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Original Research Article

Biological Efficacy of Aqueous Extracts of Some Insecticidal Plants on the Fall Armyworm (*Spodoptera frugiperda* J. E. Smith, 1797) On Corn in Niger

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Abstract: The fall armyworm (FAW) *Spodoptera frugiperda* J.E Smith poses a serious threat to cereal production in general and corn production in particular. It causes enormous damage and significant yield losses in Niger. To counter this damage, farmers are increasingly using synthetic pesticides despite their toxicity to humans and the environment. There is therefore an urgent need to find an alternative to this chemical control method, this is why a study on the biological effectiveness of biopesticides on FAW larvae was conducted during the cold dry season of 2023 and the wet season of 2024 in Kalapaté in the Birni department. The design was a completely randomized block with four replicates. The insecticide treatments were as follows: Emacot, *Bocia senegalensis*, *Jatropha curcas*, and *Eucalyptus sp*, 250 g of each fresh leaf/5 L of water), Neem (*Azadirachta indica*) grain powder 125g/2.5l of water and a negative control that was treated with plain water, i.e., 4L of water. The results shows that the severity rate was higher in the dry season (85%) than in the wet season (18%). The damage was more severe in the negative control than in the treated ones. In both seasons, the application of Emacot reduced the damage to corn plants, followed by Neem. These results reveal that aqueous neem seed extract (125 g/5 L of water) can be applied alternatively to the chemical insecticide against *S. frugiperda* in Niger in the presence and absence of rainfall.

Keywords: *Spodoptera Frugiperda*, Corn, Aqueous Plant Extracts, Attack, Niger.

INTRODUCTION

Corn (Zea mays L.) is the most widely cultivated plant in the world and is the leading cereal crop, ahead of wheat and rice Fusillier (1994); Cruz *et al.,* (2019). The United States of America is the largest producer of corn, with an annual production of 383,943 thousand metric tons. China ranks second with 272,552 thousand metric tons of annual production Xie *et al*., (2022). In Niger, annual production is approximately 37,000 tons of corn FAOSTAT (2019). In Niger, this crop is one of the most widely consumed cereals. Corn is part of the Nigerien population's diet and is used for animal feed and in the agro-industry. However, the production of this cereal is limited by multiple biotic and abiotic constraints Georgen *et al*., (2016).

Among biotic constraints, since 2016, corn productivity has been threatened by the arrival of an invasive species, *Spodoptera frugiperda*. This insect is native to America and has a strong capacity for migration, capable of traveling distances ranging from 100 km Cokola (2019) to 1,600 km in a single night when conditions are favorable Germain *et al*., (2017); Prasanna *et al*., (2018). It is a voracious and highly polyphagous pest that attacks many important food crops in Africa Abrahams *et al*., (2017); Maiga *et al*., (2017); Hruska (2019); CABI (2020).

This pest is most destructive to tropical and subtropical crops Montezano *et al*., (2018). It attacks all stages of maize growth and all above-ground plant structures Ahissou *et al*., (2021), causing damage that leads to significant yield losses in the absence of control

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measures Hruska (2019); Tshiabukole *et al.,* (2021). The FAW damage is characterized by the loss of the photosynthetic area, causing corn plants to lodge, growth retardation, deterioration of fresh seeds, and destruction of the whorl, panicle, and ears Chimweta *et al.,* (2020).

In Africa, crop losses caused by *Spodoptera frugiperda* amount to approximately $16 billion Harrison *et al.,* (2019). Faced with this extensive damage, producers are relying more heavily on pesticides, leading to the development of resistance by the fall armyworm Ndiaye *et al.,* (2022); the elimination of natural enemies and the presence of residues in food, water, air, and soil, which can affect human health and disrupt the ecosystem Devine & Furlong (2007); Aniwanou *et al*., (2021).

Aqueous plant extracts are an environmentally friendly and economical alternative for controlling fall armyworm Tounou *et al*., (2012); Deravel *et al.,* (2014).

The objective of this study was to determine the biological efficacy of aqueous extracts from some plants on fall armyworm (*Spodoptera frugiperda*) on corn in research station.

MATERIALS AND METHODS

- **Study Setting**

The study was conducted during the cold dry season of 2023 and the wet season of 2024 at the experimental station of the National Institute for Agricultural Research of Niger (INRAN) in Kalapaté (Figure 1) in the Dosso region. The area is characterized by a Sahelian climate with sandy soil. Maize production in Niger takes place in river basins and around wadis JAICAF (2009); MAE (2021). This site was chosen because the station has experimental plots with a history of *Spodoptera frugiperda* attacks and because corn is grown there year-round.

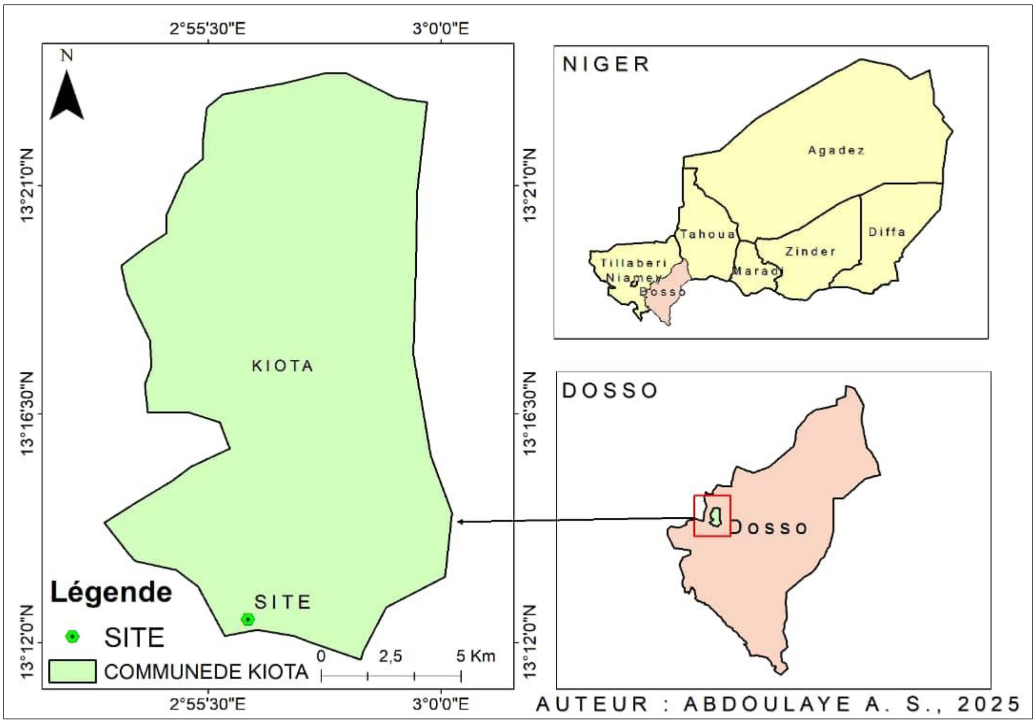

Figure 1: Map showing the location of the experimental site

- **Plant Material**

The P3 Kollo corn variety was used as plant material for the experiment. It is a composite variety with a semi-maturity cycle of 85 to 95 days and a height of 150-190 cm. The weight of 100 grains is 17 to 20 g and the potential yield is 2.5 to 4 t/ha MA (2012). It is well known to Nigerien producers and is listed in the National Catalog of Plant Species and Varieties (CNEV).

- **Experimental Design**

The design is a Fisher block with 4 replicates. The following treatments were selected: aqueous extracts of *Azadirachta indica* carnels, aqueous extract of Eucalyptus (T3), synthetic insecticide Emacot 050 WG (Emamectin benzoate 50 g/kg, T2), aqueous extract of *Jatropha curcas* (T4), aqueous extract of *Bosia senegalensis* (T5), and the control (T0). A total of 24 experimental units of 12 m² were distributed over a total area of 358.75 m². The distance between blocks was 1 m and between plots 0.5 m. Corn was sown at 80 cm in the row and 60 cm between rows.

- **Sampling of Observation Plots**

Observations were made on the two central lines of each elementary plot. All extreme plots were spared to minimize edge effects.

- **Crop Maintenance**

Soil preparation consisted of plowing with a tractor to bury residues from the previous crop. This was followed by leveling with a harrow. Then came the staking. Next, ridges were formed at 80 cm intervals. To facilitate irrigation, a cross was made between blocks and between elementary plots.

- **Sowing**

Sowing was carried out at a rate of 3 corn seeds per hole on the sides of the furrows on December 10, 2023, and July 12, 2024, for the dry season and wet season trials, respectively.

- **Follow-Up**

The base fertilizer, consisting of farmyard manure, was incorporated into the experimental units of both trials just after emergence. Two weeks later, the first weeding was carried out. Seven days after this operation, the first weeding, thinning to one plant per hole, and the first application of mineral fertilizer (NPK 15-15-15) were carried out. This was followed by the application of urea at a rate of 0.6 g/plant, or 14.5 kg/ha. A total of three weedings were carried out throughout the corn cycle.

- **Preparation of Aqueous Extracts**

To prepare the aqueous extracts of *B. senegalensis*, *J. curcas*, and *Eucalyptus.sp*, 250 g of fresh leaves were crushed in a mortar before being placed in a jar containing 2.5 L of water. For *Azadirachta indica*, 125 g of almond powder were also added to the same amount of water as before. After soaking for 24 hours, each suspension was filtered and placed in a pressure sprayer. To treat the four elementary plots for each treatment,1.5 liters were applied, or 0.37 liters per elementary plot. The reference insecticide (Emamectin benzoate) was used at the recommended dose of 240 g/ha. To ensure the same moisture conditions, the control plots were treated with the same amount of water.

- **Products' application Method**

During the corn growth cycle, four (4) phytosanitary treatments were carried out: the first when the armyworm infestation rate reached 15% and the others at 7-day intervals.

- **Collection of Entomological Data**

Weekly observations were made on the two central rows of each experimental unit.

The following parameters were noted:
The incidence on plants and ears (number of plants attacked out of the total number of plants inspected);

- **The Severity on Leaves and Ears**

This parameter is determined using the Davis and Williams scale (1992). This scale consists of 10 classes, ranging from 0 to 9.

- **The Maize Yield**

Harvest data was also collected on the two central rows of each elementary plot. To this end, all the ears of corn from these two rows were harvested by hand, dried, and husked.

Statistical Analysis of Data:

The data collected were entered and cleaned using Excel version 2019 before being analyzed. Excel was used to graph the data. R.4.3.2 software was used to perform the analysis of variance, followed by the LSD (5%) test for comparing means.

RESULTS

Incidence and Severity of Attacks on Leaves during the Wet Season

Before treatment, the incidence was less than or equal to 40% in all treatments (Fig. 2). Seven days after the first treatment (D7), the incidence decreased in all treatments except for the control. The two treatments, Neem and Jatropha, were more effective (Fig. 2) with damage reduction percentages compared to the control of 54% and 46%, respectively.

The average initial severity (before the first treatment) was 23.50%. After treatment, severity increased gradually in the control until the last treatment, when a slight decrease was observed. Severity was lower in the experimental units that received Neem and Emacot (Fig. 3), with damage reduction percentages of 42% and 53%, respectively, compared to the control.

- **Incidence and Severity of Attacks on Leaves during the Dry Season**

The average incidence was 34% before the first application of the products (Fig. 4). From the start of treatment to the end, the incidence gradually decreased in all treatments except for the control.The two treatments, Jatropha and Eucalyptus, were more effective and reduced incidence by 88.23% and 85.29%, respectively (Fig. 4).

Severity before treatment (D0) was 41.5% (Fig. 5). After treatment, neem and Emacot significantly reduced severity by 75% and 92% respectively, while *Jatropha curcas* and *Boscia senegalensis* had reduction rates of 32.44% and 26.71% respectively (Fig. 5).

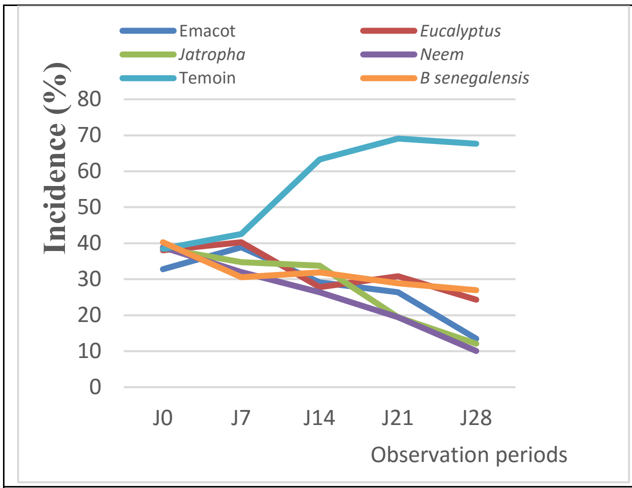

Figure 2: Incidence during the wet season

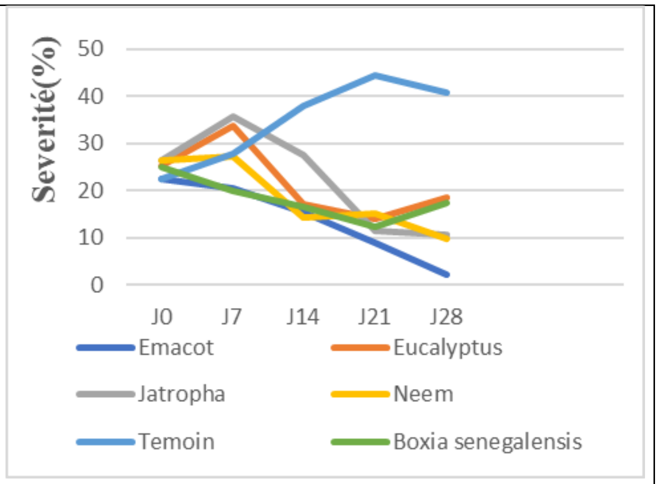

Figure 3: Severity during the wet season

Legend: J0-J28=days after treatments

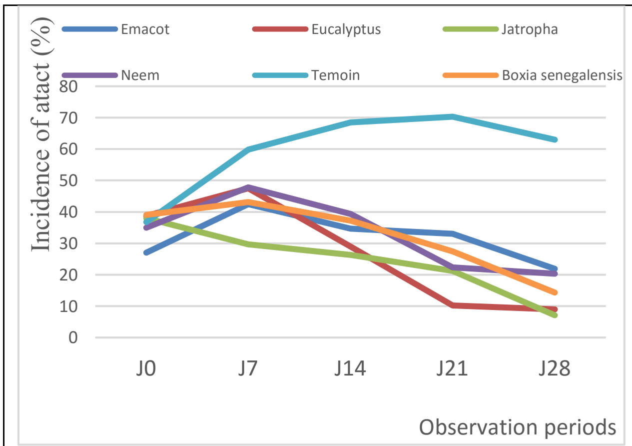

Figure 4: Incidence during the dry season

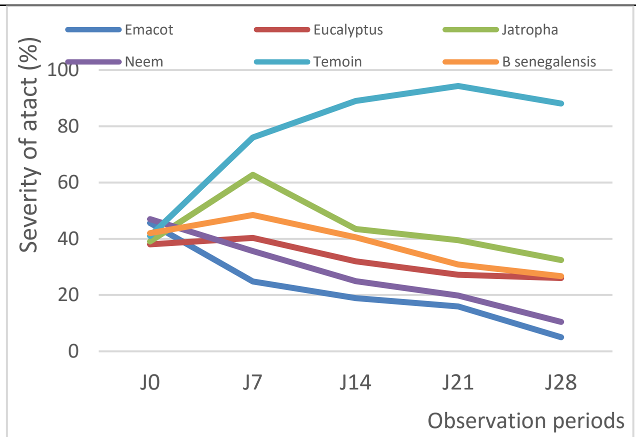

Figure 5: Severity during the dry season

Legend: J0-J28=days after treatments

- **Comparisons of Average Incidence and Severity by Season**

During the dry season, incidence was slightly higher than during the rainy season (Fig. 6). Incidence was higher in untreated plots than in treated plots for all seasons. During the dry season, severity was significantly higher than during the rainy season (Fig. 7). Overall, severity was reduced by Emacot and Neem in both the dry and wet seasons. (F= 24.65; P< 0.001) (Fig. 7).

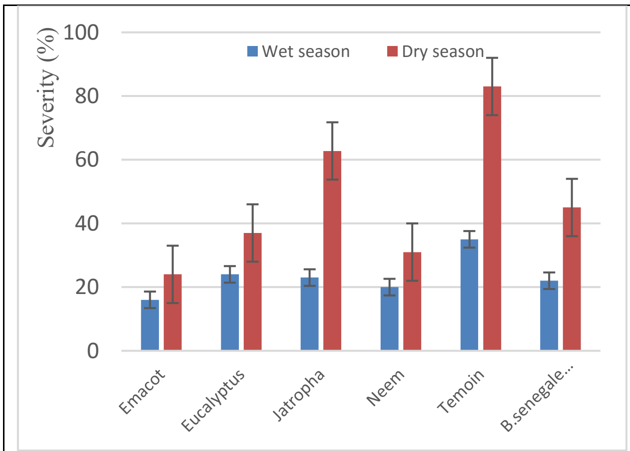

Figure 6: Severity of the FAW attack

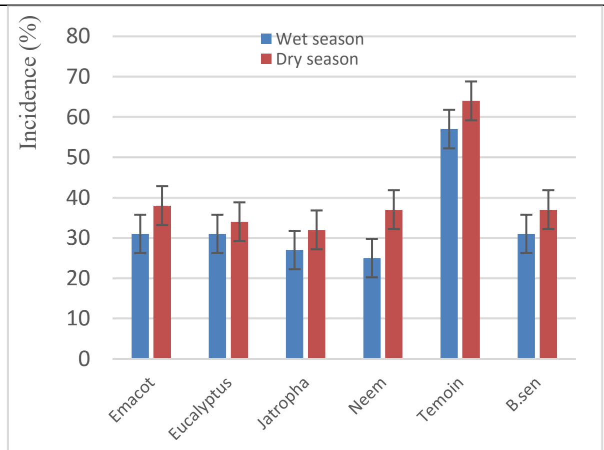

Figure 7: Incidence of the FAW attack

- **Grain Yield**

Average grain yields (kg/ha) during the dry and wet seasons are shown in Table 1. The average yield recorded during the wet season was 570.94 kg/ha. It ranged from 270.47 kg/ha on the control to 706.12 kg/ha with the neem-based treatment. The different treatments resulted in average yield increases of 231.91%. This increase ranged from 86.78% on *B. senegalensis* to 159.96% on neem.

During the dry season, the average corn yield was 103.88 kg/ha. It ranged from 55.62 kg/ha on the untreated control to 167.50 kg/ha on the *B. senegalensis* treatment. However, statistical analysis showed no significant difference (α= between treatments. The average yield increase rate for this season was 199.393%. It ranged from 6.36% with *Eucalyptus* to 199.64% on Emacot.

Table 1: Grain yield (kg/ha) according to treatments

Treatments	Wet season		Dry season	
	Rendement	Increase in yield (%)	Rendement	Increase in yield (%)
Neem	703 ,12a	159,96	83 ,33a	58,81
Jatropha curcas	692,08a	155,88	129,16a	132,22
Emacot	662,70a	145,02	166,66a	199,64
E. camaldulensis	592,08a	118,91	59,16a	6,36
B. senegalensis	505,20ab	86, 78	167,50a	201,15
Témoin	270,47b	-	55,62a	-
Moyenne générale	570,937±118,27		103,88±45,88	
	ddl=5; F=2, 62; P=0,05		ddl=5; F=1,08; P=0,4	

The averages marked with the same letters in the same column, according to growing seasons, are not significantly different.

Discussion

The results of this study showed that during the dry season the FAW incidence rate was higher than wet season. This can be explained, by the important initial attacks observed before treatment (D0). The mean of insect incidence before treatment was 35%. Both treatments (*Eucalyptus* and *Jatropha*) were effective compared to Emacot, the synthetic insecticide. It is known that the synthetic insecticides are more effective than the botanical ones. Our results contradict those of Tounou *et al*., (2012) and Deravel *et al*., (2014). The effectiveness of *Jatropha* can be explained by the presence of active compounds in the leaves, such as α-amyrin, several phytosterols Morton (1981), several glycosylated polyphenols, and caffeoylaldehyde Yao *et al*., (2010). The effectiveness of *Eucalyptus* could be attributed to the high content of phenolic compounds in the plant extracts. Studies have shown positive effects of *Eucalyptus* on lepidopteran larvae (*Spodoptera littoralis* and *Helulla undalis*) Yao *et al.,* (2022).

With regard to the severity of damage during the dry season, the significant difference between treatments could be explained by the high infestation rate and the resulting damage. The main damage observed on foliage is caused by young larvae rather than older ones. The effectiveness of Emacot at the start of treatment can be explained, on the one hand, by its rapid effect, whereas aqueous extracts have an effect on insect growth, but their effect is slower than that of a synthetic insecticide Ratnadass *et al.,* (1997) and Rahuman *et al*., (2007) on the other hand, by the presence of the active ingredient Emamectin benzoate, which was reported by Liguori *et al*., (2010) even at low concentrations and on all stages of lepidoptera. Emamectin benzoate is a synthetic translaminar insecticide that is both contact and systemic. It acts as a gamma-aminobutyric acid and glutamate-dependent chloride agonist of insect neuronal membrane channels Batiha *et al*., (2020). These synthetic active ingredients act and cause caterpillar mortality in a very short time Nboyine *et al*., (2022). Emamectin benzoate is one of the most effective synthetic pesticides for controlling fall armyworms Kouanda (2020). These results corroborate those of previous studies conducted by Sisay *et al*., (2019); Babendreier *et al*., (2020); and Yahaya (2021).

The effectiveness of neem could be explained by the presence of active ingredients (azadirachtin, alanine, nimbin, and 6-deacetylnimbin) contained in neem leaves. In addition, these ingredients act through contact or ingestion of the treated part and cause anti-appetitive and sterilizing effects in insects, as well as acting as a growth regulator Gabriel & Conseiller (2002); Morgan (2009); Nouari (2014); Rym and Meghezi (2016); Chaudhary *et al*., (2017); Aribi *et al*., (2020); Looli *et al*., (2021).

It should be noted that infestation rates on plants were higher in the dry season than in the rainy season. In the absence of rain, nutrients concentrate in the leaves, making the plant more nutritious, which leads to an increase in the number of pests that cause enormous damage to the plant. In addition, corn development is marked by several phases, but generally the vegetative stage is more favorable to attack by *Spodoptera frugiperda*. In addition to these factors, there is also damage from *Sesamia calamistis* observed during the dry season. This may explain the high severity during the dry season. In contrast, during the rainy season, rainfall washes away eggs and newborn caterpillars through the mechanical effect of water droplets on the leaves Dixon (2007). This may help to mitigate the occurrence and severity of damage to corn plants.

Average yields (kg/ha) were higher in the rainy season than in the dry season. Crops in the wet season were less affected by pests because, in the rainy season, the high number of cultivated fields means that pests are more dispersed and the damage could be less than in the dry season. The yields obtained in the plots treated with neem and *Jatropha* were the highest in the rainy season, and the yields of *B. senegalensis* and Emacot were the highest in the dry season. These results can be explained by the fact that the aqueous extract of *B. senegalensis* has a fertilizing effect on maize, unlike the other extracts used. These yields were higher than those of the positive control (Emamectin benzoate). So, the seasons have an influence on the different treatments.

The results of this study are comparable to those of Djomaha *et al*., (2022), who explain that in trials on aqueous extracts of *Chromolaena odorata* and *Pteridium aquilinum*, a fertilizing effect on the yields of yellow Pannar corn was observed. This result is similar to those obtained by Nelson and van Staden (1984) and Whapham *et al*., (1993) on the development of beans treated with seaweed extracts.

Conclusion

The fall armyworm is a destructive pest that poses a significant threat to corn production in Niger. This study highlighted the effectiveness of neem and *Jatropha* through the application of aqueous extracts from neem kernels and fresh J*atropha* leaves. The use of Neem resulted in a 42% reduction in damage compared to the control. Overall, there was more infestation in wet areas than in dry ones. The severity was lower with Neem, Emacot, and *Jatropha* and significantly higher with the control. The aqueous extract of Neem kernels provided the best yield compared to the other treatments during the rainy season. During the dry season, the best yield was collected in the plots treated with B. senegalensis. Aqueous plant extracts could be an alternative to synthetic insecticides for managing the FAW in corn fields. It is a less expensive, accessible, and environmentally friendly method that has no negative impact on the ecosystem.

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