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Review on Locusta migratoria cinerascens (Fabricius, 1781).

REVIEW ON *LOCUSTA MIGRATORIA CINERASCENS* (FABRICIUS, 1781).

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ABSTRACT

The migratory locust, scientifically known as *Locusta migratoria* (Linnaeus, 1758), is a captivating insect species that has drawn the interest of scientists, farmers, and the general public. Recognized for its notorious swarming behavior, this insect has the potential to cause extensive damage to crops, leading to agricultural plagues and food shortages. However, beyond its reputation as a pest, the migratory locust is a subject of scientific fascination due to its intricate life cycle, remarkable ability to undergo rapid and dramatic transformations, and its crucial role within the ecosystems it inhabits. This review delves into various facets of *L. migratoria,* including its taxonomy, synonyms, common names, morphological and biological characteristics, ecology, geographical distribution, as well as the damages it inflicts and the measures taken for its control.

Keywords : Locusta migratoria, captivating insects, migratory locust.

INTRODUCTION

Locusta migratoria (Linnaeus, 1758), commonly known as the migratory locust, is a fascinating and often notorious insect species that has captured the attention of scientists, farmers, and the general public alike. This remarkable insect is renowned for its swarming behavior, which can lead to devastating agricultural plagues, causing widespread crop damage and food shortages(Le Gall et al., 2019). However, beyond its pest status, the migratory locust is a subject of scientific intrigue due to its complex life cycle, ability to undergo rapid and dramatic transformations, and its pivotal role in the ecosystems it inhabits. In this review, we will dive into the key aspects of *L. migratoria,* exploring its taxonomy, synonyms, common names, morphological and biological characteristics, ecology and geographical distribution, damages and control measures.

i. Taxonomy

According to Louveaux and Ben-halima (1987), the migratory locust is classified as follows:

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta

Order: Orthoptera
Family: Acrididae
Subfamily: Oedipodinae
Genus: *Locusta*
Species: *Locusta migratoria* L.
Subspecies: *Locusta migratoria cinerascens* (Fabricius, 1781).

ii. Synonyms

Gryllus danica (Linnaeus, 1767); *Gryllus migratorius* (Linnaeus, 1758); *Locusta cinerascens* (Fabricius, 1781); *Acrydium manilensis* (Meyen, 1835); *Oedipoda migratorioides* (Reiche & Fairmaire, 1849); *Pachytylus brasiliensis* (Walker, 1870); *Pachytylus australis* (Saussure, 1884); *Pachytylus capito* (Saussure, 1884); *Locusta rossica* (Uvarov & Zolotarevsky, 1929); *Gastrimargus affinis* (Sjöstedt, 1931); *Gastrimargus morio* (Sjöstedt, 1931); *Locusta gallica* (Remaudière, 1947); *Locusta danica burmana* (Ramme, 1951); *Locusta migratoria* solitaria (Carthy, 1955); *Pachytylus punctifrons* (Dirsh, 1961); *Locusta migratoria* migratoria form remaudierei (Harz, 1962); *Locusta migratoria* tibetensis (Chen, 1963).

iii. Common Names

It is called "criquet migrateur" in French, "the migratory locust" in English, and "الجراد المهاجر" in Arabic (Defaut et al., 2013; Ali et al., 2014).

iv. Morphological Characteristics

Description

i. Eggs

The eggs measure from 5.5 to 7.1 mm in length, are yellow or light brown in color, elongated with a slight curve, and have rounded ends. They are deposited in the soil with a bilateral orientation in an ootheca, topped with a foamy plug of spongy structure, which can be white or light brown in color (Popov et al., 1990; Balachowsky and Mesnil, 1936) (Figure 1).

Figure 1: Eggs of *Locusta migratoria cinerascens.*

ii. Nymphs

The morphology of the nymphal stages resembles that of winged adults. In the gregarious phase, the nymphs are gray at the beginning of development and turn orange or black towards the end of nymphal development. In the solitary phase, they are green or brown in color, depending on humidity and the surrounding environment (Duranton et al., 1982) (Figure 2). The first three stages are similar, with an increase in size, particularly noticeable in the head and thorax. The abdomen elongates between molts due to feeding. Nymphs in the fourth and fifth stages are distinguished by their larger size and the upward direction of the wing rudiments, whereas in previous stages, they were directed downward (Bellmann and Luquet, 1995).

iii. Adults

Gregarious adults have a yellow and black body, measuring between 40 and 50 mm in males and 46 and 56 mm in females. They have a short and rounded pronotum, with a concave or straight median carina at the posterior part. In contrast, solitary adults have a green body, measuring between 34 and 60 mm in females and 29 and 46 mm in males, with a long pronotum that has a convex median carina and forms an acute angle at the posterior part (Balachowsky and Mesnil, 1936; Duranton et al., 1987; Bonnemaison, 1961).

For both forms, the head is rounded with filiform antennae, the abdomen is yellowish-brown, the elytra extend beyond the abdominal tip and are adorned with numerous small brown spots arranged in a transverse zone, and the wings are transparent with slightly smoky black veins towards the apex (Chopard, 1943; Bonnemaison, 1961) (Figure 2).

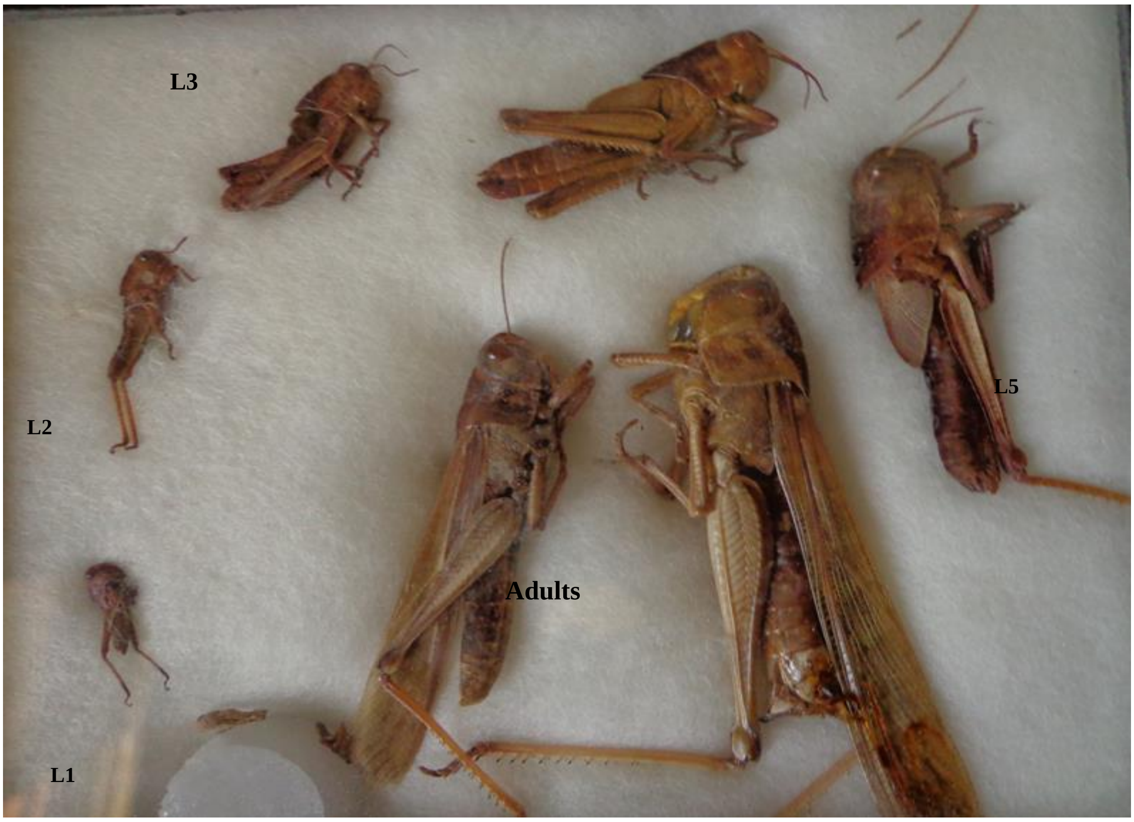

Figure 2: Nymphal stages (L1 to L5) and Adults of *Locusta migratoria cinerascens*

Biological Characteristics

i. Life Cycle

The migratory locust goes through three successive biological stages: the embryonic stage (Figure 3), the nymphal stage, and the adult stage (Bonnemaison, 1961; Duranton et al., 1982; Launois Luong and Lecoq, 1989). The eggs are deposited in an ootheca covered with a frothy substance. After 5 days of oviposition, embryonic development begins and lasts for 10 to 30 days depending on the humidity and incubation temperature in the soil (Bonnemaison, 1961; Duranton et al., 1982; Launois Luong and Lecoq, 1989).

Upon hatching, the vermiform larva is enclosed in a transparent case and, after an intermediate molt, becomes a first-instar nymph (Albrecht, 1967). The nymphs go through 5 nymphal stages, separated by nymphal molts. The nymphal stage lasts for approximately 21 to 30 days. *L. migratoria* undergoes 4 to 5 generations per year in its solitary phase and 3 generations in its gregarious phase (Launois Luong & Lecoq, 1989).

During the adult molt, the adult *L. migratoria* individuals search for a favorable habitat for feeding to increase their weight and accumulate body fat, which allows the females to prepare for their first oviposition (Lecoq, 1975). The gradual reduction and drying up of vegetation diminish the favorable areas for locust development, leading them to gather in places that still have green vegetation (Girardie, 1991).

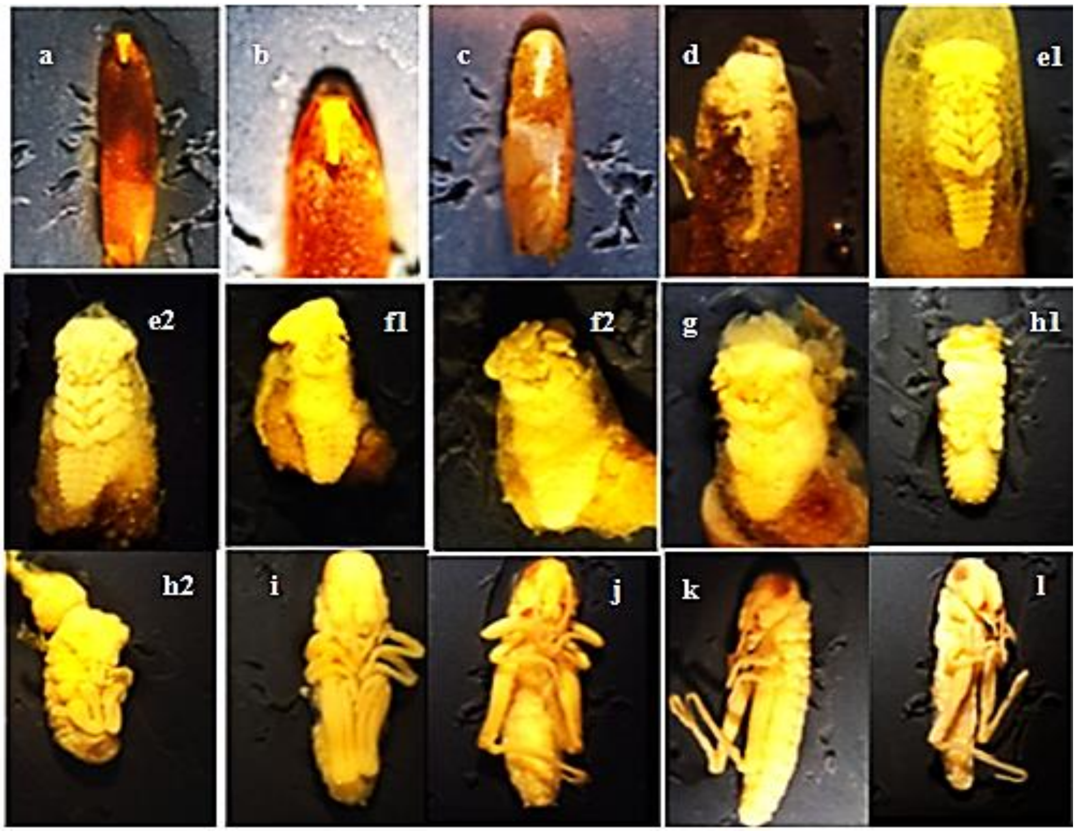

Figure 3: Embryonic stages of *L. migratoria* after oviposition a: Stage IIb at 3 days; b: Stage IIIb at 4 days; c: Stage IIIc at 5 days; d: Stage IV at 6 days; e1 and e2: Stage IVb1 and IVb2 at 7 days; f1 and f2: Stage Va and Vb at 8 days; g: Stage VI at 10 days; h1: Stage VII at 11 days; h2: Stage VII+ at 12 days; i: Stage VIIIa at 13 days; j: Stage VIIIb at 14 days; k: Stage IXa at 16 days; l: Stage IXb at 17 days (Harrat & Petit, 2009).

ii. Phase Transformation

When the density exceeds a threshold of 2,000 winged individuals per hectare, there is an increase in interindividual contacts and the triggering of the phase transformation process, which is expressed through morphological differences. Gregarious individuals exhibit modifications in size and color, distinct from solitarious individuals. Anatomical disparities are evident, with gregarious individuals displaying a decreased average count of ovarioles and seminal vesicles compared to their solitarious counterparts.

Furthermore, there are biological distinctions, as gregarious individuals manifest a reduced number of generations per year in contrast to solitarious individuals. These variations extend to ecological differences as well (gregarious individuals fly longer and farther and occupy a larger geographical area than solitarious individuals), and physiological differences (gregarious individuals have a higher metabolism than solitarious individuals) (Launois Luong and Lecoq, 1989; Popov, 1996; Rasolomandimby, 1996).

Ecology and Geographical Distribution

The choice of habitat by the migratory locust depends on vegetation structure, the number of plant species, climate, soil characteristics, availability of food plants, and oviposition sites (Otte, 1977). In the solitarious phase, the migratory locust prefers habitats with a thermal optimum around 20°C to 25°C and precipitation ranging from 50 to 100 millimeters on a monthly basis, where it finds suitable food and soil conditions for sexual maturation, sufficient egg production, and oviposition. In the gregarious phase, the migratory locust prefers rainfall ranging from 25 to 100 mm per month. The suitable biotopes include dense herbaceous formations on alluvial soils, steppes, and savannas with low woody cover, which can directly or indirectly lead to densities that trigger the phase transformation (Launois Luong and Lecoq, 1989; Popov et al., 1991).

The migratory locust exhibits Palaearctic subspecies such as *Locusta rossica* Uvarov and Zolotarevsky, 1929, and *Locusta gallica* Remaudière, 1947, which have one generation per year, prolonged diapause, eggs resistant to freezing, and a relatively sedentary solitarious phase. The tropical, subtropical, and warm-temperate subspecies from the southern hemisphere include *Locusta cinerascens* Fabricius, 1781; *Locusta migratorioides* Reiche and Fairmaire, 1849; *Locusta manilensis* Meyen, 1835; *Locusta burmana* Ramme, 1951; Locusta capito Saussure, 1884; *Locusta Australis* Saussure, 1884. These subspecies are multivoltine, without diapause, and have eggs sensitive to freezing (Farrow & Colless, 1980; Defaut et al., 2013). In Algeria, the subspecies *Locusta migratoria* cinerascens is found in coastal areas, the plains of the Tell Atlas, and the southern Sahara Atlas (Chopard, 1943).

Feeding Habits The feeding habits of *Locusta migratoria* vary depending on the region and subspecies. It primarily feeds on grasses (Uvarov, 1923; Uvarov, 1936; Zolotarevsky, 1934). During outbreaks of larval bands and swarms, several plant species, both woody and grasses, are susceptible to being consumed (Couturier et al., 1946).

Damages and Control Measures

i. Damages

The damages caused by the migratory locust worldwide can be compared to major calamities such as floods, earthquakes, and epidemics. In the gregarious phase the migratory locust's impact is profound, with its invasions encompassing steppe zones throughout Europe and Asia, as well as tropical areas in Africa and the island of Madagascar. Numerous plants are susceptible to attack during invasion periods, including both woody and grass species (Balachowsky and Mesnil, 1936; Couturier et al., 1946).

ii. Control Measures

Preventive Control

Anticipatory management relies on surveillance networks within regions of locust aggregation, enabling the prompt and efficient eradication of initial locust concentrations to avert the onset of a locust invasion (Launois Luong et al., 1988). This operation is reinforced by the use of ecological and meteorological satellites and geographic information systems that provide information and forecasts on potentially favorable sites for the development and outbreak of *Locusta migratoria* (Popov, 1997).

Chemical Control

Globally, the management of locust populations involves a comprehensive approach, often employing various types of insecticides such as organophosphates, carbamates, pyrethroids, and growth regulators or inhibitors (Rachadi, 1991; Launois Luong et al., 1988). Depending on the scale of the infestation, ground application is utilized for smaller outbreaks, while aerial application is reserved for more extensive invasions (Latchininsky & Launois Luong, 1992). In Algeria, the arsenal of insecticides employed for anti-acridian measures comprises pyrethroids (cypermethrin, alphacypermethrin, beta-cypermethrin, deltamethrin, lambda cyhalothrin), organophosphates (chlorpyriphos, chlorpyriphos-ethyl), and growth regulators (diflubenzuron) (MADRP, 2015).

Organophosphates and carbamates operate by impeding the degradation of acetylcholine at cholinergic synapses, instigating repetitive neuronal activity that ultimately leads to the demise of the insect (Buffat et al., 1989; Testud and Grillet, 2017). On the other hand, pyrethroids function by heightening the frequency of nerve discharges or prolonging the opening time of sodium (Na+) channels. This disrupts the normal transmission of nerve impulses, triggering convulsions and tetanic activity within the insect's nervous system (Testud and Grillet, 2017).

An additional category of insecticides, known as insect development modifiers, specializes in interfering with growth-related hormonal functions. This interference prompts premature, incomplete, and fatal molting processes (Dallaire et al., 2004). Moreover, these modifiers obstruct the synthesis of cuticles essential for molting, leading to the insect's demise (Biddinger and Hull, 1995; Hoffmann and Lorenz, 1998; Gordan et al., 1989; Berry et al., 1993).

Biological Control

The utilization of biopesticides derived from plant extracts, fungi, or entomopathogenic bacteria presents an intriguing and ecologically mindful substitute to synthetic chemical pesticides, owing to their efficacy, biodegradability, and specificity (Welling and Zimmermann, 1997; Prior and Greathead, 1989; Greathead et al., 1994). One notable example involves biopesticides based on the fungus *Metarhizium spp*., which exhibit the capacity to eliminate 70 to 90 % of treated locusts within a span of 14 to 20 days, without detrimental effects on non-target organisms (Kooyman et al., 1997; Lomer et al., 2001).

For instance, an application of 2×10^3 blastospores of *Metarhizium anisopliae* against adults of Locusta migratoria var. acridum led to a mortality range of 17.3 % to 100 % after 6 days, contingent upon the presence or absence of thermoregulation, a behavioral fever developed by the insect post-infection (Ouedraogo, 2005). Entomopathogenic bacteria, *Bacillus thuringiensis* and *Bacillus sphaericus*, integrated into the diet of *Locusta migratoria* larvae, demonstrate efficacy on par with chemical pesticides due to their bacterial toxin-induced lysis and destruction of intestinal epithelial cells (Dunphy and Tibelius, 1992; Zimmerman et al., 1994; Mohandkaci et al., 2014).

When *Locusta migratoria* individuals were exposed to three escalating concentrations of *B. sphaericus* (1.72 mg/ml, 0.75 mg/ml, and 0.28 mg/ml), mortalities of 76.67 %, 53.33 %, and 43.33 % were recorded on the 22nd day post-treatment (Mohandkaci et al., 2014).

Similarly, the aqueous extract of *Schinus molle* at a concentration of 166.66 g/L induced 100% mortality in fifth instar larvae within 10 days through ingestion treatment, and within 7 days through contact treatment. This high mortality is attributed to secondary metabolites in *Schinus* leaves, including limonene, α-phellandrene, thymol, citronellyl acetate, β-caryophyllene, cis-menth-2-en-1-ol, and trans-piperitol (Chilali and Benrima, 2018).

Moreover, the methanolic extract of *Olea europaea* at 8 % concentration resulted in an 82.26 % mortality rate in fifth instar *Locusta migratoria* larvae after an 8-day treatment (Abdellaoui et al., 2018), believed to be due to the substantial presence of phenolic compounds, particularly oleuropein, as suggested by Benhamouda et al. (2016). Furthermore, the ingestion of gibberellic acid (GA3), a plant hormone, by *Locusta migratoria* leads to inhibited larval and adult development, as well as impaired molting processes. Research conducted by Laib et al. (2020, 2021) delved into the insecticidal potential of fungal extracts from endophytic fungi *Alternaria tenuissima* and *Trichoderma* sp., isolated from the leaves of *Ricinus communis* L. (common castor bean). The findings indicated that the efficacy of the extracts was contingent upon concentration and treatment duration.

Regarding *Alternaria tenuissima*, the highest insecticidal activity was observed at a concentration of 2 g/L. Contact treatment resulted in a 73 % mortality rate for *Locusta migratoria*, while ingestion treatment achieved a maximum mortality of 100 % (Laib et al., 2021). For *Trichoderma* sp., mortality rates of targeted *L. migratoria* adults displayed a positive correlation with both fungal extract concentration and exposure time (24, 48, 72 hours). After 72 hours, the concentration of 0.4 g/L exhibited the highest efficacy, leading to a mortality rate of 56.52 % (Laib et al., 2020).

The efficacy of entomopathogenic bacteria *Photorhabdus luminescens* in targeting *L.migratoria* was assessed across a range of concentrations and exposure durations. Specifically, bacterial densities of 4×10^7, 4×10^6, 4×10^5, and 4×10^4 colony-forming units (CFU) per milliliter were examined, along with varying concentrations of its cell-free filtrate (100 %, 50 %, 25 %, and 12.5 %).The findings unveiled that the highest bacterial cell density of 4×10^7 cells per milliliter, as well as the undiluted cell-free filtrate at 100 %, exhibited the most potent insecticidal properties. These formulations achieved insect mortality rates of up to 76.7 % and 80 %, respectively, over a span of 7 days.Additionally, the study determined the LC50 values for both the bacterial suspension and the cell-free filtrate. The LC50 value for the bacterial suspension was estimated to be 2.7×10^6 cells per milliliter, while the LC50 value for the cell-free filtrate corresponded to the 50 % dilution level (Muhammad et al., 2022)

The research conducted by You et al., (2023) provides valuable insights into the lethal concentration of *Aspergillus oryzae* XJ-1 for adult *Locusta migratoria*, as well as its practical applications in pest control. In a controlled laboratory setting, the lethal concentration of *Aspergillus oryzae* XJ-1 in adult *Locusta migratoria* was determined to be $3.58 \pm 0.09 \times 10^5$ conidia per milliliter, 15 days post-inoculation. Subsequently, a field-cage experiment was conducted to assess the impact of the same fungus on adult *L. migratoria*. The mortalities observed were 92.0 ± 4.6 % and 90.1 ± 3.2 % when inoculated with 3×10^5 and 3×10^3 conidia per square meter, respectively, also 15 days post-inoculation.

To evaluate the practicality of using *Aspergillus oryzae* XJ-1 in large-scale pest management, a substantial field trial spanning 666.6 hectares was conducted. A water suspension was applied via aerial spraying using drones, at a concentration of 2×10^8 conidia per milliliter, with a rate of 15 liters per hectare. This application resulted in a significant reduction in *L. migratoria* population densities, with a reduction rate of 85.4 ± 7.9 %.Furthermore, the infection rates of surviving locusts collected from the treated plots were assessed on the 17th and 31st days after treatment, revealing infection rates of 79.6% (You et al., 2023).

CONCLUSION

In conclusion, *Locusta migratoria*, the migratory locust, stands as both a captivating subject of scientific study and a formidable agricultural challenge. Throughout history, its swarming behavior has inflicted economic hardship and food insecurity on communities worldwide. However, in recent years, advancements in our understanding of its biology, ecology, and management strategies have provided a glimmer of hope in mitigating its destructive impact.

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AUTHORS CONTRIBUTION

Laib Djamel Eddine: Writing original draft, Benzehra Abdelmadjid: supervision, validation, Laib imen: Review and editing,Aouzal Badis: Data curation, Akkal Salah: Funding acquisition, resources

CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interests related to this article

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