

INTRODUCTION The Aleppo pine (*Pinus halepensis*) is the most common tree in Algeria and it has a very important place in the balance of Mediterranean ecosystems. Among the individuals collected, *T. destruens* and *O. erosus* were the only species found in living trees, demonstrating that *O. erosus* is also capable of attacking stressed trees while it is usually considered as a secondary beetle. The vegetation is composed of Aleppo pine (*Pinus halepensis* Mill.), Atlas cedar (*Cedrus atlantica* Manetti), holm oak (*Quercus ilex* L.), narrow-leaved mock privet (*Phillyrea angustifolia* L. Rouy), turpentine tree (*Pistacia terebinthus* L.), lentisk (*Pistacia lentiscus* L.), Phoenician juniper (*Juniperus phoenicea* L.), cedar juniper (*Juniperus oxycedrus* L.), rosemary (*Salvia jordanii* J.B.Walker), globe daisies (*Globularia alypum* L.) and hairy thyme (*Thymus munbyanus* subsp. It is in the middle of three provinces Setif, Bordj Bou Arreridj and M'sila (35°48'36.3"N 5°08'58.5"E, 700–1500 m asl.). The annual rainfall is 396 mm and the mean annual temperature is 14.17°C. The majority of the massif is made of hard dolomitic limestones and marls. The most widespread forest formations in the area are composed of Aleppo pine, holm oak, Atlas cedar, Phoenician juniper, cedar juniper, globe daisies, narrow-leaved mock privet, oriental hawthorn (*Crataegus laciniata*), and Eucalyptus tree (*Eucalyptus* sp.). The Ouannougha forest (17671 ha) is a part of the mountain range of Bibans, it is located in the province of Bordj Bou Arreridj (36°09'35.2"N, 4°12'16.8"E, 900–1280 m asl.), 420 mm of precipitation falls annually with a mean annual temperature of 15.6°C. *Orthotomicus*), procoxae contiguous, intercoxal piece longitudinally emarginate to absent, never complete; elytra moderately sulcate to elaborately excavated, with lateral margin usually armed by tubercles or spines; pronotum more strongly declivous on anterior third, asperities usually larger; worldwide (Wood 1986) *Orthotomicus erosus* Wollaston, 1857 (Mediterranean pine beetle) Close to the genus *Ips*, from which it is distinguished by the straightness of its declivity whose apical edge is not explained backward.

MATERIALS AND METHODS Study area The study was carried out in a semi-arid region located in the Hodna and the Bibans Mountains, in North-Eastern Algeria, between 35°41'05.2" and 36°11'34.0" latitude (N) and 4 and 5° longitude (E), and at an altitude of 900–1300 m. The three forests of Boutaleb, Ouled Tebben and Ouenougha were selected for sampling, taking into account the forest dieback, the surface area of the forests and their ecological importance in the region (Figure 1). The study area is part of the semi-arid bioclimatic domain. Twenty-three, 25 and 30 sites were investigated in the Boutaleb, Ouled Tebben and Ouenougha forests, respectively (Figure 1). The Boutaleb forest (28427 ha) is located between the high Setifian plains to the north and the Hodna basin to the south (35°44'21.1"N 5°19'47.9"E, 950–1886 m asl.). *Scolytinae* subfamily *Tibiae* armed on apical and/or lateral margins either by spines or socketed denticles, apical mucro formed by mesal element (compared to *Protohijlastes* structure); male spiculum gastrale present, antennal club variable, with or without sutures, head narrower than pronotum; pronotum almost never with constriction near middle, pronotum edged on the sides and back. For example, with the aggressive Mediterranean species *Tomicus destruens*, the bored galleries damage the vascular system (xylem or phloem) and the cambium, resulting in various physiological imbalances (Chakali 2007; Lieutier et al. 2017). The trees composing this forest are Aleppo pine, holm oak, Atlas cedar, Phoenician juniper, and cedar juniper.

Bark beetles collection and identification Bark beetles were collected from *Pinus halepensis* trees in the three forests. *Crypturgini* tribe LeConte, 1876 Small size species, antennal funicle 2- or 3-segmented, club with

sutures on posterior face about equal to those on anterior face; pronotum feebly declivous on anterior half and unarmed, punctuated, reticulate in many species (Balachowsky 1949; Wood 1986). Collected insects were observed under a stereomicroscope and grouped in morphotypes for the identification with keys according to their taxonomic characteristics (Balachowsky 1949; Gil and Pajares 1986; Wood 1986; Alonso–Zarazaga 1988; Pfeffer 1995; Alonso–Zarazaga and Lyal 2009). The tunnel is about 8 to 10 cm long and 3 to 4 mm wide, the larval galleries develop in the bark thickness without affecting sapwood

Discussion This study investigated the diversity of bark beetle species in the North–Eastern region of Algeria for the first time. Breeding in the bark of the trunk and branches of decaying pines previously infested by more aggressive species such *Orthomicus*, egg galleries forming a confused system partially bored into the bark thickness. Attacks by these two bark beetle species in coniferous forests rely on two complementary factors: the existence of trees weakened by stress and a certain level of pest population (Lieutier and Levieux 1985). Global warming and its consequences like repeated heatwaves and drought have a significant impact on trees and their predators, resulting in an increased mortality and forest decline (Morcillo et al. 2019). Global warming and its effects cause stress and weaken the defense of fragile trees, which facilitates the development of species already existing in the territory and potentially the introduction of new species of bark beetles (Suarez–Vidal et al. 2019).

Ipini tribe Bedel, 1888 Eye shallowly sinuate with lower half narrower than above; protibia with 3–4 socketed teeth; antennal club rarely obliquely truncate (*Pityokteines*). This species which has long been confused with the neighboring species *Tomicus piniperda*, is responsible for the dieback of Aleppo pine forests in the semi–arid regions of Algeria (Guit et al. 2016). It is clear that the colonization of Aleppo pines is initiated by *T. destruens*, a more aggressive primary species, followed by *O. erosus* which is considered a secondary species (Lopez et al. 2007; Sanguesa–Barreda et al. 2015; Lieutier et al. 2016). The main objective of our study was to investigate the distribution of bark beetle species responsible for the decline of the Aleppo pine in the Central–Est semi–arid region of Algeria. Antenna funiculus is composed of 2 short segments, with an oval–shaped club provided with a fine and incomplete digitula, diffuse sutures rejected at the end. Pronotum longer than wide with parallel sides beyond the middle, with dense and tight punctuation, devoid of short bristle brushes at the apex of the elytra replaced with scattered silks denser than on the rest of the elytra. These two species are common on *Pinus* throughout the Mediterranean basin including the semi–arid regions in Algeria (Balachowsky 1949; Chakali 2004; Lopez et al. 2007; Lieutier et al. 2016). Species such as *O. erosus*, *H. ligniperda*, and *C. micklitzii* use aggregation pheromones to attract other individuals and thus massively attack the trees (Lieutier et al. 2016). Species of the genus *Crypturgus* are secondary bark beetles that occupy biotypes previously colonized by other species and do not affect healthy trees (Lieutier et al. 2016). In Algeria, 17 coniferous bark beetle species are monitored (Lieutier et al. 2016), but the bark beetle fauna of Algeria was not reviewed recently, and most of the existing records are old. Other scientific names: *Crypturgus abbreviatus* Eggers, *Crypturgus barbeyi* Strohmeier, *Crypturgus brevipennis* Reitter *Crypturgus mediterraneus* Eichhoff, 1889 Has a size of 1,1–1,5 mm. Longer, slender shape (Figure 4). Mesal surface of elytra at suture with interlocking groove and flange continued to base without a series of nodules or cavities immediately behind scutellum (Balachowsky 1949; Wood 1986). Taking advantage of the entrances to the galleries of other

species, the galleries of *C. numidicus* are bored irregularly throughout the thickness of the Aleppo pine bark, and these galleries are abandoned as soon as the bark dries out (Balachowsky 1949). However, trees can withstand the stresses and avoid dieback when favorable conditions return, but biotic factors such as pests can aggravate the stress and lead to their death (Anderegg et al. 2015). The attack occurs at different levels of plant vitality; some species develop on healthy plants, but many select hosts that are physiologically stressed or injured. The Boutaleb massif is exclusively made up of sedimentary rocks (marl, limestone, dolomite and clays with a lesser extension). Galleries: forming a marbled network that penetrates the thickness of the bark, rapidly reducing it to a spongy mass that is abandoned as soon as it dries out. This species is multiplying rapidly due to the physiological stress of Aleppo pines caused by climate change (Chakali 2004; Guit et al. 2016). In a recent survey in Europe, *O. erosus* was the most commonly found species in Portugal, Spain, France, Greece, Italy and Hungary (Faccoli et al. 2020). Several authors have reported the presence of these species in Algeria (Balachowsky 1949; Pfeiffer 1995), and for instance, Nichane (2013) reported the presence of *H. ligniperda* in the region of Tlemcen. This poorly known species were abundantly found under the trunk bark of Aleppo pines in the Boutaleb forest, with galleries dug into the sapwood of dead trees. Other bark beetle species attack recently dead trees and introduce symbiotic fungi (Ambrosia), and the hatched larvae then feed on the mycelium of these fungi. Some of the bark beetles are known for their association with xylophagous fungi, which can aggravate the mechanical damage caused by the insects leading to dieback. The Ouled Tebben forest or Righa Dahra (14932 ha) is located in the east of the Boutaleb forest between the high Setifian plains to the north and the Hodna basin to the south. At least five colonized trees were chosen randomly in every sampling day, based on direct observation of the bark (trunk, branches) and the presence of boring dust or pitch tubes as indicators of bark beetle infestation. Pronotum coarsely and uniformly punctuated over its entire surface by large closely spaced dots of irregular diameter and not very deep. *Crypturgus numidicus* was the most abundant species in the three forests, followed by *Orthomicus erosus* and *Tomicus destruens*. When reaching a high population density, *O. erosus* can overwhelm the host defenses, thus causing tree mortality (Faccoli et al. 2020). *Aphanommata filum* live in conifer trunks, it has already been observed in Algeria (Folwaczny 1973; Alonso-Zarazaga 1988). This is consistent with the findings of H. Jordal (Jordal 2014), which showed that Rhyncolini species live in the wood and under the bark of dead trees, adults lay eggs in excavated tunnels, and show similar behavior as Scolytidae. Common pests are the pine processionary caterpillars and bark beetles (Lieutier et al. 2016; Bao et al. 2020). They are represented worldwide by 6,000 species grouped in 29 tribes (Alonso-Zarazaga and Lyal 2009). The Boutaleb forest was the most affected with a total number of individuals collected of 666 followed by the Ouenougha and Ouled Tebben forests with 547 and 416 individuals, respectively (Figures 2, 3, and Table 3). *Crypturgus numidicus* Ferrari, 1867 The genus *Crypturgus* comprises the smallest species within Scolytidae (0.8–1.5 mm). *Crypturgus* species exhibit a narrow-shaped and cylindrical elongated body (Figure 4), and a brown or black colour with shiny or matt reflections. It has a convex and smooth elytral declivity, without a denticular processes, bristles of the interstriae at least twice as long as the striae. Anterolateral areas of pronotum unarmed; precoxal costa on prothorax absent. The mother gallery measures 10–16 cm, the larval galleries are numerous, irregular,

long and intertwined (Balachowsky 1949). *Tomicus destruens* has been reported on Aleppo pines in the Djelfa region (Chakali 2004). Very few studies have focused on this species, which is common throughout Algeria and the most common bark beetle in the forests studied here. This confirms that this species nests in the bark of trunks and branches of dying Pine trees attacked by other bark beetles (Balachowsky 1949). *Crypturgus mediterraneus* is poorly spread and was detected here only in the forests of Boutaleb and Ouled Tebben. *C. mediterraneus* has been sampled in the thick bark of the trunks of trees colonized by *O. erosus*, where it uses the gallery systems of other species to penetrate and lay eggs. These last insects develop in lignified stems and feed on vascular tissues, from the shoots to the tree trunk. Most species develop on decaying trees or dead wood but some species can also colonize stressed living trees (Paine et al. 1997). Saproxylous insects that only develop in deadwood, are not considered as pests (Sauvion et al. 2013). The bark was removed to access the galleries and collect in situ all present insects, placed in sterile microtubes and then stored at 4°C. Dorsally the head is not visible, the anterior of the pronotum has transverse spicule bands. Stocky, broad, robust species, especially in the female, whose apical brushes of the elytra are very dense. Host plants: *Pinus halepensis*, *P. pinaster*, *P. nigra*, *P. brutia* (Pfeffer 1995). Hylurgini tribe Gistel, 1848 Pronotum, elytra and abdomen fully free of scales. *Hylurgus ligniperda* Fabricius, 1787 Elongated and cylindrical in appearance, with a size of 4.5–5.8 mm. General color of the body is black–brown with reddish antennae (Figure 4). Striations formed by a row of large, regularly spaced, shallow circular dots. Another differential character, from *H. ligniperda*, is the length of the lateral silks of the pronotum, which are the same size as the elytrals, while they are longer in *H. ligniperda*. Shiny black and finely dotted pronotum inclined forwards in relation to the elytra. On the other hand, *Tomicus destruens* is attracted by terpenes emitted from wounds in trees attacked by pioneer bark beetles. All these bark beetle species are associated with xylophagous fungi which probably play a role in the colonization of the host trees. Females of *T. destruens* preferentially seek for the northern slopes of the relief and the southern side of the tree to make their maternal gallery. In the region of Zaragoza in Spain, galleries of *O. erosus* occupy a large area of the attacked trees compared to *T. destruens*. The density of galleries of *O. erosus* on attacked Aleppo pine trees was higher than that of *T. destruens* (Sanguesa–Barreda et al. 2015). In Algeria, *O. erosus* can also colonize Atlas cedar trees (Talbi and Bouhraoua 2015). In the three forests studied, *C. numidicus* was sampled from the bark of trees colonized by *O. erosus*. In conclusion, 6 bark beetle species and one Cossoninae species were recorded for the first time in the center of the East region of Algeria. Therefore, the geographical distribution of bark beetle species in Algeria remains to be further clarified. There are no studies that focus on bark beetles in the study region despite the recent forest decline phenomenon. A total of 7 species were identified, 6 belonging to the Scolytinae subfamily and one to the Cossoninae subfamily (Table 2). Antennae mace sutures are procurved upwards in their middle in an arc shape. The margin of the elytral declivity is concave with 4 teeth on each side, the second ones are the largest and fused to the base of the third one. Galleries: Irregular star-shaped gallery with 2 or 3 arms, 4 to 8 cm long, sub-cortical in decaying trees. Has a size of 1.5–1.6 mm, antenna funiculus composed of 2 segments, antenna head formed by a single segment. Light colored, pronotum and underside of body more or less dark brown, elytra are much lighter and

yellowish. Galleries: forming an irregular network that penetrates the thickness of the bark. Galleries: The female bore a longitudinal uniramous gallery in the middle–upper part of stem and large branches, sapwood is little affected. Another study showed the presence of *T. destruens* in the Tlemcen region in the extreme east of Algeria (Nichane et al. 2013). According to Chakali (2007), Mediterranean pine forests have been confronted with *T. destruens* over the last two decades. In our study, *O. erosus* was found on living trees in Boutaleb forest, suggesting that it can be a serious pest in semi–arid regions. The larval galleries are highly branched and start from the galleries of other species (Lieutier et al. 2016). This species colonizes the middle or upper part of the trunks of Aleppo pines (Markalas 1997). Hylurgus species are secondary bark beetles, attacking only weak or dead trees. The diversity of bark beetles in the studied region is low compared to other countries. The females dig a gallery under the bark to deposit their eggs into the cambium (Davi et al. 2020). Reference individuals for each species were stored in ethanol.

RESULTS AND DISCUSSION

Identification

In this study, 1629 specimens were collected and identified from 76 Aleppo pine trees. When visible, scutellum usually flushes with elytral surface, often flattened (Wood 1986). Elytra with deep and regular striae, smooth or punctuated interstriae with long intervals. Nests in the bark of the trunk and branches of dying pine trees attacked by more aggressive species. Dotted and hairy pronotum, with a smooth longitudinal midline. Lateral pronotum hairiness are less abundant but longer than the sides of elytra hairiness. *Hylurgus micklitzii* Wachtl, 1881 Has a size of 3.2–4.4 mm. Differs from *H. ligniperda* by its smaller size (Figure 4). Galleries: At the base of the trunk of which it nests, driving its oblique galleries into the thickness of the bark. Interstriae with a row of granules, except in the second interstriae of the elytral declivity, where the granules disappear. Seven species were identified, unevenly distributed between the three forests. All Mediterranean bark beetles that are able to colonize living trees use the host exhaustion strategy. Although *O. erosus* is considered an important pest in many regions of the Mediterranean basin, many consider it a secondary pest. For instance, very often trees colonized by *O. erosus* or *T. destruens* are later colonized by *Crypturgus numidicus*. This species which has been little studied, is often misidentified as *C. numidicus* (Balachowsky 1949). *Hylurgus micklitzii* was present in all of the studied forests, but it was found only in decayed trees. Bark beetles or Scolytinae belong to Curculionidae. In addition, bark of the same trees was put in plastic bags and examined in the laboratory to collect the insects. The total number of beetles collected for each sampling site was estimated. The antennae is composed of 5 segments, the second one is shorter than the first. The teeth are more reduced in the females, presenting 3 small denticles, since the third pair is small. Long and narrow elytra, evenly rounded declivity. Silks of interstriae shorter and more regular than in *C. numidicus*, arranged in a single row. Nests in the bark of the trunk of dying pine trees attacked by more aggressive species. Antennal funicle composed of 5 to 7 segments. Antennae funiculus formed by 6 segments. *Orthomicus erosus* and *T. destruens* were the only species found on living trees. It was reported for the first time in the Babors massif (Peyerimhoff 1919). Females settle in the basal part of the trunk and exposed roots of dead or weakened trees. Geographic coordinates were noted for every tree. Pilosity is present all over the body (Balachowsky 1949; Wood 1986; Lopez et al. 2007). Limited to the Mediterranean region. Antenna is composed of 6 segments. Elytra with irregular hairiness. *Tomicus destruens* Wollaston, 1865 Adults are 3.0–5.3 in size. By contrast, *H. ligniperda* was present only in

Ouennougha forest. The strategy of mass attack is used to overwhelm the defenses of the host. The annual rainfall is 468 mm and the mean annual temperature is 13.3°C. *C. ciliatus* Desf). The sampling began in May 2017 and was carried out every 15 days for each forest until September 2017 (Table 1). Adults are 3 to 3.8 mm in size, orange or yellowish when young and black at maturity. Reflections slightly shiny. Pronotum totally dotted. Head extended forward in form of short rostrum. Pronotum and elytra are dark brown in color. Posterior edge of pronotum is straight. Wide but rough interstries. Can also grow on large bare roots. Brown elytra in mature adults (Figure 4). Secondary