoxine G1

AFG2: Aflatoxine G2

OM: Onychomycosis

OTA: Ochratoxin

STC: Sterigmatocystin

USA : United states of America

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Introduction

Introduction

Aspergillus is a genus of fungi widely spread in the environment (Varg *et al.*, 2014 ; Paulussen *et al.*, 2017; Perrone et Gallo, 2017; Teertstra *et al.*, 2017; Sahubert *et al.*, 2018), as his study is considered one of the most important studies related to filamentous fungi (Vries *et al.*, 2017).

This genus contains more than 340 species that lead many different lifestyles (Varga *et al.*, 2014; Park *et al.*, 2017; Abo-Zed et Phan, 2020). It can coexist in many places, such as soils, as studies have shown that it is found in the soil of pepper fields and vineyards (Gibbons and Rokas, 2013; Giusiano *et al.*, 2017; Palumbo *et al.*, 2019; Piontelli *et al.*, 2019), this also indicates its colonization of several agro-ecosystems (Olarte *et al.*, 2015; Alaniz Zanon *et al.*, 2018; Tavakol Noorabadi, 2020). This genus has been proven found in salt marshes as well (Moustafa, 1975; Maciá-Vicente *et al.*, 2008; Abdel-Hafez, 1978). It has also been studied in the Arctic (Kirtsideli *et al.*, 2016), humans (Talbot and Barrs, 2018), stones (Essa and Khallaf, 2016). Some species of *Aspergillus* parasitize on living organisms (plant, animal, human) and cause them a lot of diseases (Meis, 2016; Varga *et al.*, 2014) (e.g., *A. flavus* and *A. parasiticus*) are the two very important species for producing aflatoxins and polluting most agricultural commodities in various agricultural lands around the world (Olarte *et al.*, 2015; Toyotome *et al.*, 2019). It was noted that their presence causes contamination of food and feed with mycotoxins, the most important of which are (aflatoxin and ochratoxin). Some of its species have been highlighted in terms of study (e.g., *A.* section *Flavi*, *A.* section *Circumdati* and *A.* section *Nigri*) (Perrone et Gallo, 2017; Kagot *et al.*, 2019; Douksouna *et al.*, 2019; Varg *et al.*, 2014). On the positive side, the genus *Aspergillus* is widely used in industry where it is involved in the fermentation of food and the production of enzymes, organic acids and bioactive compounds (Park *et al.*, 2017). Its importance included many fields, even medicine and economics, where there are species that have been studied and affect human and the economy namely, *A. fumigatus*, *A. parasiticus* and *A. flavus* (Kwon-Chung et Sugui, 2009; Varg *et al.*, 2014), because of its technological, industrial, and medical importance to researchers in the applied field, the study focuses on it (Houbraken *et al.*, 2014).

In our study, we are detecting the genus *Aspergillus* in Algeria, passing by its taxonomy and morphology, finishing with results that show some features about this genus's presence in the country.

Chapter I : Aspergillus in Algerian studies

I. *Aspergillus* in Algerian studies

I.1. *Aspegillus* in Algerian studies

Aspergillus has been studied in various places in Algeria, namely, Oran (Chamekh *et al.*, 2019), Batna (Sakhri *et al.*, 2019), Bechar (Abdelillah *et al.*, 2013), Chiffa, Blida (Boukhatem *et al.*, 2014), Mitidja, Sétif (Riba *et al.*, 2010), Canstantine (Redouane-Salah *et al.*, 2015), Tizi ouzou (Riba *et al.*, 2008; Belasli *et al.*, 2020), Tlemcen (Tabti *et al.*, 2014; Senouci *et al.*, 2020; Yassine et Haiet, 2018), Annaba (Benhadj *et al.*, 2020), M'sila (Ladjal *et al.*, 2013), Adrar (Rahmoun *et al.*, 2013), Tamanrasset (Lahoum *et al.*, 2016) and Skikda (Hassaine and Bordjiba, 2019).

Many studies have been conducted around the world to study the possibility of fungi in saline ecosystems and their coexistence under salt pressure, as this was confirmed after studying the fungal diversity of some saline environments such as the solar saltwaters, the Dead Sea, the arid desert and the sabkha. It was observed that the fungal communities of *Aspergillus* and *Penicillium* largely dominate these environments compared to other fungi found there (e.g., *Alternaria, Cladosporium, Fusarium, Chaetomium, Wallemia*). The fungal study in this low-lying region northwest of Algeria, called the Greater Oran Sebkha, is the first of its kind in Algeria, although it was classified as one of the important wetlands globally by the Ramsar Convention in 2002, where a soil sample was taken After removing the surface layer at a depth of 5 to 15 cm to transfer it to the laboratory for the purpose of isolating fungi. The sabkha was divided into two regions in order to facilitate the study, as the research team extracted DNA from these fungi for molecular identification. One hundred thirty-six (136) species of fungi have been isolated, of which 120 are known microscopically and macroscopically, while 13 species have not been accurately identified, as only their genera was known, including *Aspergillus*. The first region, in which halophilic plants and cereal crops dominate, was isolated from it 83 samples consisting of 17 species, including *Aspergillus*, which was found at a frequency of 13.25% with more than three species: *A. subramanianii*, *A. terreus*, *A. calidoustus*, *A. europaeus*, *A. amstelodami* and *A. micronesiensis* as a dominante species. In the second region characterized by a total absence of vegetation, 53 species of 14 genera were isolated, with some *Aspergillus* species having a very low frequency compared to the first region represented by: *A. calidostus*, *A. sabramanianii* and three strains of an unidentified species *Aspergillus sp* having 95% to 96%

similarity with the species *A. micronesiensis.* The same study revealed that these strains secrete extracellular enzymes on a solid medium, represented by: lipase, amylase, protease and cellulase in different ways. Lipase is secreted by all species in the samples (*A. subramanianii*, *A. terreus*, *A. calidoustus*, *A. europaeus*, *A. amstelodami*) even unknown samples *Aspegillus sp*. Likewise, protease are produced by most species except *A. calidoustus* and *A. amstelodami*. As for amylase, it is not produced by sample of unknown samples and *A. subramanianii*, *A. terreus*, *A. amstelodami*, finally, the lipase produced by each of *A. amstelodami* and one unknown samples. *Aspergillus* is one of five fungi that grow in medium cintaining 17.5% of NaCl (Chamekh *et al.*, 2019).

In a study conducted by Janos Varga *et al*. (2014) about the genus *Aspergillus*, it was noted that the diversity of this genus in Algeria is the lowest compared to the six countries studied: Thailandits, Croatia, Hungary, the Netherlands, and Turkey, Algeria. Distribution in European countries was similar. In their study, they observed only two types of *Aspergillus*, and what aroused his interest is that the *A. carbonarius*, which is widely present in different types of environments and of high importance for its ability to produce high quantities of ochratoxin A, was observed only in this country (Varg *et al.*, 2014).

Sakhri and his colleagues(2019) indicated that the types of *A. Versicolores* are widely spread compared to other species and are frequently isolated from various environments. It spreads in indoor environments and has the ability to produce sterigmatocystin and mycotoxins that cause cancer and diverse biotechnological applications. It should be noted that all isolates belonging to the section *Versicolores* were classified as *A. versicolor*, and this is before the use of molecular methods on the basis of which species identification is made. The species *A. creber* was described for the first time as a new species and this is after a review of a group of species belonging to a section *Versicolores* through which 13 species were accepted and the latter consists of 17 distinct species, where the two species *A. versicolor* and *A. sydowii* are the most studied and common species. Where Sakhri and his colleagues proved that the reports related to the study of this species *A. creber* were very few, and the available ones dealt only with phenomena such as pollution and the species' ability to produce sterigmatocystin.

Aspergillus has been reported as a prevalent species in indoor environments in the *USA*, Italian libraries, and Saudi telecom companies. The information about this species is scarce, so they were interested in studying the diversity of its secondary metabolites using the technique of UHPLC-MS/MS and division of its antimicrobial activity. He also confirmed that the genus *A. creber* has the ability to produce many diverse secondary metabolites, which were identified as strong biologically active compounds such as: Asperlactone a strong antibacterial and antifungal metabolite, Emodin derived from anthraquinone anti-bacterial, anti-fungal, antioxidant and anti-cancer, STC mycotoxins, Deoxybrevianamide E anti-bacterial, insect, anti-tuberculosis, anti-proliferative T24 human bladder cancer cells. It should be noted that this genus has an antibacterial activity against Gram-negative bacteria compared to gram-positive bacteria, and this is due to the morphological difference, specifically the cell membranes (Sakhri *et al.*, 2019).

Boukhatam *et al*. (2014) used some species of the genus *Aspergillus* to test the antifungal activity of lemon grass essential oil (LGEO) in the laboratory, in addition to some types of yeast and other genus such as: *Condida*, *Penicillium*, and *Muccor*; these four species are represented in *A. niger*, *A. terreus*, *A. flavus* and *A. fumigates***,** they were isolated from patients with mucocutaneous fungal infection and superficial. This study proved that *A. niger* and *A. fumigatus* are the most sensitive strains to lemon grass essential oil (LGEO) and *Penicillium*, where application of 20 µl and 60 µl to the isolates led to a clear inhibition of the growth zones and an increase in the volume of the oil (Boukhatem *et al.*, 2014).

A group of researchers revealed the contamination of 112 samples collected from Algeria of peanuts, almonds and dried figs with aflatoxin from *A*. section *Flavi*. Where it found aflatoxins B1, B2, G1, G2, and it was found AFS in 28 samples of peanuts, 16 samples of almonds and 26 samples of dried figs (Ait Mimoune *et al.*, 2018).

In research by Riba *et al*., (2010), it was stated that mycotoxins are secondary metabolites of some molds, such as: *Aspergillus*, *Penicillium* and *Fusarium*, under certain environmental conditions. The species that produce aflatoxins are: *A. flavus*, *A. parasiticus*, *A. nomius*, *A. pseudotamarii*, *A. bombycis*, *A. toxicarius*, *A. minisclerotigenes*, *A. parvisclerotigenus* and *A. arachidicolain*, *A.* section *Flavi*. The species *A. flavus and A. Parasiticus*, they are the two important producers of aflatoxin, where it was noted that aflatoxin B is the most abundant and the highest concentration in foods. Through this study, the rates of contamination with aflatoxin secreted by species such as *Aspergillus* in wheat.

Among the 108 samples, 64.5% of *Aspergillus* were found, while the percentage of *A.* section *Flavi* was 22.5% and 15.1% were whole fungi. The colonization of this genus in stored wheat was also greater (6%, 26.2% and 28.7%) compared to field wheat (5%, 5.1%, 6.8% and 18.5%), and both durum and soft wheat contained high levels of these species by 3.4% to 23.8% with an average of 13.6% of the total fungi. A group of *Aspergillus* strains were isolated from wheat and its derivatives (flour, semolina and bran), 150 strains were selected for AFs, CPA production and sclerotia characterization. They are classified into 144 isolates of *A. flavus.* Isolated samples of *A.* section *Flavi* were classified into five groups that secrete aflatoxin B, varying between 0.02 to 234 µg/g, and the secretion varies according to the different substrates and the environment, and the secreted quantities differ between species. The following species were not found in this study (*A. parasiticus*, *A. nomius*, *A. bombycis*, *A. toxicarius* and *A. arachidicola)* which produces aflatoxine G, to make sure that the only fungus responsible for poisoning Algerian wheat is *A. flavus* (Riba *et al.*, 2010).

Riba *et al*. (2010) also studied the possibility of ochratoxin production by *Aspergillus* for 85 wheat samples collected from different regions of Tizi Ouzou and Setif during different stages: before harvest, storage, and after processing, in which a total of 275 to 1277 fungi were obtained. Where it was noted that the dominant species are: *A. flavus*, *A. niger* and *A. versicolor*. The other isolated species were *A. ochraceus*, *A. alliaceus, A. carbonarius*, *A. terreus*, *A. fumigatus*, *A. candidus* and *Aspergillus spp*. It is noticeable that the proportions of *Aspergillus* were more compared to the other genus *Penicillium*, *Fusarium*, *Alternaria* and *Muccor.* The species *A. flavus* showed a high recurrence rate in silos (60% - 85%), while *A. niger* had low rates. Equal distributions of fungal contamination were observed in the bran, flour and semolina fractions of flour mill and semolina mill. 135 isolates consisting of 11 *Aspergillus* species have the ability to produce ochratoxin, samples of *A. ochraceus* and *A. alliaceus* produce ochratoxin at a concentration between 0.23 to 11.50 µg/l, *A. carbonarius* strains (80%) were OTA producers 0.01 to 9.35 µg/l, *A. terreus* (50%), *A. niger* (28%), *A. fumigatus* (40%), *A. versicolor* (18%) and *Penicillium spp.* 21.7% were low level producers 0.01 to 0.07 µg/l (Riba *et al.*, 2008).

Thirty-one (31) samples were collected from pistachios to study the extent of their contamination with mycotoxins, aflatoxin and ochratoxin found 30% *Aspergillus* section *Nigri* and (22%) *A. flavus* and among the latter, 56% are able to produce aflatoxin B1 and aflatoxin B2. No samples of *A.* section *Nigri* uniseriate capable of producing oxytoxin were recorded, unlike *A.* section *Nigri* biseriate. Fernane and his collegues study of the presence of mycotoxins in pistachios was considered the first of its kind at the time (Fernane *et al.*, 2010).

A study of aflatoxin contamination of 40 nut samples (almonds, pistachios, hazelnuts, peanuts and walnuts) was conducted by Riba and his colleagues, through it, it was confirmed the presence of a large number of *Aspergillus*, with percentages ranging from 99.8% to 57%, also, 90 isolates of studied nuts had a contamination rate between 0.2 to 25.82 µg/kg. The existing *Aspergillus* were divided into *Aspergillus* section *Flavi* by 27.9% and *Aspergillus* section *Nigri* by 30.6%. It should be noted that 420 isolates of the *Flavi* section in this study produced both aflatoxin and cyclopiazonic acid, the majority of which were later identified as

A. flavus. Other species were also mentioned namely: *A. parasitucus*, *A. minisclerotigenes*, *A. parvisclerotigenus*, but in almost non-existent proportions (Riba *et al.*, 2013).

Mycotoxins were detected in four samples of peanuts of Chinese origin and marketed in Algeria (Khraissia, Bab Ezzouar, Bordj El Kiffan, and Kouba). In this study, from 82 isolates, a large proportion of aflatoxins were found, which are produced from *Aspergillus* section *Flavi* especially *A. flavus*, in particular, and they are represented in four types as follows: AFB1, AFB2, AFG1, AFG2. Other species were also found in varying proportions, such as: (*A. parasitivus*, *A. minisclerotigenes*, *A. caelatus*, *A. tamarii*, *A. terreus*, *A. nomius*, *A. pseudotamarii*, *A. bombycis*, *A. pseudocaclatus* and species from *Aspergillus* section *Nigri*) (Tebibel *et al.*, 2013).

In another Algerian study, the presence of toxin-producing fungi (*Aspergillus*) was confirmed in 44 samples of 9 spices, marketed in different regions of Algeria. These species are: aniseed (*Pimpinella anisum*), red pepper (*Capsicum frutescens*), sweet cumin (*Foeniculum vulgare*), sweet pepper (*Capsicum annuum*) from Algiers, black pepper (*Piper nigrum*), caraway (*Carum caraway*), coriander (*Coriandrum sativum*) from Batna, cumin (*Cuminum cyminum*) from Biskra, cinnamon (*Cinnamomum zeylanicum*), ginger (*Zingiber officinale*), saffron (*Crocus sativus*) from Oran. The presence of each of the following species was achieved in varying proportions: *A. flavus*, *A. parasiticus*, *A. parvisiclerotigenus*. The variety of *A. flavus* recorded an estimated 28.9 % of the total fungi obtained (Azzoune *et al.*, 2015).

The herb *Ammoides verticillata Briq* was distilled by a device called Clevenger using gas chromatography (GC) and its antifungal activity was examined against four plant fungi including *A. niger*. *Ammoides verticillata* oil has shown strong antifungal activity against *A. niger*, where the team of researchers isolated a group of fungi that cause olive rot (*Alternaria alternata*, *Aspergillus niger*, *Fusarium solani* and *Penicillium crustosum)* from fruits (Senouci *et al.*, 2020).

Redouane-Salah and his colleagues (2015) also indicated that aflatoxin M1 produced by *Aspergillus spp* can be present in milk, as its presence was confirmed in milk samples collected from Algeria, specifically from Constantine between February and October 2011 from 11 farms. Five samples were found poisoned with aflatoxin M1 out of 47 samples whose secretion rates ranged between 9 to 103 ng/l and less than 8 ng/l in 11 samples. Then they confirmed in their study that the incidence of contamination in raw milk (5%) is less than that of powdered milk (29%) (Redouane-Salah *et al.*, 2015).Also, a set of tests was conducted on *Aspergillus* by applying a group of lactic acid bacteria taken from different samples of milk to study its antifungal activity and it showed an effective result by slowing down the fungal target in some products such as sour cream and sourdough bread (Ouiddir *et al.*, 2019).

In a study by Alioui and his colleagues, they tested a group of nanopowders on a group of bacteria and the genus *Aspergillus* in order to study their antimicrobial activity, and thus they showed strong activity (Alioui *et al.*, 2019).

Some studies indicated that the genus *Aspergillus* is a causative agent of otomycosis, followed by *Candida*, where another study indicates that *A. flavus* it is the most recovering species, which indicates a relationship between ear self-injury and otomycosis (Yassine et Haiet, 2018).

A group of internal fungi from *Aleppo pine* was isolated. Among 600 sterile needles collected from 15 trees, 29 fungal isolates were obtained, including: *Penicillium*, *Acremonium*, *Aspergillus*, *Rhizopus*, *Trichosporon*, *Cladosporium*, *Fusarium*, *Trichodermq*, this indicates the presence of antifungal activity (Ladjal *et al.*, 2013).

In another study of the anti-*Aspergillus* activities, four essential traditional vegetable oils (*Ruta angustifolia*, *Ruta chalepensis*, *Ruta graveolens* and *Ruta tuberculata*) were applied to *A. fumigatus* to study the extent of its resistance, as it showed great sensitivity to it, except for *Ruta tuberculata* oil, whose composition is different compared to the others essentials oils (Haddouchi *et al.*, 2013).

Another study in the field of food preservation, the essential oils of laurel (*Laurus nobilis*) were applied to *A. flavus* at a concentration of (1.75 and 2) µg/l, respectively, and thus both aflatoxin B1 was inhibited to the point of its absence. This oil was able to provide protection for wheat grains ranging from 51.5% to 76.7% against *A. flavus* during storage for 6 months at 15°C and an estimated humidity of 62%. A group of other *Aspergillus* species was also isolated from cereals, represented by: *A. carbonarius*, *A. fumigatus*, *A. niger*, *A. ochraceus*, *A. tamarii*, *A. terreus (*Belasli *et al.*, 2020).

Antimicrobial activity of one of the extracts of *Streptomyces sp* (ActiF450) showed strong and widespread activity against a group of human pathogens including *A. fumigatus* and *A. niger* (Benhadj *et al.*, 2020).

In another study, it was revealed that *Aspergillus* is one of the causes of Onychomycosis (OM), an infection that affects the fingernails due to a group of pathogens, it was detected through a group of experiments conducted on 58% samples, 54% of them were positive (Hafirassou *et al.*, 2017).

Another study showed that 18 strains of lactic acid-producing bacteria isolated from fermented Algerian wheat delayed or impeded the growth of fungal targets, including *A. flavus* (Merabti *et al.*, 2019).

Rahmoun and colleagues' study showed a high degree of inhibition of both *A. flavus* and *A. niger* by *Lawsonia inermis* (henna) (Rahmoun *et al.*, 2013).

Use *Aspergillus* for fermentation of a manually obtained *Jatropha curcas kernel* meal in order to obtain a cured *Jatropha kernel* meal. Physically, chemically and biologically treated *Jatropha curcas kernel* can be an important poultry feed product (Nesseim *et al.*, 2019).

A. carbonarius was also one of the genera present in the wastewater treated with pistachio, on which electrochemical treatment was applied before applying the fungal treatment, and the results of this process were better than the fungal treatment, but they are expensive (Isik *et al.*, 2020).

The essential oil of *Daucus gracilis* flowers showed effective antifungal activity against *A. flavus* at 0.06 µg/ml (Nadia *et al.*, 2020).

The activity of ethanol extracted from *Thymus capitatus* showed high activity against a group of fungal genera, including: *A. niger*, *A. oryzae*, which were isolated from among the isolates that cause citrus rot (Tabti *et al.*, 2014).

The antifungal activity of extracts of free fatty acid methyl esters fraction from Linum usitatissimum seed oil was investigated on a group of fungal samples including *A. flavus* and *A. ochraceus*, It showed high effectiveness against them (Abdelillah *et al.*, 2013).

In Brakni and colleagues' study, Cyclohexane extracts were found to be particularly effective against human diseases caused by fungi such as: *A. fumigatus*. To highlight lichen extracts as antibacterial and antifungal agents (Brakni *et al.*, 2018).

Chekiri confirmed in his medical research with his colleague that ear infections in Algeria are often caused by *A. flavus*, *A. niger*, *A. terreus*, *A. fumigatus*, they also added another statistical information, which is that the presence of *A. flavus* and *A. niger* is more abundant compared to *A. fumigatus* in the Algerian environment (Chekiri and Denning, 2016; Ayate *et al.*, 2020).

A new strain of Actinomycetes isolated by Lahoum *et al*. (2016) and his colleagues demonstrated potent activity against pathogenic fungi including *Aspergillus* and *Fusarium* (Lahoum *et al.*, 2016). The anti-*Aspergillus* section *Nigri* activity was studied with and without starch in five types of honey in order to study the synergistic activity between them (Boukraâ *et al.*, 2008). Aspergillosis is a disease caused by types of superficial and cutaneous aspergillosis: distal lateral onychomycosis, proximal subungual onychomycosis, otomycosis, and cutaneous aspergillosis, newborns or immunocompromised patients are among those affected by this disease. The species that have been isolated and cause the previous diseases are: *A. fumigatus*, *A. flavus*, *A. terreus*, and *A. ustus* (Merad *et al.*, 2021).

I.2. Taxonomy

The genus *Aspergillus* is one of the most important species for the environment, technology and economy, so taxonomic studies about this genus are necessary and this is done by defining the criteria for classification of species and with the advancement of many computer biological and biochemical techniques, where the transition from the traditional classification based on morphological characteristics (Gautier *et al.*, 2016; Chi-Ching Tsang *et al.*, 2018) (size and arrangement of *Aspergillus* heads, color of conidia, growth rate in different media and physiological characteristics) (Abdel-Azeem *et al.*, 2020) to phenotypic and chemical classification (Chi-Ching Tsang *et al.*, 2018). The proposed phenotype-based classification system for *Aspergillus* was based on conidium colour, conidiophore morphology and growth rates on agar medium. This classification system still significantly overlaps with the current system that relies on molecular data. Some researchers have identified distinct groups of species in these genera and called these "groups" or "chain". The genus *Aspergillus* has been divided into 18 subgroups based on their phenotype, but this classification has undergone many changes (Chi-Ching Tsang *et al.*, 2018). However, it was deemed invalid. The following taxonomic ranks have been adopted: Subgenera, sections, subsections, series and subseries are useful classes between genus and species level and are formal naturalists. *Aspergillus* was divided into 25 sections (Houbraken *et al.*, 2020), Gautier in his research with his team, he points out that the current classification of *Aspergillus* is composed of only four sub-genera (*Aspergillus*, *Circumdati*, *Fumigati* and *Nidulantes*) and 20 sections. The availability of DNA sequencing technology has led to the acquisition of a large amount of DNA sequencing data, which allowed the classification of fungi through genetics, and through which we came to the concept of the currently accepted standard species, or informally known as the “multiphasic taxonomic approach”, the latest A revolution in fungal classification, the classification scheme for a large number of fungi has been corrected. Houbraken and co-workers have shown that chain classification in *Aspergillus* is often obsolete or missing, but is still relevant, for example, assigning a type to a chain can be very predictive in the functional properties a species may have and may be useful when using Determine based on phenotype. The majority of the series in *Aspergillus* have been incorrectly described, and here we present a new classification for the series. Using a genetics approach, often supported by phenotypic, physiological and/or exogenous data, *Aspergillus* is divided into six subgenera, 27 divisions (five new divisions) and 75 series (73 new, one new group), and *Penicillium* in Two sub-generations, 32 divisions (seven new) and 89 series (57 new and six new collections). And in other results for the same research team, they got 6 subgenus and they are as follows: *Circumdati*, *Fumigati*, *Nidulantes*, *Aspergillus*, *Cremei*, *Polypaecitum*. The first subgenus (*Circumaditi*) consists of 10 sections, which are*:* *Candidi*, *Petersoniorum*, *Nigri*, *Terrei*, *Flavipedes*, *Janorum*, *Circumdati*, *Tannerorum*, *Robusti*, *Flavi*: The second subgenus (*Fumigati*) consists of 04 sections, which are: *Fumigata*, *Clavati*, *Vargarum*, *Cervimi*. The third subgenus (*Nidulantes*) consists of 07 sections, which are: *Nidulantes*, *Aenei*, *Cavemicolarum*, *Silvatici*, *Bispori*, *ochraceorosei*, *sparsi*, followed by the subgenus (*Aspergillus*) consists of 02 sections, which are: *Restricti* and *Aspergillus*, the next is the subgenus (*Cremei*) consists of 01 sections, which is : *Cremei*, and the last one is *Polypaecitum* sebgenus which consists of 01 section is *Polypaecitum* (Houbraken *et al.*, 2020). There are some cases where some species were transferred from *Aspergillus* genus to another genus, or they were changed between divisions eg., section *Ornati* transferred to genus *Sclerocleista* and excluded from *Aspergillus*, Section *Versicolores* merged with section *Nidulantes*, section *Warcupi* Transferred to genus *Warcupiella* and excluded from *Aspergillus*, Section *Zonati* Trasnferred to genus *Penicilliopsis* and excluded from *Aspergillus* (Chi-Ching Tsang *et al.*, 2018).

I.3. Morphology

The genus *Aspergillus* is high morphological and genetic variance fungi. Characterization of morphological features using light microscopy or by sequencing housekeeping genes and comparing them to genetic repositories, methods by which fungi are widely recognized (Strycker *et al.*, 2019). Macro and microscopic colony morphology was characteristic of fungi from the genus *Aspergillus* (restricted growth series). It is one of the criteria for classification, with colony growth rates, texture, degree of sporulation, production of sclerotia or cleistothecia, colours of mycelia, sporulation, soluble pigments, exudates, colony reverses, sclerotia (Machowicz-Matejko *et al.*, 2018; Abdel-Azeem *et al.*, 2020). This genus carries out both sexual and asexual reproduction (Emri *et al.*, 2018; Ojeda-López *et al.*, 2018).

We can easily distinguish genera by its characteristic conidiophores, but identification of species and differentiation is difficult, because it has traditionally relied on some macro and micro morpgological features (Guezlane-Tebibel *et al.*, 2013).

The morphology of ascospores including colour, shape, size and decoration is of particular importance for the identification and identification of species in many genera including *Aspergillus*. Multiple methods of species identification are currently being implemented, polyphasic analysis with description (Chen *et al.*, 2016). The number of conidia, asexual spores released by *Aspergillus* colonies (**Figure 2**.d; **Figure 3**.A), contributes to the spread and continuation of this genus. After vegetative growth, conidia are formed (**Figure 2**.f). To do this, specialized aerial filaments differentiate into conidiophores. These stems extend about 100-3000 µm in the air, after which the so-called vesicle is formed by swelling of the tip of the hypothalamus, more than 10,000 conidia can be produced per conidiophores (**Figure 3**.C,G,H) , it is considered one of the criteria for classification (Teertstra *et al.*, 2017), for example, the appearance of obscure microscopic features of *A. penicillioides* such as overgrowth of conidiophores from aerial mycelium or substrate pasty, different shapes and sizes of vesicles, surface smoothness or roughness of conidia made them difficult to classify in the classical way (Machowicz-Matejko *et al.*, 2018). There are other morphological characteristics that are adopted in the classical classifications spores (Strycker *et al.*, 2019), morphology, diagnostic ornamentation (roughening, rims, wings, furrows, etc) (Abd-Azeem *at al.*, 2020).

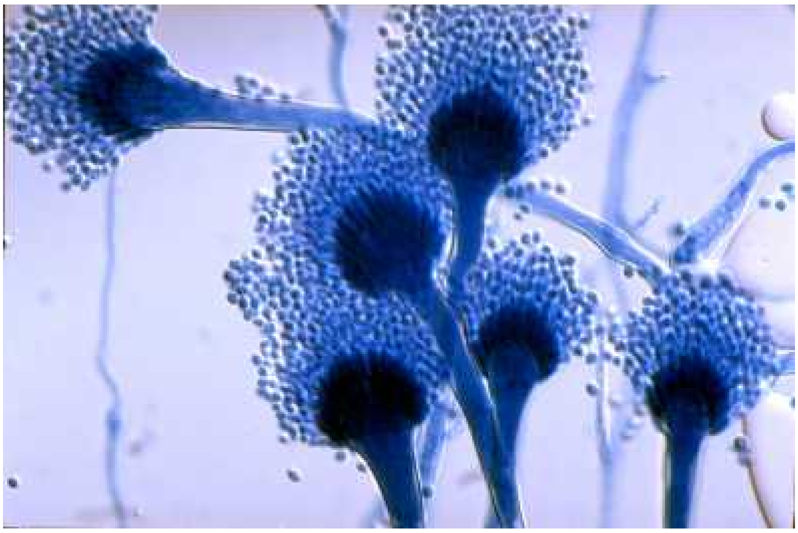

Figure 1: Light microscopy of *Aspergillus fumigatus* (Xuekun *et al.*, 2016).

Figure 2: *Aspergillus niger* morphological characteristics of colony, conidiophores and conidia. (d) The colony of *A. niger* on PDA, (e) Conidiophores of *A. niger*, (f) Conidia of *A. niger* (Xuekun *et al.*, 2016).

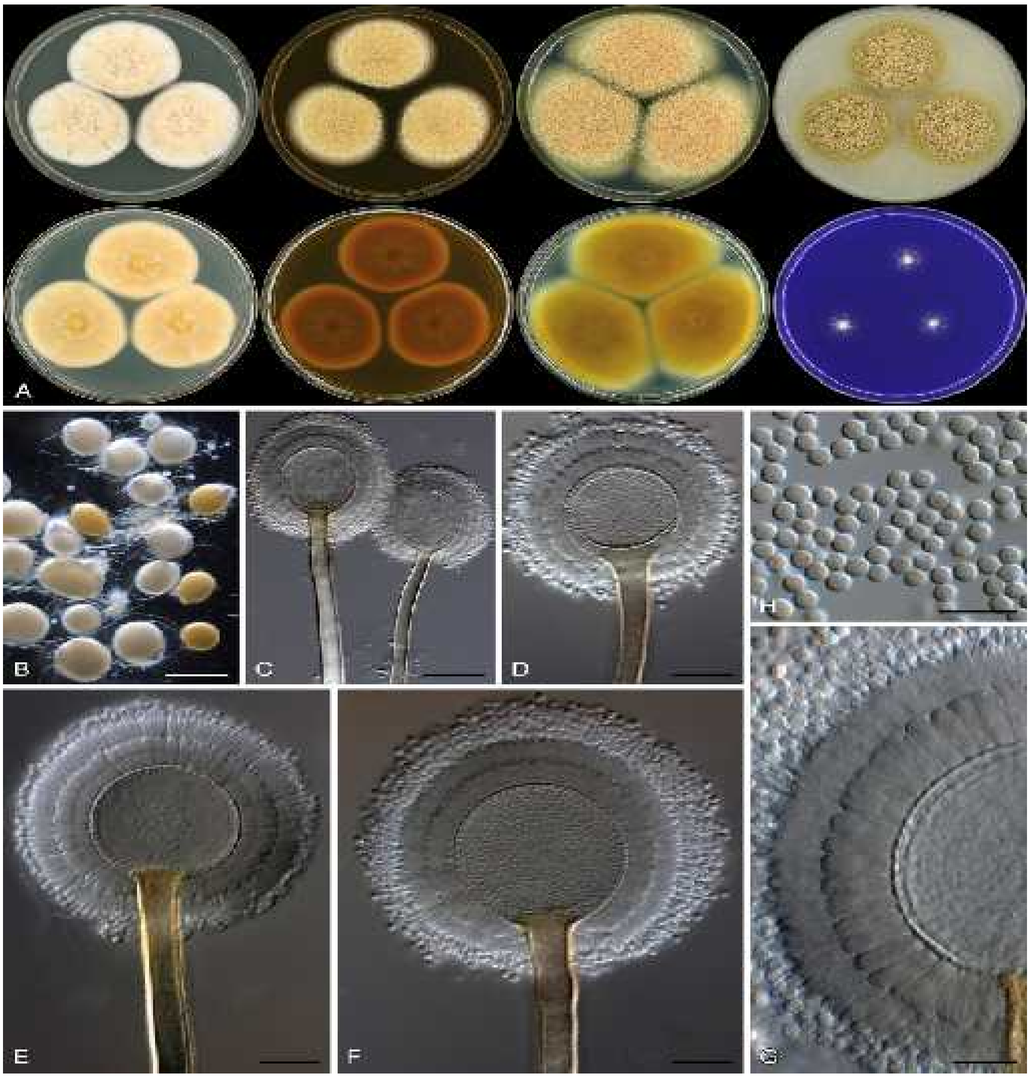

Figure 3: *Aspergillus ochreaceus* morphological characteristics of colony, conidiophores and conidia. Note (A) colonies, (B) sclerotia, (C,G) conidiophores, (H) conidia, (E, F, G) scales bras (Visagie *et al.*, 2014).

I.4. Methods

I.4.1. Study area

Algeria is located in North Africa (Lalis *et al.*, 2019), occupies an area of 2,381,739 km^2 and a population of approximate 40.4 millions inhabitants (Bekadja *et al.*, 2017). Algeria is situated in the middle of the Maghreb countries and is located between Tunisia and Libya to the East (Hakimi *et al.*, 2021) and Morocco and Western Sahara to the West (Beddek *et al.*, 2018; Yahyaoui-Azami *et al.*, 2017), it is bordered on the North by the Mediterranean Sea, its climate is hot and humid, which promotes the growth of fungi (Matmoura *et al.*, 2013), on the South by Niger and Mali and Mauritania, it contains many lakes, many salt lakes are to be found spread from southern Tunisia up to the Atlas Mountains in northern Algeria. Oum Eraneb and Ain El beida sebkhas (salt lakes), are located in the Algerian Sahara (Khallef *et al.*, 2018), among the most prominent terrains are the Atlas Mountains (Laboudi *et al.*, 2001).

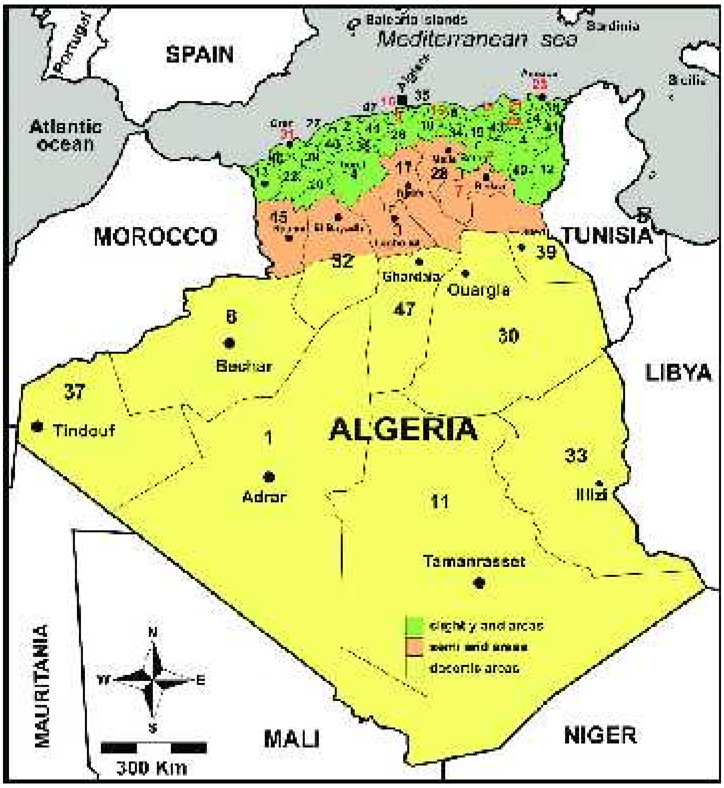

Figure 4: Map of Algeria and its geographical boundaries (https://www.jawebi.com/).

I.4.2.Data collection

The species included in this research were collected from previous Algerian research in this field, which was conducted by researchers (Sakhri *et al.*, 2019; Chamekh *et al.*, 2019; Abdelillah *et al.*, 2013; Boukhatem *et al.*, 2014; Rahmoun *et al.*, 2013; Lahoum *et al.*, 2016; Ait Mimoune *et al.*, 2018; Riba *et al.*, 2010; Senouci *et al.*, 2020; Fernane *et al.*, 2010; Ouiddir *et al.*, 2019; Redouane-Salah *et al.*, 2015; Alioui *et al.*, 2019; Haddouchi *et al.*, 2013), and we relied on the following scientific sites:

- https://pubmed.ncbi.nlm.nih.gov/
- https://www.sciencedirect.com/
- https://sci-hub.st/
- https://atrss.dz/detail_projet.php?id=833
- https://www.researchgate.net/

Studies on this genus have continued since 2008, but taxonomic studies were rare, as the antagonistic activities of many extracts were studied on pathogenic samples of this genus and some samples were isolated from milk, grains and plants, and studies are still ongoing on this genus.

I.5. Results

Many researches have been conducted on *Aspergillus* in Algeria. In this study, in which all studies on this genus were collected in Algeria, 5 subgenus were obtained: *Aspergillus*, *Circumdati*, *Nidulantrs*, *Fumigati*, *Cremei* (Benhadj *et al.*, 2020; Nadia *et al.*, 2020; Abdelillah *et al.*, 2013; Merabti *et al.*, 2019).

The total of the sections in the original for this genus is 25 sections (Houbraken *et al.*, 2020), But the number of sections obtained in this research is only 12 sections which are: (*Aspergillus*, *Cremei*, *Flavi*, *Terrei*, *Nigri*, *Circumdati*, *Candidi*, *Versicolores*, *Fumigata*, *Usti*, *Nudilante*, *Flavipedes*), there are also 150 species belonging to 25 sections (Abdel-Azeem *et al.*, 2020) (Fig4, Tab1). But in our study, we got only 33 species: *(A. westerdijkiae*, *A. stynii*, *A. pseudotamarii*, *A. nomius*, *A. europaeus*, *A. oryzae*, *A. flavus*, *A. parasiticus*, *A. alliaceus*, *A.tamarii*, *A. terreus*, *A. niger*, *A. foetidus*, *A. carbonarius*, *A.* t*ubingensis*, *A. ochreaceus*, *A. candidus*, *A. versicolor*, *A. fumigatus*, *A. fisheri*, *A. utus*, *A. calidoustus*, *A. nidulans*, *A. subramanianii*, *A. micronesiensis*, *A. caelatus*, *A. amstelodami*, *A. miniclerotegenus*, *A. sydowii*, *A. creber*, *A. bombycis*, *A. paroisclerotigenus*, *A. pseudocaelatus*). (Fig 3, Fig 6).

We noticed during this study that the study of the section *A.* section *Nigri* was much compared to the other sections (Boukhatem *et al.*, 2014; Riba *et al.*, 2008; Senouci *et al.*, 2020;

Belasli *et al.*, 2020; Brakni *et al.*, 2018), followed by *A.* section *Flavi* (Merad *et al.*, 2021; Nadia *et al.*, 2020; Belasli *et al.*, 2020; Yassine et Haiet, 2018; Riba *et al.*, 2008), followed by the two sections *Fumigata* and *Terrei*, then come after the other sections with a very few studies.

We are likely to find differences and some problems such as the difficulty of classifying some species to the fluctuations that the classification of fungi has been exposed to in the transmission of morphological profiling and the adoption of groups by moving to accurate methods (Ch

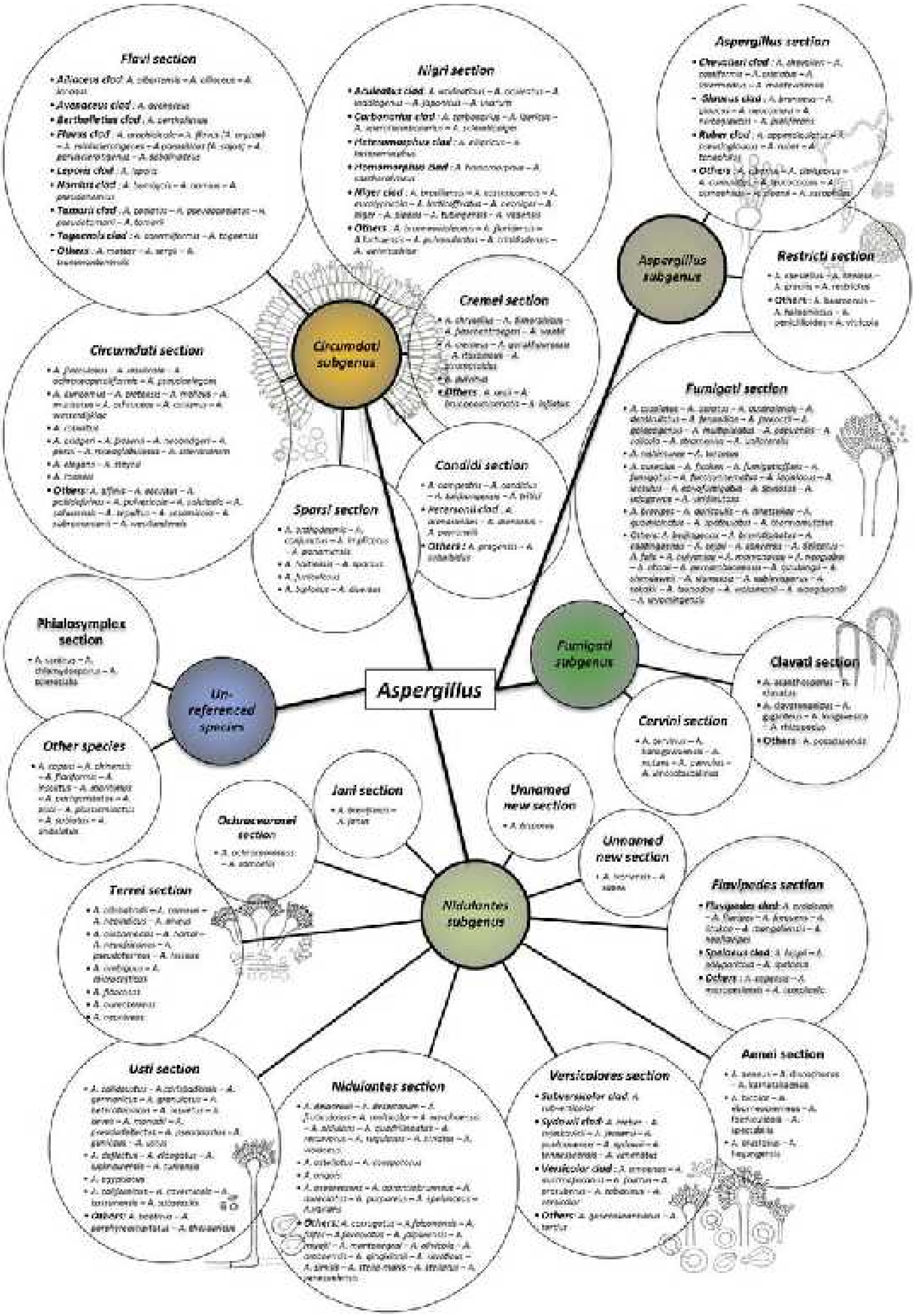

Figure 5: Classification according to their subgenus and section of 339 valid species in the *Aspergillus* genus (Gautier *et al.*, 2016).

Figure 6: table shows an overview of major subgeneric classifications of *Aspergillus* species (Tsang *et al.*, 2018).

Blochwitz (1929)	Thom and Church (1926) Thom and Raper (1945) Raper and Fennell (1965)	Gams et al. (1986)	(Peterson 2000)	Peterson (2008)	Houbraken and Samson (2011)	Houbraken et al.(2014)	Jurjević et al. (2015) Kocsubé et al. (2016) Sklenář et al. (2017)
Eglobosi	Group *A. candidus*	Subgenus *Aspergillus*	Subgenus *Aspergillus*	Subgenus *Aspergillus*	Subgenus *Aspergillus*	Subgenus *Aspergillus*	[f]**Subgenus** *Aspergillus*
Flavi	Group *A. cervinus*	Section *Aspergillus*	Section *Aspergillus*	Section *Aspergillus*	Section *Aspergillus*	Section *Aspergillus*	Section *Aspergillus*
Fulvi	Group *A. clavatus*	Section *Restricti*	Section *Candidi*	Section *Restricti*	Section *Restricti*	Section *Restricti*	Section *Restricti*
Glauci	Group *A. cremeus*	Subgenus *Circumdati*	Section *Cervini*	Subgenus *Candidi*	Subgenus *Circumdati*	Subgenus *Circumdati*	**Subgenus** *Circumdati*
Nidulantes	Group *A. flavipes*	Section *Candidi*	Section *Circumdati*	Section *Candidi*	Section *Candidi*	Section *Candidi*	Section *Candidi*
Nigroides	Group *A. flavus*	Section *Circumdati*	Section *Cremei*	Subgenus *Circumdati*	Section *Circumdati*	Section *Circumdati*	[g]Section *Circumdati*
Phaei	Group *A. fumigatus*	Section *Cremei*	Section *Flavi*	Section *Circumdati*	Section *Flavi*	Section *Flavi*	[h]Section *Flavi*
	Group *A. glaucus*	Section *Flavi*	Section *Flavipedes*	Section *Cremei*	Section *Flavipedes*	Section *Flavipedes*	[i]Section *Flavipedes*
	Group *A. nidulans*	Section *Nigri*	Section *Nigri*	Section *Flavi*	Section *Nigri*	Section *Nigri*	Section *Jani*
	Group *A. niger*	Section *Sparsi*	Section *Restricti*	Section *Nigri*	Section *Terrei*	Section *Terrei*	Section *Nigri*
	Group *A. ochraceus*	[c]Section *Wentii*	Section *Terrei*	Subgenus *Fumigati*	Subgenus *Fumigati*	Subgenus *Fumigati*	Section *Petersonii*
	[a]Group *A. ornatus*	Subgenus *Clavati*	Subgenus *Fumigati*	Section *Cervini*	Section *Cervini*	Section *Cervini*	Section *Robusti*
	Group *A. restrictus*	Section *Clavati*	Section *Clavati*	Section *Clavati*	Section *Clavati*	Section *Clavati*	Section *Tanneri*
	Group *A. sparsus*	Subgenus *Fumigati*	Section *Fumigati*	Section *Fumigati*	Section *Fumigati*	Section *Fumigati*	Section *Terrei*
	Group *A. terreus*	Section *Cervini*	Subgenus *Nidulantes*	[a]Subgenus *Ornati*	Subgenus *Nidulantes*	Subgenus *Nidulantes*	[j]**Subgenus** *Cremei*
	Group *A. ustus*	Section *Fumigati*	[a]Section *Ornati*	[a]Section *Ornati*	Section *Aenei*	Section *Aenei*	**Subgenus** *Fumigati*
	[b]Group *A. versicolor*	[a]Subgenus *Ornati*	Section *Nidulantes*	Subgenus *Nidulantes*	Section *Ochraceorosei*	Section *Bispori*	Section *Cervini*
	[c]Group *A. wentii*	[a]Section *Ornati*	Section *Sparsi*	Section *Bispori*	Section *Nidulantes*	Section *Cremei*	[k]Section *Clavati*
		Subgenus *Nidulantes*		Section *Ochraceorosei*	Section *Sparsi*	Section *Ochraceorosei*	[l]Section *Fumigati*
		Section *Flavipedes*		Section *Nidulantes*	Section *Usti*	Section *Nidulantes*	**Subgenus Nidulantes**
		Section *Nidulantes*		Section *Raperi*	Unassigned section	Section *Silvati*	[m]Section *Aenei*
		Section *Terrei*		Section *Silvati*	Section *Cremei*	Section *Sparsi*	Section *Bispori*
		Section *Usti*		Section *Sparsi*		Section *Usti*	Section *Cavernicolus*
		[b]Section *Versicolores*		Section *Usti*			Section *Ochraceorosei*
				Subgenus *Terrei*			[m]Section *Nidulantes*
				Section *Flavipedes*			Section *Raperi*
				Section *Terrei*			Section *Silvati*
				Subgenus *Warcupi*			Section *Sparsi*
				[d]Section *Warcupi*			[m]Section *Usti*
				[e]Section *Zonati*			**Subgenus** *Polypaecilum*

a Transferred to genus Sclerocleista and excluded from Aspergillus (Subramanian, 1972; Houbraken and Samson, 2011).
b Merged with section Nidulantes (Peterson, 2000)
c Merged with section Cremei (Peterson, 2008)
d Transferred to genus Warcupiella and excluded from Aspergillus (Subramanian, 1972; Houbraken and Samson, 2011).
e Trasnferred to genus Penicilliopsis and excluded from Aspergillus (Houbraken and Samson 2011; Kocsubé *et al*., 2016).
f Sexual synonym= Eurotium (Houbraken *et al*., 2014).
g Sexual synonym = Neopetromyces (Houbraken *et al*., 2014).
h Sexual synonym = Petromyces (Houbraken *et al*., 2014).
i Sexual synonym = Fennellia (Houbraken *et al*., 2014).
j Sexual synonym = Chaetosartorya (Houbraken *et al*., 2014).
k Sexual synonym = Dichotomomyces and Neocarpenteles (Houbraken *et al*., 2014).
l Sexual synonym = Neosartorya (Houbraken *et al*., 2014).
m Sexual synonym = Emericella (Houbraken *et al*., 2014).

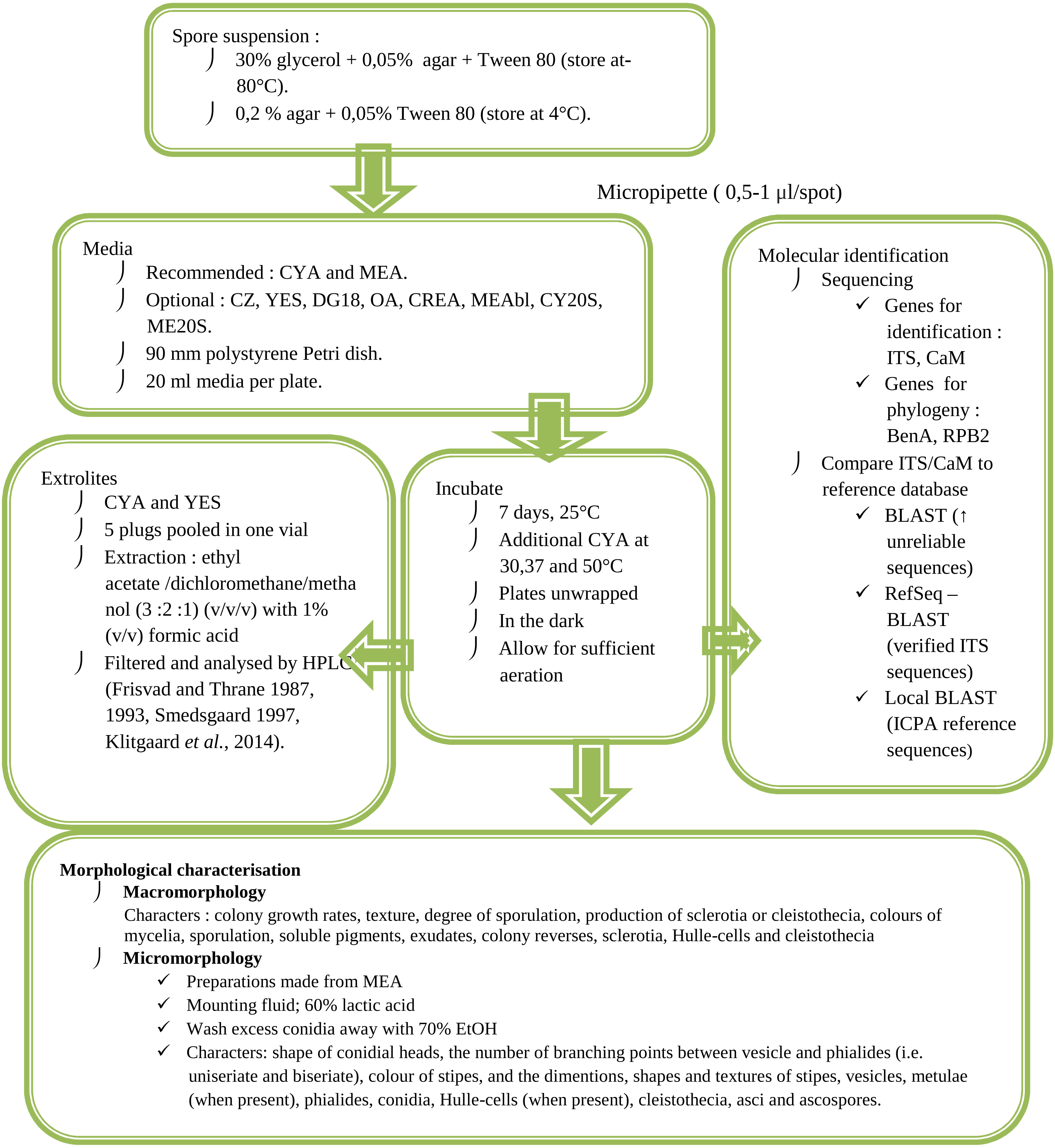

Figure 7: Flow diagram summarizing the recommended methods for the identification and characterization of *Aspergillus* (Frisvad et Thrane 1987, 1993; Smedsgaard, 1997; Klitgaard *et al.*, 2014) refer to methods described for detecting extrolites in fungi.

Table 01: Subgenera and number of sections, and number of species of *Aspergillus* recorded in Algeria.

Subgenus	Section	Species	%
Aspergillus	01	01	3.03
Circumdati	07	26	78.78
Cremei	01	01	3.03
Fumigati	01	02	6.06
Nidulantes	02	03	9.09
Total	12	33	100

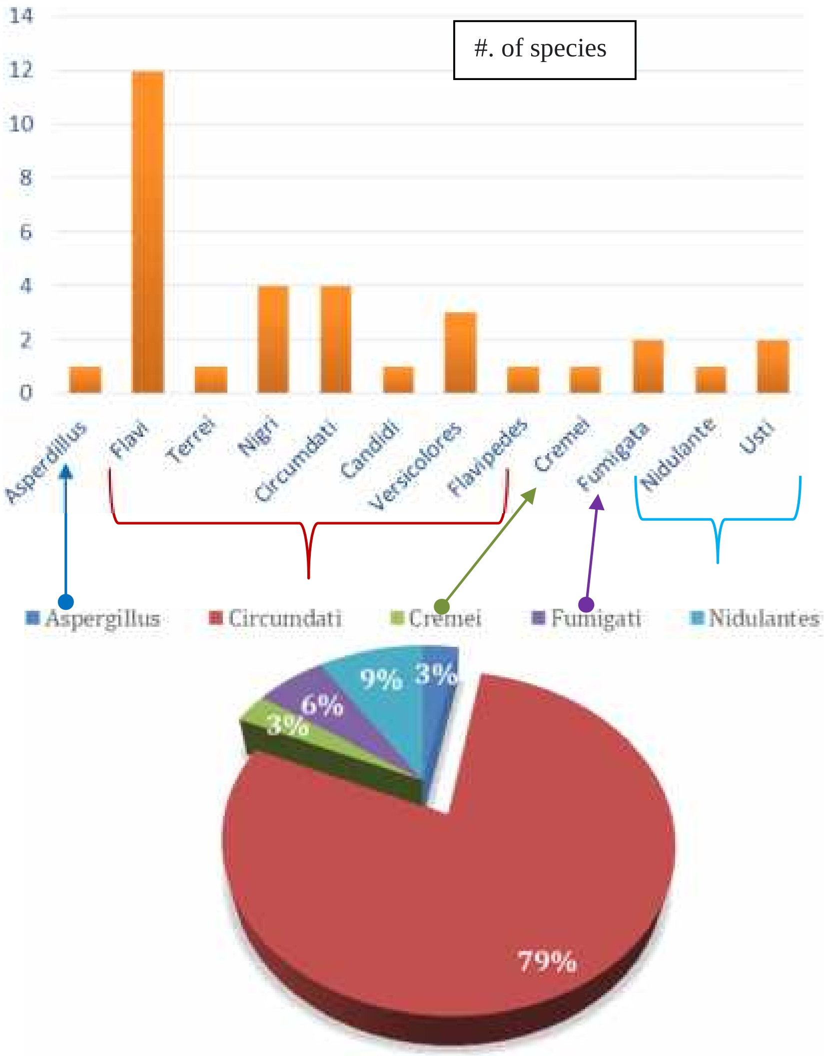

Figure 8: Distribution of different subgenera and sections.

Table 2: List of *Aspergillus* species recorded since 1921 (Abd-Azeem *et al.*, 2020).

Sebgenus	**Sections**	**Species**
Aspergillus	**Section 1: *Aspergillus***	***Aspergillus amstelodami***: a species isolated from salt marshes soil by Moubasher (1965) (Abdel-Hafez *et al*.,1977), then from air by Moubasher and Moustafa (1974).
		Aspergillus athecius: a species isolated by (Moubasher *et al*., 2018) from plants, and from desert soil by (Abdel-Hafez *et al*., 1995).
		Aspergillus chevalieri: a species isolated by Moubasher (1969) from Triticum, and from salt marshes soil by Abdel-Hafez *et al*. (1977)
		Aspergillus cristatus: a species isolated from herbs and spices by El-Said (1997).
		Aspergillus echinulatus: a species isolated by Moubasher (1966) from soil.
		Aspergillus glaucus: isolated by Sabet (1939) from soil, and from salt marshes by Ezz-ElDin (1988).
		Aspergillus halophilicus: this species has been described by C.M. Chr., Papav. & C.R. Benj after isolating from soil (Abdel-Sater, 1994).
		Aspergillus intermedius: after first described in 1975, this species was isolated from cinnamon by Abdel-Hafez and El-Said (1997).
		Aspergillus leucocarpus: Moubasher (2018) has isolated this species from plants.
		Aspergillus manginii: a species isolated from plants by **(**Moubasher *et al*., 2018).

		Aspergillus montevidensis: Malloch and Cain (1972) have isolated this species from air dust (AbdelHafez *et al*., 1990a, d).
		Aspergillus niveoglaucus: Ismail *et al*. (1995) have isolated the species from beef bones.
		Aspergillus proliferans: this species has been isolated after finding in a soybean meal by Moharram *et al*. (1989).
		Aspergillus pseudoglaucus: El-Rakawy (1966) has isolated this fungi from Citrus aurantifolia.
		Aspergillus repens: El-Magraby (1989) has found this species after isolating from crops.
		Aspergillus ruber: this fungi has been found in certain kinds of cereals and isolated by Moubasher and his colleagues (1972). (**Table 2** continued)
		Aspergillus tonophilus: a fungi species found in seeds by Moharram *et al*. (1989).
		Aspergillus umbrosus: El-Abyad (1997) has isolated this fungi from spices seeds.
		Aspergillus xerophilus: Samson and Mouchacca (1974) have found this species in a sandy soil of the Western Desert.

	Section 2: ***Restricti***	***Aspergillus conicus*** : found by (Moharram *et al*. 1989a) after isolating from chickens 'feedstuff.
		Aspergillus penicillioides: isolated from asian rice by Abdel-Azim (1975).
		Aspergillus restrictus: Kowalik and Sadurska (1973) have isolates this species from a museum in Egypt.
Subgenus 2: ***Circumdati***	**Section 3:** ***Assiuti***	***Aspergillus assiutensis***: Moubasher and Soliman (2011) have found this fungus in the air of a grape farm.
		Aspergillus campestris*:* Moubasher and his colleagues (2016) have isolated this species from a fruits farm air.
	Section 4: ***Candidi***	***Aspergillus candidus*** : in Egypt, and from sandy soil, Sabet (1935) has isolated this species, after being recorded by Reichert (1921) and Melchers (1931).
	Section 5: ***Circumdati***	***Aspergillus alutaceus***: Sabet (1935) has isolated this fungus from sand in Ismailia, Egypt.
		Aspergillus auricomus: Abdel-Azim (1973) has isolated this species from rice.
		Aspergillus bridgeri: Moubasher *et al*. (2016) have isolated this species from the air of fruits farm.
		Aspergillus elegans: found in soil by Misshnicky (1964).
		Aspergillus flocculosus: found in a lake water in Egypt by Moubasher *et al*. (2016).
		Aspergillus fresenii: El-Abyad (1997) has found this species in soil.

		Aspergillus gaarensis: Al-Bedak and Moubasher (2020) have isolated this species in Egypt from soil.
		Aspergillus insulicola: Moubasher *et al*. (2016) have found this fungus in the soil of fruits farm. (**Table 2** continued)
		Aspergillus melleus: found in sandy soil by Samson and Mouchacca (1975) in Egypt.
		Aspergillus ochraceus: Sabet (1935) has isolated this species from soil in Egypt.
		Aspergillus ostianus: Moubasher *et al*. (2016) have isolated this species from fruits farm.
		Aspergillus petrakii: this species is isolated by Ezz-ElDin (1988) from soil.
		Aspergillus robustus: found in Egypt by Abdel-Sater *et al*. (2016).
		Aspergillus roseoglobulosus: found by Samson and Mouchacca (1974), and again by Moubasher *et al.* (2016) in a lake water in Egypt.
		Aspergillus sclerotiorum: in air, soil and seeds, this fungus exist and has been found by El-Kady and his colleagues (1992).
		Aspergillus sulphureus: El-Coorani (1966) has found this species in potato.
	Section 6: *Flavi*	***Aspergillus alliaceus***: this species is found in jojoba seed and isolated by Malloch and Cain (Al-Bedak, 2007).
		Aspergillus avenaceus: isolated by Shindia (1990) from composts.

		Aspergillus flavofurcatus: found in air-dust by Abdel-Hafez *et al*. (1986).
		Aspergillus flavus: found in certain kinds of leguminous and seeds by El-Maraghy (1989). (**Table 3** contined)
		Aspergillus parasiticus: Moubasher *et al*. (1990) have isoltaed this fungus from soil.
		Aspergillus subolivaceus: a species found in Egyptian desert by Moubasher and Abdel-Hafez (1978).
		Aspergillus tamarii: Metwalty (1966) has isolted this fungus from a certain insect (*Attacus ricini*).
		Aspergillus terricola: found in soil by Moubasher and Moustafa (1970).
		Aspergillus thomii: El-Morsy (1999) has isolated this fungus from a plant's rhizosphere in Egypt. (**Table 2** continued)
	Section 7: *Flavipedes*	***Aspergillus flavipes***: found in Egypt by Sabet (1935).
		Aspergillus neoflavipes: found in soil by Moubasher and Abdel-Hafez (1978).
	Section 8: *Jani*	***Aspergillus janus***: isolated from marsh soil by El-Morsy (1999).

	Section 9: *Nigri*	***Aspergillus aculeatinus***: isolated from fruits farm's soil by Abdel-Sater *et al*. (2016).
		Aspergillus aculeatus: found in Egypt by (Abdel-Hafez *et al*., 1990c) in wheat.
		Aspergillus awamori: found by Ragab (1956) in soil.
		Aspergillus brasiliensis: Abdel-Sater and his colleagues (2016) have found this species in fruits farm's soil.
		Aspergillus carbonarius: El-Abyad *et al*. (1982) have isolated this fungus from a plant's rhizospheres.
		Aspergillus costaricensis: a species found by Abdel-Sater *et al*. (2016) in fruits farm's soil.
		Aspergillus ellipticus: Raper and Fennell, The Genus *Aspergillus*: 319 (1965) IMI 278384.
		Aspergillus ficuum: found by Zohri *et al*. (2014) in foodstuffs.
		Aspergillus foetidus: a species found in Egypt by Zohri *et al*. (2014) in food stuff. (**Table 3** continued)
		Aspergillus fonsecaeus: found by El-Abyad (1997) in soil.
		Aspergillus helicothrix: Musallam, Antonie van Leeuwenhoek 46 (4): 407 (1980) IMI 278383.
		Aspergillus heteromorphus: found in Egypt by El-Morsy (1999) in a plant's rhizosphere.

		Aspergillus japonicus: found in Egyptian desrt soil by Moubasher and Abdel-Hafez (1978).
		Aspergillus lacticoffeatus: this species is isolated from an Egyptien hospital by Moharram *et al*. (2013).
		Aspergillus niger: a species found by Sabet (1935) in marsh soil. (**Table 2** continued)
		Aspergillus pulverulentus: Moubasher *et al*. (2015) have found this species in soil in Egypt.
		Aspergillus sclerotiicarbonarius: Abdel-Sater *et al*. (2016) have found this species in fruits farm's soil.
		Aspergillus tubingensis: Abdel-Sater *et al*. (2016) have found this species in fruits farm's soil.
		Aspergillus vadensis: this fungus is reported by Samson *et al*.(2005).
		Aspergillus violaceofuscus: found in soil by El-Abyad (1997).
	Section 10: *Terrei*	***Aspergillus aureoterreus***: a species found by Moubasher *et al*. (2018d) in flowers.

		Aspergillus carneus: a species found by Moubasher (1963) in soil.
		Aspergillus neoniveus: a species isolated by Moubasher (1965) from soil.
		Aspergillus terreus: Sabet (1935) has isolated this fungus from soil, also did Moubasher and Moustafa (1970).
		Aspergillus terreus* var. *terreus: a species found in many parts of humain body, animals, air and in soil too by El-Abyad (1997).
Subgenus 3: *Cremei*	**Section 11: *Cremei***	***Aspergillus chrysellus***: found in the Egyptian Museum by Abdel-Kareem (2010).
		Aspergillus cremeus: a species found by (Abdul-Wahid 1990) in soil. (**Table 2** continued)
		Aspergillus dimorphicus: Moubasher *et al*. (2016) have found this species in fruits farm's air in Egypt.

Subgenus 4: *Fumigati*	**Section 12: *Cervini***	***Aspergillus flaschentraegeri***: found in the intestine of a larva by Stolk (1964).
		Aspergillus pulvinus: Zohri *et al*. (2014) have found this fungus in foodstuffs.
		Aspergillus sepultus: El-Kady (1992) and his colleagues have isolated this species from many environments in Egypt.
		Aspergillus wentii: this species has been isolated by Sabet (1935) from soil in Egypt. ***Aspergillus cervinus***: Moubasher and Abdel-Hafez (1978) have isolated this fungus from soil in Egypt.
		Aspergillus parvulus: Abdel-Kader *et al*. (1979) have found this species in barley grains. (**Table 3** continued)
	Section 13: *Clavati*	***Aspergillus clavatonanicus***: Moubasher and Abdel-Hafez (1978) have found this species in soil.
		Aspergillus clavatus: isolated by El Esaily (1965) from rhizospheric soil of Vicia faba.
		Aspergillus giganteus: Elgindy (1975) has found the species in rhizosphere soil of corn.
	Section 14: *Fumigati*	***Aspergillus brevipes***: found in composts by Shindia (1990).
		Aspergillus duricaulis: a species that has been found in seeds Ammar *et al.* (2017).

		Aspergillus fennelliae: Kwon-Chung & S.J. Kim, Mycologia 66 (4): 629 (1974) IMI 278382.
		Aspergillus fischeri: a species isolated from corn by Kamara (1964).
		Aspergillus fumigatus: a species found in soil by many among them Moubasher and Moustafa (1970).
		Aspergillus neoellipticus: found in Egypt by Hamed (2016) in a farmland.
		Aspergillus turcosus: a species found in Egypt by Moubasher *et al*. (2016) in a lake water. (**Table 2** continued)
		Aspergillus viridinutans: Abdel-Sater *et al*. (2016) have found this fungus in fruits farm soil.
Subgenus 5: *Nidulantes*	**Section 15: *Aenei***	***Aspergillus bicolor***: Ismail *et al*. (1995) have isolated this species from various substrates.
	Section 16: *Bispori*	***Aspergillus bisporus***: this fungus is found in Egypt in a medicinal plants by Salem and Abdel-Azeem (2014).
	Section 17: *Cavernicolus*	***Aspergillus egyptiacus***: this fungus is found in an alove tree farm by Moubasher and Moustafa (1972).

		Aspergillus subsessilis: this fungus is isolated from desert soil by Samson and Mouchacca (1974).
	Section 18: *Nidulantes*	***Aspergillus aurantiobrunneus***: this species is found in many substrates by Ismail *et al*. (1995).
		Aspergillus aureolatus: found in various herbs by El-Kady *et al*. (1992).
		Aspergillus caespitosus: found in soil by Moubasher (1966).
		Aspergillus desertorum: Samson and Mouchacca (1974) have isolated this fungus from sandy soil in the Egyptian desert.
		Aspergillus floriformis: Samson and Mouchacca (1975) have isolated this fungus in desert soil.
		Aspergillus fruticulosus: Samson and Mouchacca (1974) have found this fungus in the Egyptian desert.
		Aspergillus latus: Moubasher and Abdel-Hafez (1978) have found this species in a cultivated soil.
		Aspergillus multicolor: Abdel-Hafez *et al*. (1991) have isolated this species from the Egyptian desert.
		Aspergillus nidulans: Sabet (1935) has found this species in different soil types.
		Aspergillus parvathecius: a species found in various substrates by Ismail *et al*. (1995).
		Aspergillus purpureus: Samson and Mouchacca (1975) have been isolated this species from the Egyptian desert soil.

		Aspergillus quadrilineatus: a species isolated by many such as Moubasher and Moustafa (1970) from soil. (**Table 2** continued)
		Aspergillus rugulosus: a species isolated by many such as) by Moubasher and Moustafa (1970) from soil.
		Aspergillus rugulovalvus: a fungus isolated from cultivated soil (El-Abyad, 1997).
		Aspergillus spelunceus: Abdel-Sater *et al*. (2016) have isolated this species from fruits farm in Egypt.
		Aspergillus spinulosporus: Abdel-Fattah *et al*. (1977) have found this species in salt marsh soil.
		Aspergillus stella-maris: a species found in the air of orange farm by Moubasher *et al*. (2010, 2013). (**Table 3** continued)
		Aspergillus stellatus: found in the Egyptian desert soil by Moubasher and Abdel-Hafez (1978).
		Aspergillus stellifer: found by Abdel-Sater *et al*. (2016) in citrus and grape phyllosphere and carposphere in Assuit, Egypt.
		Aspergillus striatus : a species found byIsmail *et al*. (1995) from various substrates.
		Aspergillus sublatus: a species found byIsmail *et al*. (1995) from various substrates.
		Aspergillus tetrazonus: isolated from cultivated soil (El-Abyad 1997).
		Aspergillus unguis: a species found by Ismail *et al*. (1995) from various substrates.
		Aspergillus violaceus: a species found byIsmail *et al*. (1995) from various substrates.
		Aspergillus violaceobrunneus: found in barley grains by El-Kady and Abdel-Hafez (1981).

	Section 19: ***Ochraceorosei***	***Aspergillus funiculosus***: isolated from desert soil (El-Abyad 1997).
	Section 20: ***Silvati***	***Aspergillus silvaticus***: El-Hissy *et al*. (1990) have isolated this species from a lake in Egypt.
	Section 21: ***Sparsi***	***Aspergillus conjunctus***: El-Morsy (1990) has isolated this fungus from Red Sea soil in Egypt.
		Aspergillus panamensis: a species isolated by Abdel-Sater *et al*. (2016) from fruits farm soil.
		Aspergillus sparsus: a species found in the Egyptian Museum by Abdel-Kareem (2010).
	Section 22: ***Raperi***	***Aspergillus raperi***: found in citrus farm soil by Moubasher et al. (2016). (**Table 3** continued)
	Section 23: ***Usti***	***Aspergillus calidoustus***: found by Moubasher *et al*. (2016) in citrus farm soil.
		Aspergillus carlsbadensis: found by Moubasher *et al*. (2018b) in fruits farm soil.
		Aspergillus deflectus: a species isolated by Isolated by El-Hissy *et al.* (1990) from a lake in Egypt.
		Aspergillus granulosus: El-Abyad (1997) has isolated this species from saline sandy soil.
		Aspergillus insuetus: Sabet (1935) has found this fungus in soil in United Arab Emirates.
		Aspergillus minutus: Sabet (1935) has isolated this species from soil in Giza, Egypt.

		Aspergillus porphyreostipitatus: isolated by (Moubasher *et al*. 2018b) from phyllosphere sample of orange plantations.
		Aspergillus pseudodeflectus: found in desert soil by Samson and Mouchacca (1975).
		Aspergillus puniceus: a species isolated by Naguib and Mouchacca (1970) from desert soil.
		Aspergillus ustus: found in soil by Sabet (1935).
		Aspergillus ustus* var. *pseudodeflectus: found in desert soil by Samson and Mouchacca (1975).
	Section 24: *Versicolores*	***Aspergillus humicola***: found in soil by El-Abyad and Migahed (1989).
		Aspergillus peyronelii: found in sandy soils byEl-Abyad (1997).
		Aspergillus spelunceus: found in sandy soils byEl-Abyad (1997).
		Aspergillus versicolor: found in soil by Moubasher (1966).
		Aspergillus sydowii: found in soil in Egypt by Sabet (1939).
Subgenus: *Ornati* (Problematic taxon)	**Section: *Ornati***	***Sclerocleista ornate:*** found farm soil in Egypt by Hamed (2016).

I. 5.1. Key to the *Aspergillus* taxa recorded in Algeria

Subgenus 1: *Aspergillus*

Section 1: *Aspergillus*

The section *Aspergillus* is recorded in Algeria (Ouiddir *et al*., 2019). It is isolated from Sebkha of Oran as the species *A. amstelodami* (Chamekh *et al*., 2019), from Setif, Tizi Ouzou and Metija (Riba *et al*., 2013), also from Canstantine (Radoune-salah *et al*., 2015).

Aspergillus section *Aspergillus* (formerly the genus Eurotium) includes xerophilic species with uniseriate conidiophores (Chen *et al*., 2017), with hyaline, brownish or greenish stipes holding green conidia in mass and slightly inflated to subglobose vesicles (Gams *et al.*, 1985).

Table 3: *Aspergillus* section's morphology (Abdel-Azeem *et al*., 2020).

Sections	Morphological characteristics				
Aspergillus	Cleistothecia present	Ascospores 6 µm or less along the main axis, conidia less than 7 µm in diameter	Ascospore equatorial ridges lacking or showing only as traces	Ascospore furrow shallow	Conidial surface spinulose : *A. ruber*
					Conidial surface verrucose: *A. tonophilus*
					Conidial surface microtuberculate (3.5–5.5 × 3–4.5) µm: *A. xerophilous*
				Ascospore furrow showing as a slit, conidial surface spinulose	Conidial heads small: *A. pseudoglaucus*
					Conidial heads large:.*A. repens*
			Ascospore equatorial ridges interrupted	Conidiophor-es, phialides and sub-vesicular area are proliferating: *A. proliferans*	
				Conidiophor-es, phialides and sub-vesicular area are none proliferating	Smooth, minute rough ornamentation of ascospore convex surface: *A. glaucus*
					Smooth to slightly verruculose ornamentation of ascospore convex surface: *A. chevalieri*
			Ascospore equatorial	Conidial	

			crests well developed	surface smooth: *A. intermedius*	
				Conidial surface verrucose	Ascospore crests thick, ascospores 5 µm or smaller along the main axis: *A. montevidensis*
					Ascospore crests thin and wavy, ascospore size up to 6 µm: *A. cristatus*
					Ascospore crests short and rigid, valve surface definitely rough to verrucose: ***A. amstelodami*** (**Table 11** continued)
		Ascospores 6 µm or more along the main axis, conidium diameter 7 µm or more	Ascospore equatorial ridges lacking or very limited, furrow present.	conidial surface verrucose: *A. halophilicus*	
				conidial surface spiny: *A. umbrosus*	
			Ascospore equatorial ridges and furrow present, conidial surface verrucose to spinulose	Conidial diameter up to 10 µm or more, conidial surface verrucose	Ascospore main axis not greater than 7 µm:*A. mangini*
					Ascospore main axis up to 10 µm: *A. echinulatus*
				Conidial diameter less than 10 µm	Conidium surface with small scattered spiny processes, ascospore main axis up to 8 µm: *A. niveo-glaucus*
					Thick spines covering the whole

					conidium surface, ascospore main axis never exceed 7 µm: *A. leucocarpus*
	Cleistothecia lacking, ascospores borne in naked clustered asci: *A. athecius*				

Subgenus 2: *Circumdati*

Section 4: *Candidi*

These fungi grow slowly; Their white to yellowish conidia are held on smooth and small conidiophores; metulae covers the entire vesicle (Varga *et al.*, 2007).

The section *Candidi* was recorded in Algeria in 2008 as the species *A. candidus* in three different regions: Setif, Tizi Ouzou and Metija (Riba *et al.*, 2013). This species grows in white colour colonies, with uncoloured to yellow reverse, conidial head globose, smooth conidiophore, subglobose smooth conidia, with purple to black sclerotia. These fungi can exist in sulphur yellow colonies, with an uncoloured reverse, radiant conidial head, smooth conidiophores, and ellipsoidal smooth conidia with no sclerotia as the species *A. campestris* (Abdel-Azeem *et al.*, 2020).

Section 5: *Circumdati*

Fungi with biseriate conidial heads, rough walled stipes, yellow to ochre conidia and sclerotia that do not turn black (Visagie *et al*., 2014). These creatures were isolated in Algeria as *A. ochreaceus*, specifically in Setif, Tizi Ouzo and Mttija in 2008 (Riba *et al.*, 2013), in Bechar in 2003 (Abdelillah *et al*., 2013), and again in Tizi Ouzou in 2020 (Belasli *et al*., 2020).

Aspergillus steynii (El Aaraj *et al*., 2015) and *A. westerdijkiae* (Saadi *et al*., 2020; Louai *et al*., 2020) are two species that are recorded in Algeria and that belong to section *Circumdati* but not mentioned in the next table, also is the species *A. subramanianii* that is isolated from Sebkha of Oran by Chamekh and his colleagues (2019).

Table 4: *Circumdati* section's morphology (Abdel-Azeem *et al*., 2020).

Section	Morphological characteristics	
Circumdati	Conidial heads in pale pure yellow Shades	Sclerotia cream to pale yellow, produced in a dense layer, conidial heads loosely radiate, spore chains adherent into narrow divergent columns: *A. sulphureus*
		Sclerotia white to light orange to yellow, colonies are poorly sporulating after 7 day, conidial heads globose, minor portion elongated and radiate: *A. fresenii*
		Sclerotia white to cream to pale pink, produced singly, (1.0 to 1.5) mm in diameter, conidial heads hemispherical to loosely columnar or split into two or more compact columns: *A. sclerotiorum*
		Sclerotia light yellow, sparse, 115-550 µm in diameter, conidial heads globose, radiate: *A. bridgeri*
		Sclerotia black white when young, produced centrally, 155–820 µm in diameter, conidial heads radiate, globose: *A. robustus*
		Sclerotia only detected on MEA, white, 740–990 x 660-800 µm, conidial heads radiate splitting into two columns: *A. roseoglobulosus*
		Sclerotia absent, conidial heads radiating, globose: *A. gaarensis*
	Conidial heads in bright golden yellow shades	Sclerotia orange to rufous, globose to subglobose, 500-700 µm in diameter, conidia heavy walled, smooth, elliptical or ovate, 3.3-4.4 µm by 2.5-3.0 µm, conidial heads remaining bright in age: *A. auricomus* (**Table 4**

<table>
<tr><td rowspan="6"></td><td></td><td colspan="3">continued)</td></tr>
<tr><td rowspan="5">Conidial heads in dull yellowish cream, buff or ochraceous shades</td><td rowspan="4">Sclerotia produced in most strains</td><td colspan="2">Sclerotia abundant, small, commonly (400 to 500) µm Sclerotia pure yellow then brown, conidia globose, subglobose or elliptical, 2.75-3.5 µm or 3.0 -3.3 µm by 2.5 to 2.8 µm: A. melleus</td></tr>
<tr><td rowspan="3">Sclerotia scattered, developing late, large, commonly 500 to 1000 µm</td><td>Sclerotia pink to vinaceous purple when mature, globose, ovate to cylindrical, conidia globose to subglobose, mostly 2.5 to 3.0 µm: A. ochraceus</td></tr>
<tr><td>Sclerotia cream to buff or clay colour, globose to ovate, conidia elliptical to pyriform (4.0 to 5.0) µm by (3.0 to 3.5) µm: A. ostianus</td></tr>
<tr><td>Sclerotia white to cream, ovate to discoid, conidia ovate to elliptical, mostly (3.2 to 4.0) µm by (2.8 to 3.2) µm: A. elegans</td></tr>
<tr><td>Sclerotia Unknown</td><td colspan="2">Colonies close textured, sporulating slowly, conidial heads pinkish buff, conidia subglobose, ovate or elliptical, mostly (3.0 to 4.0) µm by (2.5 to 3.0) µm: A. petrakii</td></tr>
</table>

	Conidial heads in light yellow to olive brownish to brown	Sclerotia reddish brown, 350 - 650 µm: *A. flocculosus*
		Sclerotia absent: *A. insulicola*

Section 6: *Flavi*

Some of the most important species in the genus belong to this section, which are of significance in biotechnology, foods and health (Varga *et al*., 2011). These fungi have radiant Conidial heads, and yellow-green to deep olive-brown conidia held on stipes hyaline conidiophore. Vesicles clavate, flask-shaped, globose or subglobos (Samson, 2013).

The section *Flavi* was recorded in Algeria in 2018 by Ait Mimoune *et al*. (2018). It is isolated in Algeria as the species *A. flavus* (Boukhatem *et al*., 2014; Fernane *et al*., 2010; Merabti *et al*., 2019; Nadia *et al*., 2020; Merad *et al*., 2021; Chekiri *et al*.,2016; Saadi *et al*., 2020; Louail *et al*., 2020), and found in Setif, Tizi Ouzou and Metija in 2008 by Riba *et al*. (2013), by Rahmoun *et al*. (2013) in Adrar , by Yassine et Haiet (2018) in Tlemcen, and again in Tizi Ouzou by Belasli *et al*. (2020), in Bechar by Abdelillah *et al*. (2013), and also in Algiers by Tebibal and her colleagues (2013). The same species is isolated from many other Wilayas such as Batna, Biskra, Oran and Algiers by Azzoune *et al*. (2015).

The species *A. tamarii* from the same section was isolated in Algeria in 2008 by Riba *et al*. (2013), specifically from Setif, Tizi Ouzou and Metija, and also by Tebibal *et al*. (2013), then again in 2020 by Belasli *et al*. (2020).

The species *A. parasiticus* is recorded in Algeria by Louail *et al*. (2020), and by Riba *et al*. (2013), by Tebibal and her colleagues (2013) in Algiers, and in Batna, Biskra, Oran and again in Algiers by Azzoune *et al*. (2015).

A. alliaceus is one of the species found in Algeria by Louail *et al*. (2020). In Setif, Tizi Ouzou and Metija specifically, Riba *et al*. (2013) isolated this species in 2008, where they isolated also the species *A. pseudotamarii* in the same year2013.

The species *A. pseudotamarii* was isolated again, from Algiers in 2013 by Tebibal *et al.* (2013). However, *A. nomius* is one of section *Flavi* species recorded in Algiers by Tebibal and her colleagues (2013). Also the species *A. oryzae* has been isolated from Tlemcen in 2014 by Tabti *et al*. (2014).

Aspergillus caelatus and *A. pseudocaelatus*, are two species belong to the section *Flavi* (Frisvad *et al*., 2019), they were isolated from Algiers in 2013 by Tebibal *et al*. (2013). This group of researchers isolated more species from the section *Flavi* which are: *A. bombycis*, *A.*

pseudotamarii from Algiers too in 2013, while the two species *A. minisclerotigenes*, *A. parvisclerotigenus* from the same section (Godet and Munaut, 2010) were found in 2008 by Riba *et al*. (2013) in Setif, Tizi Ouzou and Metija, and also by Tebibal *et al*. (2013), but the species *A. parvisclerotigenus* is more common in Algeria after isolating from Batna, Biskra,Oran, Algiers by Azzoune *et al*. (2015).

Table 5: *Flavi* section's morphology (Abdel-Azeem *et al*., 2020)

Section	Morphological characteristics	
Flavi	Conidial heads in pale to intense yellow or yellow-green shades when young	Heads uniseriate, radiate, conidia prominently echinulate, dark yellow green in mass, sclerotia absent: ***A. parasiticus***
		Heads biseriate in many conidiophores, radiate or very loosely columnar, conidia finely echinulate, brownish, yellow green in mass, irregularly shaped sclerotia sometimes present: ***A. flavus***
	Conidial heads in bright golden yellow shades to cinnamon	Heads biseriate on old conidiophores, uniseriate on small vesicles, columnar to radiate, conidia smooth, oval to subglobose, abundant grey black sclerotia present: ***A. alliaceus***
	Conidial heads in deep yellow-green to olive-brown shades when young; conidia conspicuously verruculose.	Conidial heads at first deep yellow-green, shifting to brownish green or brown on Czapek's agar: ***A. tamari***
		Conidial heads quickly olive-brown then dark brown: *A. flavofurcatus*
	Conidial heads in pale yellowish olive or grayish olive shades; conidia smooth or nearly so	Conidiophores conspicuously echinulate: *A. subolivaceous*
		Conidiophores smooth or nearly so: *A. avenaceus*

Section 7: *Flavipedes*

This section has a global distribution in so many different environments such as soils and rhizospheres, indoor and caves, as endophytes, food contaminants and occasionally as human pathogens (Hubka *et al*., 2015).

Chamekh *et al*. (2019) isolated one of this section's species in sebkha of Oran. This species is *A. micronesiensis* which is not mentioned in the next table but it belongs to section *Flavipedes* (Visagie *et al*.,2014).

Table 6: *Flavipedes* section's morphology (Abdel-Azeem *et al*., 2020).

Section	Morphological characteristics	
Flavipedes	Colonies on MEA and CYA at 25 oC after 14 day brightly yellow	Ascospores develop after 3–4 week of cultivation on MEA at 25 oC: *A. neoflavipes*
	Colonies on MEA and CYA at 25 oC after 14 day otherwise colored	No or very restricted (2 mm) growth on CYA at 40 oC after 7 day, vesicles predominantly spathulate, no production of Hülle cells on MEA: *A. flavipes*

Section 9: *Nigri*

This section was recorded in Algeria in 2008 by Boukraa *et al*. (2008), and then in 2010 by Fernane *et al*. (2010). Also by Tebibal and her colleagues from Algeiers (2013).

A. niger is one of *Nigri* section species recorded in Algeria (Boukhatem *et al*., 2014), in Setif, Tizi ouzou and Metija by Riba *et al*. (2013), in Tlemcen by Senouci *et al*. (2020) and Tabti *et al*. (2014), again in Tizi Ouzou by Belasli *et al*. (2020), in Annaba by Benhadj *et al*. (2020), in Adrar by Rahmoun *et al*. (2013).

The species *A. carbonarius* was recorded in Algeria by Varga *et al*. (2014), in 2019 by Saadi *et al*. (2020), and again in 2020 by Isik *et al*. (2020). In 2008, Riba *et al*. (2013) have found this fungus in Setif, Tizi Ouzou and Metija, Belasli *et al*. (2020) have isolated the same species from Tizi Ouzou in 2020.

Ouiddir *et al*. (2019) have recorded the species *A. tubingensis* that belongs to the same section *Nigri* in Algeria and also the species *A. foetidus*.

These fungi are known by globose or nearly so vesicles, sometimes dark brown. Black conidia with radiant conidial heads (Abdel-Azeem *et al.*, 2020), and the next table gives more details about its morphology.

Table 7: *Nigri* section's morphology (Abdel-Azeem *et al*., 2020).

<table>
<tr><th>Section</th><th colspan="5">Morphological characteristics</th></tr>
<tr><td rowspan="5">Nigri</td><td rowspan="5">Sterigmata in two series (biseriate)</td><td rowspan="5">Colonies (conidial heads) on Czapek's agar appearing hair brown to dark blond, dark brown to carbon black</td><td rowspan="4">Conidia (6 to 10) µm or more in diameter</td><td colspan="2">Conidia 7 to 11 µm in diameter, globose, very rough: A. carbonarius</td></tr>
<tr><td colspan="2">Conidia (6 to 8) µm in diameter, globose, conspicuously roughened with prominent color bars: A. fonsecaeus</td></tr>
<tr><td colspan="2">Conidia (6 to 8.5) µm in diameter, globose to subglobose, conspicuously echinulate: A. helicothrix</td></tr>
<tr><td colspan="2">Conidia (5.1–) 6–8 (–9.5) 6 (4.8–) 5.8–7.8 (–8.5) µm in diameter, subglobose, conspicuously echinulate when young, becoming verruculose when mature: A. sclerotiicarbonarius</td></tr>
<tr><td>Conidia 5 µm or less in diameter at maturity</td><td>Conidiophores not exceeding 4 mm in length</td><td>Conidia 3.5-4 µm in diameter, globose, irregularly roughened when young, becoming horizontally flattened and longitudinally striate at</td></tr>
</table>

					maturity: *A. ficuum*
					Conidia 4-5 µm in diameter, globose, irregularly roughened with conspicuous ridges and echinulations not arranged as longitudinal striation: ***A. niger***
				Conidiophores commonly exceeding 5 mm in length	Conidiophore reaching 1cm but also with shorter stalk bearing diminutive heads, conidia globose to subglobose, 3.5-0.5 µm, smooth to definitely verruculose: *A. pulverulentus* **(Table 7** continued**)**
					Conidiophore (0.3 to 1.2) cm, conidia subglobose, 3.5-4.1 x 3.4-3.9 µm, usually smooth to finely roughened: *A. lacticoffeatus*

					Conidiophore (0.7 to 1.7) cm, conidia subglobose, (3.5-4.8) µm in diameter, echinulate: *A. brasiliensis*
					Conidiophore (1.0 to 1.7) cm, conidia globose to subglobose, (3.1–) 3.5–4.3(–4.5) µm in diameter, smooth when young, becoming distinct rough walled: *A. costaricensis*
		Colonies (conidial heads) grayish olive brown or deep olive brown when young; usually becoming reddish brown to brownish black, but with olive or grayish colours often persistent	Heads quickly dark black-brown or reddish-brown	Heads quickly dark black-brown; colony reverse uncoloured; conidiophores mostly 2 to 3 mm but up to 5 mm long; conidia mostly (3.0 to 3.5) µm in diameter: *A. tubingensis*	
				Heads quickly reddish brown; colony reverse in similar shades; conidiophores usually (1 to 1.5) mm long; conidia mostly (4.0 to 4.5) µm in diameter: *A. awamori*	
			Heads	Conidia at maturity elliptical, conspicuously	

			persistently dark greyish brown or olive brown	echinulate, (5.0 to 5.5) µm (by 3.3 to 3.8) µm: *A. ellipticus*	
				Conidia at maturity globose or nearly so, sometimes elliptical when young	Conidia at maturity conspicuously spinulose: *A. heteromorphus*
					Conidia at maturity irregularly and finely roughened: ***A. foetidus***
					Conidia at maturity rough to finely echinulate: *A. vadensis*
	Sterigmata uniseriate	Conidia globose to subglobose, conspicuously echinulate; vesicle commonly (20 to 35) µm ranging from (15 to 45) µm: *A. japonicas*			
		Conidia subglobose to definitely elliptical, conspicuously echinulate	(3.5-4.0) µm x (4.5-05) µm, vesicle commonly (60 to 80) µm but ranging from (35 to 100) µm:.***A. aculeatus***		
			(2-4 x 2.3-4.4) µm, vesicle commonly (55 to 65) µm but ranging from (43 to 82) µm: *A. aculeatinus*		
		Conidia typical ellipsoidal to fusiform conidia, coarsely roughened to echinulate; vesicle (10 to 18) µm wide: *A. violaceofuscus*			

Section 10: *Terrei*

These creatures were found in Algeria in 2014 as the species *A. terreus* by Tebibal and her colleagues in Algeiers (2013), by Boukhatem *et al*. (2014), and then in 2021 by Merad *et al*. (2021).

In 2008, Riba and his partners (2013) isolated this fungus from Setif, Tizi Ouzou in Metija, and from Sebkha of Oran by Chamekh *et al*.(2019), also by Belasli *et al.* (2020) from Tizi Ouzou.

Abdel-Azeem and his colleagues (2020) stated that this section contains species with columnar conidial heads in shades of buff to brown. They clarified more about this section's morphology as shown in next table.

Table 8: Terrei section's morphology (Abdel-Azeem *et al*., 2020).

<table>
<tr><th>Section</th><th colspan="2">Morphological characteristics</th></tr>
<tr><td rowspan="4">Terrei</td><td>Colonies velvety, conidial heads long, compactly columnar, in cinnamon to orange brown or brown shades; born on short conidiophores</td><td>Sclerotium-like masses of swollen, relatively heavy-walled cells lacking on MEA: A. terreus</td></tr>
<tr><td colspan="2">Colonies floccose, aerial mycelium conspicuously golden yellow, conidial heads small, compactly columnar, cream to buff; born on conidiophores 500 µm or more long: A. aureoterreus</td></tr>
<tr><td rowspan="2">Conidiophores unpigmented or very faintly yellowed</td><td>Conidia heads at first white, becoming vinaceous fawn, conidia globose to subglobose, smooth, (2.4 to 2.8) µm rarely exceeding 3.2 µm, irregular hyphal branching may occur: A. carneus</td></tr>
<tr><td>Conidia heads lemon yellow to lemon chrome, conidia globose to subglobose, smooth, (2.0 to 2.5) µm, crusts of Hülle cells recorded: A. neoniveus</td></tr>
</table>

Subgenus 3*: Cremei*

Section 11: *Cremei*

The section *Cremei* was present in Algeria as the species *A. europaeus* that was isolated in 2019 from Sebkha of Oran By Chamekh and his colleagues (2019).

These fungi are known by their buff-brown, pale yellow-green or blue-green conidia, held on stipes mostly hyaline, smooth-walled conidiophores and loosely radiant conidial heads, with large and globose vesicles (Samson, 2013). The next table shows more about this section's morphology.

Table 9: *Cremei* section's morphology (Abdel-Azeem *et al*., 2020)

Section	**Morphological characteristics**		
Cremei	Ascocarp present	Conidia typically barrel to elliptical or occasionally subglobose, cleistothecia cream to yellowish, ascospores (6.0 to 7.0) µm by (4.0 to 4.5) µm, with sharp spines on convex surface, with two wide equatorial crests: *A. chrysellus*	
		Conidia ovate to pyriform but varying from cylindrical to subglobose, cleistothecia cream to buff, ascospores (6.6 to 7.7) µm by (4.5 to 5.0) µm, with two prominent equatorial crests, convex surfaces ornamented with few hyaline spikelike extensions: *A. cremeus*	
	Ascocarp absent	Heads biseriate	Conidia up to 6 µm, globose to broadly ellipsoidsmooth: *A. wentii*
			Conidia up to 4 µm, globose, echinulate: *A. pulvinus*
			Conidia up to 4 µm, subglobose to globose, rarely ovate, very delicately roughened: *A. dimorphicus*
			Conidia up to 4.5 µm, globose, slightly roughened: *A. sepultus*
		Heads mostly uniseriate occasionally biseriate	Conidia mostly subglobose, varying from globose to slightly ellipsoidal, hyaline, some what roughened, mostly (4.5 to 6.0) µm by (4 to 5) µm, occasionally up to 7 µm in long axis: *A. flaschentraegeri*

Subgenus 4: *Fumigati*

Section 14: *Fumigati*

The section *Fumigati* is recorded in Algeria as the species *A. fumigatus* and also as *A. fischeri* by Boukhatem *et al*. (2014), Haddouchi *et al*. (2013), Brakni *et al*. (2018), and recently by Merad and his colleagues (2021). Riba *et al*. (2013) isolated this species from Setif, Tizi Ouzou and Metija in 2008, also have Belasli *et al*. (2020) from Tizi Ouzou and benhadj *et al*. (2020) from Annaba.

This section have grey-green to dark blue-green conidia, held on smooth-walled conidiophore stipes Metulae absent. Phialides confined to the apical part, parallel (Samson, 2013), and more morphological characteristics are shown in next table.

Table 10: *Fumigati* section's morphology (Abdel-Azeem *et al*., 2020).

Section	**Morphological characteristics**			
Fumigati	Ascocarp Absent	Conidial heads erect, compact, strongly to loosely columnar, vesicle commonly 15 to 30 µm in diameter, upright on the conidiophores	Conidiophores 0.5 mm or less, conidial head dark green, conidia globose, echinulate: ***A. fumigates***	
			Conidiophores 0.08 mm, conidial head gray-turquoise to gray-green, conidia subglobose, ovoid and smooth: *A. turcosus*	
		Conidial heads often presenting a nodding appearance, smaller than the preceding and not consistently columnar; vesicles less than 20 µm in diameter	Conidiophores thin walled, sinuous, vesicles uncoloured, and often strongly nodded, conidia in pale blue-green shades: *A. viridinutans*	
			Conidiophores heavy walled, vesicles and sterigmata coloured, conidia in dark blue-green shades	Conidia conspicuously echinulate, colony reverse uncoloured or nearly so: *A. duricaulis*
				Conidia finely spinulose, colony reverse in reddish brown to deep rose shades: *A. brevipes*
	Ascocarp present	Cleistothecia and enveloping hyphae	Heterothallic	Convex surfaces of ascospores distinctly cerebriform: *A. fennelliae*

		white to cream in colour	Homothallic	Convex surfaces bearing anastomosing ridges to give a large and somewhat irregular reticulation: ***A. fischeri***

Subgenus 5: *Nidulantes*

Section 18: *Nidulantes*

This section is recorded in Algeria by Medjber and his colleagues (2018) as the species *A. nidulans*.

Fungi of this section are known with their green shades conidia, held on brown, smooth-walled conidiophore stipes brown. Hemispherical to flask-shaped vesicles. Hülle cells typically abundantly produced, globose to irregularly ovate or pyriform (Samson, 2013). More details are clarified in the table below.

Table 11: *Nidulantes* section's morphology (Abdel-Azeem *et al*., 2020).

Section	**Morphological characteristics**				
Nidulantes	Cleistothecia present	Ascosp-ores lenticul-ar, non-stellate	Ascospore, orange-red, reddish brown in color	Convex surfaces are smooth, two equatorial crests	Light orange, (4–5 × 3.5–4.5) µm, crests 0.8–1 µm: *A. aurantiobrunneus*
					Orange to reddish brown, (4.5–5.5 × 3–5) µm, crests 0.8–1 µm: *A. fruticulosus*
					Orange to reddish brown, (3.5–5 × 3–4.5) µm, crests 0.5–1 (entire or dentate): ***A. nidulans***
					Light orange, orange or reddish brown, (3.5–5 × 3–5) µm, incompletely reticulate or ribbed, crests 1–1.5 µm: .*A. latus*
					Orange to reddish brown (4–4.5 × 3–4.5) µm, crests 0.5–1 µm (entire, defective or with irregular protuberance): *A. quadrilineatus* (≡ *A. tetrazonus*)
					Light orange, orange or reddish brown, convex surfaces smooth, incompletely reticulate or ribbed, globose to subglobose, (3.5–5 × 3–5) µm; in side view lenticular, with two pleated equatorial crests measuring (1–1.5) µm: *A. sublatus*
				Convex surfaces are smooth, four	Reddish brown, 4 crests, two of them are equatorial, conspictous, pleated and about 0.5 µm

				equatorial crests	wide, the other two are in a subequatorial position and only seen under SEM, (3.2-3.8 × 2.5–2.8) µm: *A. parvathecius* (**Table 11** continued)
				Convex surfaces are tuberculate, reddish brown, (6.5–7.5 × 6–7.5) µm, crests 0.5 µm: *A. desertorum*	
				Convex surfaces are roughened, bearing simple or anastomosing thickenings arranged in more or less concentric rings, orange, (6–7 × 5–5.5) µm; in side view broadly lenticular: *A. striatus*	
				Convex surfaces are echinulate, (3.5–4.5 × 3–4.5) µm; with two pleated equatorial crests measuring 0.8–1 µm: *A. spinulosporus*	
			Ascospores orange, greyish violet, reddish purple or brownish red Spore body (4–4.5 × 3.5–4) µm, convex surfaces are rugulose, crests (0.5–0.6) µm: *A. rugulosus* (≡ *A. rugulovalvus*)		
			Ascospores brown Spore body (6–7 × 4.5–5) µm, crests (0.3–0.6) µm: *A. purpureus*		
			Ascospores violet Spore body (4–6.5 × 3–5) µm, convex surfaces roughened, with reticulate intertwined ornamentation, low equatorial crest, less than 0.3 µm wide: *A. violaceus* (≡ *A. violaceobrunneus*)		
		Ascospores stellate	Ascospore size 13–16 µm, spore body 3–4.5 × 2.5–4.5 µm : *A. stella-maris*		
			Ascospore size 10–14 µm, spore body 3.5–4×3–4 µm: *A. stellatus*		

			(= *A. stellifer*)
	Cleistothecia absent	Conidiophore 80–200 × 4–5.5 µm, vesicle 9–12 µm, metulae 5–8.5 × 2–4 µm, phialide 5–7 × 2.5–3 µm, conidia 3.5– 5 µm, green in mass: *A. aureolatus*	
		Conidiophore 200–300 × 3–6 µm, vesicle 10–15 um, metulae 5–8 × 3–3.5 µm, phialide 6.5–8 × 3–4.5 µm, conidia 3–4 µm, green in mass: *A. caespitosus*	
		Conidiophore 150 × 5.5–7 µm, vesicle 11–15 µm, metulae 9–11 × 4-5 µm, phialide 6–8 × 4-6 µm, conidia 3.5–4.7 µm, green in mass: *A. floriformis*	
		Conidiophore 300–350 × 5–7 µm, vesicle 16–20 µm, metulae 6–10 × 3–4 µm, phialide 8–9 × 2.5–3 µm, conidia 3.5– 5.5 µm: *A. multicolor*	
		Conidiophore 130–300 × 4–6 µm, vesicle 7–11 µm, metulae 4–6.5 × 2.5–3.5 µm, phialide 5.5–7.5 × 2–2.5 µm, conidia 2.5–3.5 µm, blue green in mass: *A. spelunceus*	
		Conidiophore 50–100 × 3–5 µm, vesicle 8–10 µm, metulae 5–7 × 2.5–3.5 µm, phialide 5–9 × 2–2.5 µm, conidia 2.5–4 µm: *A. unguis*	

Section 23: *Usti*

The section *Usti* was found in Algeria as the species *A. calidoustus* in 2019 by Chamekh *et al*. (2019) after isolating from Sebkha of Oran, and recently as *A. ustus* by Merad and his partners (2021).

This section's fungi have drab, olivaceous or dull brown conidia, brown smooth-walled conidiophore stipes, with radiant or broadly columnar conidial heads (Samson, 2013). The next table shows more about theses fungi's morphology.

Table 12: *Usti* section's morphology (Abdel-Azeem *et al*., 2020).

Section	**Morphological characteristics**			
Usti	Vesicles upright on the conidiophores	Conidial heads in olive-grey to drab or red-brown shades	Conidial heads variable, radiate when young to loosely or broadly columnar at maturity	Grey to brown colored colony, irregular to elongate hülle cells sometimes present, associated with pigmented mycelium, rough walled globose conidia: ***A. ustus***
				Drab colored colony, elongate hülle cells abundantly produced, forming conspicuous masses associated with bright pigmented yellow mycelium, globose conidia, spinulose, to finely roughened : *A. puniceus*
		Conidial heads pale blue-green in color, hülle cells abundantly produced, irregularly globose, ovoid or somewhat elongated, conidia globose delicately echinulate: *A. granulosus*		
		Conidial heads yellow brown with white tufts of conglomerates of Hülle cells. Conidiophores smooth, brown, 4–5 µm wide, vesicles globose, 10–14 µm in diameter, conidia distinctly ornamented with spines or warts, ellipsoidal (2.5–3.0 × 3.0–3.5) µm: *A. carlsbadensis*		
		Conidial heads yellow brown blond/grayish yellow, brownish gray or grayish brown, hyphae inconspicuous, conidiophore short (150 to 300) µm (minimum, 130 µm), smooth, brown;		

		vesicles 9 to 15 µm (range, 7 to 20 µm) wide, pyriform to broadly spathulate; conidia globose (2.7 to 3.5) µm, very rough ornamentation (0.5 to 0.8 µm high), inner and outer wall visible. Hülle cells sparsely produced, irregularly elongated, in scattered groups: ***A. calidoustus***	
		Conidial heads brown	Vesicles 11-16 µm in diameter, conidia globose, 5 µm in diameter, echinulate, dark brown: *A. insuetus* (**Table 12** continued)
			Vesicles (8.0 to 18.0) µm in diameter, conidia globose, (3.2 to 4.5) µm in diameter, verrucose, light Brown: *A. minutes*
	Vesicles borne at a sharp angle to the vertical axis of the conidiophores	Conidiophore long (40 to 50) µm in some strains up to 125 µm in others, smooth, brown, conidia globose to subglobose, 3.0-3.5 µm in diam, with variable ornamentation, smooth when young to irregularly roughened: *A. deflectus*	
		Short conidiophore, curved, rough-walled with warty protuberances, brown, conidia globose to ellipsoidal, thick-walled, brown, ornamented with small warts and colour bars, 3.5-4.0 µm in diam. Hulle cells absent: *A. pseudodeflectus*	
	Penicillium-like conidiophores present, conidiophores reddish brown, hyaline also present, mostly smooth, some areas contain warts, vesicles globose, sometimes slightly elongated; conidia globose to subglobose, often covered by a thick layer, rough, Hülle cells produced on OA; Sclerotia absent: *A. porphyreostipitatus*		

Section 24: *Versicolores*

In Algeria, this section was recorded in 2008, then isolated by Riba *et al*. (2013), specifically in Setif, Tizi Ouzou and Metija such as the species *A. versicolor*, and then from Batna in 2019 by Sakhri *et al*. (2019) as the same species, and as the species *A. sydowii*.

Aspergillus creber is a poorly studied species, which is still unexplored for its biological activities (Sakhri *et al*., 2019). In 2012, Jurjevic and his colleagues revised the section *Versicolores* and accepted 13 species; among them, *Aspergillus creber*, that was described for the first time as a new species (Jurjevic *et al*., 2012). This species was found in Algeria after isolating from maize grains collected from Batna in 2019 by Sakhri *et al*. (2019).

The section *Versicolores* belongs to the previous subgenus *Nidulantes*. According to Samson (2013), *Versicolores* characterized by presence of metulae that covers the upper half to three quarters of the ovate to ellipsoidal vesicles, also by smooth-walled, hyaline or pale brown, mostly >300 µm long conidiophore stipes, radiant or loosely columnar conidial heads, conidial masses that are usually in some shades of green, and also by globose hülle cells that are usually abundant.

In the coming table Abdel-Azeem and his colleagues tell us more about this section's morphology.

Table 13: section *Versicolores*'s morphology (Abdel-Azeem *et al*., 2020).

<table>
<tr><th>Section</th><th colspan="4">Morphological characteristics</th></tr>
<tr><td rowspan="4">Versicolores</td><td rowspan="3">Vesicles globose to somewhat elongate, fertile over most of the vesicular surface; globose to subglobose Hülle cells often present, compact hyphal masses and sclerotia lacking</td><td rowspan="3">Mature conidia not exceeding 0.4 µm, consistently globose to subglobose</td><td rowspan="2">Conidioph-ores uncoloured to faintly yellowish</td><td>Conidial heads variable in colour, light yellow green, buff to orange-yellow, or occasionally flesh coloured: A. versicolor</td></tr>
<tr><td>Conidial heads always blue-green when young: A. sydowii</td></tr>
<tr><td colspan="2">Conidiophores definitely brown, smooth walled; conidial heads variable in shape, often loosely columnar: A. spelunceus</td></tr>
<tr><td colspan="4">Vesicles turbinate, often borne at a slight angle to the conidiophore, conidial head dark yellow-green; conidia globose, minutely asperulate, 2.5-3.0 µm in diameter, true sclerotia present, cream to buff: A. peyronelii</td></tr>
</table>

Conclusion and perspectives

Conclusion

The study on the genus *Aspergillus* is somewhat far from the required level and scale, especially taxonomic studies. In this study, we collected all the studies conducted on this genus in different environments in Algeria (soil, salt marshes, agricultural soil, isolated samples of different types of crops, wheat, dairy, etc. from its different states: Oran, Bechar, Adrar, Batna, Blida, Setif, Tizi Ouzo etc. There are some species, the information about their morphology is very scarce such as: *A. europaeus*, *A. creber*, *A. tubingensis*, *A. micronesiensis*, *A. oryzae*, *A. bombycis* etc, or let's say there are no research sources that we can rely on to describe it, so we were content with information that they were found in Algeria in the hope of developing studies and determining their morphology accurately. No species were obtained from the *Polypaecitum sebgenus*, while we got 12 sections from the 25 known sections in the world, also we got 33 species out of 150 known species , a good amount compared to the available species, which calls for more research studies in order to study the possibility of the remaining unstudied areas.

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