

Full Length Research Paper

Comparative efficacy of selected Plant Extracts in Controlling Fall Armyworm (*Spodoptera frugiperda* J.E Smith) On Maize (*Zea mays* L.) In Gombe, Sudan Savanna Of Nigeria

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Profitable maize production in Nigeria is hinged on chemical control of insect pests with its attendant problems. The use of synthetic insecticides for the control of field and stored insect pests has created many problems such as environmental hazards, pest resistance which necessitated a search for alternative means of controlling fall armyworm (*Spodoptera frugiperda*) with plant products. Field experiments were conducted at Teaching and Research farm of Department of Agronomy, Faculty of Agriculture, Federal University of Kashere, Gombe State, Nigeria to compare the efficacy of four plant extracts on fall armyworm (*S. frugiperda*) on maize (*Zea mays* L.) under rain fed conditions in 2024 and 2025 cropping seasons. A randomized complete block design in three replications was used. There were five treatments (desert palm leaves , *Balanites aegyptiaca* Del; mahogany leaves, *Khaya senegalensis* L.,*Jatropha* leaves, *Jatropha curcas* L., Neem leaves, *Azadirachta indica* A. Juss and a standard check Lambda-cyhalothrin 2.5 EC). The results showed that neem leaf extract (NLE) was found to be effective for the control of fall armyworm on maize in the study area. Fall armyworm percentage incidence, number of larvae/plant, and leaf area damaged were significantly reduced at 20% w/v while plant height, number of leaves/plant, stem girth, leaf area, cob weight, number of seeds/cob, seed weight and grain yield were significantly ($P<0.05$) increased in both 2024 and 2025 cropping seasons in the study area. The plot treated with Lambda-cyhalothrin 2.5 EC gave the best results which was at par with NLE followed by BLE and MLE while the growth and yield attributes of maize were significantly reduced when the maize crops were treated with JLE during the study period. It can therefore be safely concluded that neem leaf extract at 20% w/v was effective in controlling fall armyworm on maize and was at par with the Lambda-cyhalothrin 2.5 EC. This suggest that application of neem leaf extract at 20% w/v could therefore be used as an eco-friendly and environmentally safe option for the control of fall armyworm infestation on maize in the study area.

Key words: Extracts, Lambda- cyhalothrin , fall armyworm, maize, incidence, damage

INTRODUCTION

Maize (*Zea mays* L.) is among the ten most important world crops in terms of its nutritional, food and economic value (Anyim *et al.*, 2020). It is one of the most staple foods in many African countries including Nigeria

(Akhigbe *et al.*, 2021). Over 230 million people in Nigeria are dependent on maize for food security (Akhigbe *et al.*, 2021). It is grown across diverse agro-ecological zones of Nigeria where many people and animals depend on it for food, feed and raw materials for agro-based industries (Macauley, 2015). In Nigeria, maize is ranked as the second most important cereal crop after rice (Akhigbe *et al.*, 2021). Despite the importance of maize, the average maize yield in Nigeria is one of the lowest in the world (Ragasa *et al.*, 2014; Day, 2017, Abrahams *et al.*, 2017).

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Maize is one of the cereals that is most vulnerable (Makgoba et al., 2021) and faces significant threats from a diverse array of insect pests, requiring the application of insecticides for optimal production (CABI, 2017). The yield potential of maize production is greatly being affected by insect pests, causing losses at 13.5 % of its production annually as a staple crop (De Groote et al., 2002; Prasanna et al., 2008; Choice, 2013).

Production of maize is currently being threatened by fall armyworm (*S. frugiperda*) (Babendreier et al., 2020; Bharadwaj et al., 2020; Zaman and Patel, 2023). The insect is a common pest in many African countries throughout sub-Saharan Africa and elsewhere (Yigezu and Wakgari, 2020; Sangle et al., 2020; Anyim et al., 2020).

Fall armyworm (*S. frugiperda*) is one of the major insect pests that is causing serious maize damage and losses in Africa, Nigeria inclusive (IITA,2016; FAO, 2018). They are known for their voracious feeding behavior and can cause substantial damage to crops (Makgoba et al., 2021). Fall armyworm feed on maize leaves. Their feeding will always lead to reduced yields, poor crop quality, and even crop failure if infestations are severe FAO (2018); Yigezu and Wakgari, 2020). *Spodoptera frugiperda* primarily causes damage by feeding on both vegetative and reproductive parts of the host plant. Fall armyworm larvae damage crops by defoliation and can cause serious damage to the leaf tissue from one side by leaving the opposite epidermal layer intact. At the second or third instar stage, larvae start to produce holes in the leaves and consume from the edge of leaves on the inward (Wild, 2017; Wilson, 2017; Kumela et al., 2018 and Makgoba et al.,2021). Feeding on folded leaves result to holes (Abrahams et al., 2017). The densities of larvae always reduce to 1-2 per crop because of the behavior of cannibalism (Capinera, 2017; Baudron et al.,2019). The densities of 0.2-0.8 larvae per crop occurring at the late whorl stage can decrease yield by 5-20 %. The older larvae can cause defoliation by leaving the crop with a ragged and torn up appearance. These larvae can also cause damage by burrowing into maize tassels and ears (Abrahams et al., 2017; Day, 2017; FAO, 2017). Usually, the young larvae hide in the funnel of maize during the day and at night it emerges to consume the leaves (Ibenegbu, 2018, Odeyemi, 2018, Makgoba et al., 2021). Fall armyworm cause more damage to maize plant than other species of the same genus present in Africa (CABI, 2017;Du Plessis et al., 2018; Hugo et al.,2020). It is difficult to control fall armyworm once the population is high.

Currently, to cope with the spectrum of fall armyworm attacking maize, farmers in the sub-Saharan Africa are using insecticides. However, its use is constrained by high cost and ecological hazards (Siazemo and Simfukwe, 2020; Anyim et al., 2020; Kamunhukamwe et al., 2022).

In the last decades, synthetic insecticides have been used to control agricultural insect pests. These synthetic

insecticides have brought a lot of detrimental effects on the environment and caused contamination of non-target organisms because of massive and repeated applications. Hence, they are termed ecologically unsafe as they persist for a more extended period in the environment and exhibit residual effects in the food chain, where they cause serious havoc on non-target organisms, most especially humans (Ifebueme et al.,2020). One prominent insect pest targeted by these synthetic insecticides is the fall armyworm (*S. frugiperda*), a major pest of maize (Ugwu et al., 2019; Popoola et al., 2020).

The potential increase in use of synthetic insecticides is hazardous due to its negative impacts and direct increased costs of production on the poor-resource farmers and the indirect negative impacts on human health, environmental contamination, development of insect resistance to insecticides and subsequent pest resurgence (Suzette et al.,2016; Stevenson et al.,2017; Sangle et al., 2020). In the other hand, plant materials are still used in various parts of the world for pest control in different field and stored crops (Bateman et al., 2018;Anyim et al.,2020; Sangle et al., 2020; Tulashie et al., 2021). Botanical extracts have many desirable properties. They are less toxic, biodegradable, target specific and environmentally friendly (Degri et al., 2012; Anyim et al.,2020; Babendreier et al.,2020). Hence, there is need to substitute these synthetic insecticides with botanical extracts to bring about effective insect control with minimal damage to non-target organisms, environment, human and animals. This study therefore, evaluate the impact of neem extract concentrations on fall armyworm infestation and damage on maize under rain fed conditions in Gombe , Gombe State of Nigeria.

MATERIALS AND METHODS

Research Site

Field experiments were conducted at Teaching and Research farm of Department of Agronomy, Faculty of Agriculture, Federal University of Kashere, Gombe State, Nigeria in 2024 and 2025 cropping seasons. This location has an average annual rainfall of between 500 to 1700 mm with rich fertile soils for the cultivation of diverse annual crops (GSADP, 2018).

Experimental Design and Layout

The experimental plots were laid out in a randomized complete block design (RCBD) with three replications. The plot size measured 4 m x 3 m (12 m²) with plant spacing of 25 cm x 75 cm. Distance between replications was 1.5 m and between each plot is 1.0 m. The experimental materials used were (Balanites leaves (BLE) , *Balanites aegyptiaca* Del; mahogany leaves (MLE), *Khaya senegalensis* L.,*Jatropha* leaves (JLE), *Jatropha curcas* L., Neem leaves (NLE), *Azadirachta*

indica A. Juss were applied at 20% w/v and a standard check Lambda-cyhalothrin 2.5 EC) 20ml/16 L of water.

Sources of the experimental materials and Preparation of the Neem Leaf Extract Concentrations

Maize seeds (SAMMAZ 52) and Lambda-cyhalothrin 2.5 EC (karate) manufactured by Green life Crop Protection Africa, were purchased from a reputable agro-chemical input shop located in Gombe main market. The selected plant leaves were collected from the available trees found around the experimental site.

The leaves of the four plants used were obtained from the Department of Agronomy Teaching and Research farm. They were washed, pulverized to paste using Binatone electric blender (Model BLG 400). Fifty grams of each plant paste poured into four bottles and labeled according to the treatments were added to 1000 ml of water, agitated constantly and kept for 24 hours at ambient temperature. The solutions were filtered through whatmann filter paper no. 42 (125 mm). The filtrate was concentrated using rotary evaporator and their percentage extracts (%w/v) was calculated as described by Degri *et al.*, 2013; Samaila *et al.*, 2017, and Birhanus *et al.*, 2019).

Agronomic practices

The experimental field was cleared, ploughed, harrowed and ridged using power tiller. The field was laid out using ranging poles, pegs and lines. Maize seeds (SAMMAZ 52) were sown using 2-3 seeds per hole at a spacing of 25 cm x 75 cm. Simazine herbicide was applied at the rate of 2.5 kgai a day after sowing for weed control. After germination, maize seedlings were thinned down to one plant per hole at two weeks after sowing and empty holes (stands) were refilled to maintain the optimum plant population per plot. Weeding was done as at when due manually until harvest. Maize plants were treated with the various plant extracts and Lambda-cyhalothrin 2.5 EC as standard check and water (control) under field conditions in the study area.

Data collection

Both agronomic and insect incidence data were collected, which include plant height, mean number of leaves/plant, stem girth, leaf area, fall armyworm incidence, number of larvae/plant percentage leaf area damaged, cob weight, number of seeds /cob, seed weight/cob and grain yield. Fall armyworm percentage incidence was collected by physically counting number of maize plants that were infested by fall armyworm and converting it to percentage of the total number of maize plants observed.

Incidence (%) =No. infested maize plants

$$\times 100 \quad (1)$$

Total number of maize plants observed

b) Plant height (cm): Five maize plants were randomly

selected and tagged. These randomly selected and tagged maize plants were measured using a graduated measuring plastic tape at two weeks interval and their heights were recorded accordingly.

c) Stem girth (cm): This is obtained by measuring the girth of the five randomly selected and tagged maize plants in centimeters and recorded accordingly.

d) Number of fall armyworm larvae: This was carried out by carefully opening the maize plant whorls and counting the number of fall armyworm larvae found in them and the number recorded on each.

e) Percentage maize leaf area damaged: This was done by outlining the damaged area of the maize leaf on a graph sheet and the number of squares counted. The numbers of full squares obtained were converted as a percentage of the leaf area.

$$\frac{\text{Leaf area damaged}}{\text{Total leaf area}} \times 100 \quad (2)$$

a) Number of leaves/plant: The total number of leaves of the randomly selected and tagged maize was counted and recorded at two weeks interval and were recorded accordingly until harvest.

b) Leaf area: This was done by outlining the damaged area of the maize leaf on a graph sheet and the number of squares counted or measuring the length and breadth of the tagged maize leaves using graduated measuring plastic tape at two weeks interval and their areas were recorded accordingly in cm².

c) Cob weight: This was obtained after the maize cobs were harvested from the five randomly selected maize plants, threshed, sun dried and the cobs were weighed using a weighing balance in grammes (g).

d) Number of seeds /cob: This was obtained after the maize cobs were harvested from the five randomly selected maize plants, threshed, sun dried, shelled and the seeds were weighed using a weighing balance and recorded per cob in grammes (g).

e) Seed weight/cob: This was obtained after the maize cobs were harvested from the five randomly selected maize plants, threshed, sun dried, shelled and the seeds obtained from the cobs were weighed using a weighing balance in grammes (g)

f) Maize Grain yield: This is obtained at harvest after the maize cobs were harvested, sun dried, shelled with a mechanical Sheller to obtain the grains. The grains were weighed using a weighing balance (Genway model 1300TL

Data Analysis

The data collected were subjected to analysis of variance (ANOVA). The means of the treatments were separated using Student Newman Keuls Test (SNK) at 5% probability level ($p<0.05$).

RESULTS

Table 1: Effect of different plant leaf extracts on maize plant height and number of leaves affected by fall armyworm in 2024 and 2025

Treatment (%w/v)	Mean plant height (cm)		Mean No. leaves/plant	
	2024	2025	2024	2025
Untreated (control)	40.11 ^c	40.17 ^c	6.16 ^c	6.27 ^c
<i>Jatropha curcas</i>	54.33 ^c	55.31 ^c	7.62 ^c	7.60 ^c
<i>Khaya senegalensis</i>	65.36 ^b	64.98 ^b	9.71 ^b	9.70 ^b
<i>Balanites aegyptiaca</i>	66.07 ^b	65.05 ^b	8.99 ^b	8.97 ^b
<i>Azadirachta indica</i>	78.01 ^a	78.03 ^a	12.11 ^a	12.13 ^a
Lambda-cyhalothrin 2.5EC	78.94 ^a	79.01 ^a	13.16 ^a	13.12 ^a
SE±	13.09	13.17	3.70	3.69

Mean values followed by the same letter are not significantly different at 5% level of probability by Student Newman Keuls Test (SNK).

Table 2: Effect of different plant leaf extracts on maize stem girth and mean leaf area affected by fall armyworm in 2024 and 2025

Treatment (% w/v)	Mean stem girth (cm)		Mean leaf area (cm ²)	
	2024	2025	2024	2025
Untreated (control)	6.74 ^c	6.72 ^c	447.19 ^c	445.20 ^c
<i>Jatropha curcas</i>	7.02 ^c	6.95 ^c	486.60 ^{bc}	487.97 ^{bc}
<i>Khaya senegalensis</i>	9.58 ^b	9.57 ^b	574.01 ^b	574.18 ^b
<i>Balanites aegyptiaca</i>	10.90 ^b	10.86 ^b	689.62 ^b	691.47 ^b
<i>Azadirachta indica</i>	10.97 ^b	10.96 ^b	691.33 ^b	693.43 ^b
Lambda-cyhalothrin 2.5EC	12.82 ^a	12.80 ^a	761.14 ^a	763.12 ^a
SE±	1.71	1.69	51.32	52.53

Mean values followed by the same letter are not significantly different at 5% level of probability by Student Newman Keuls Test (SNK).

Table3. Effect of different plant leaf extracts on FAW percentage incidence, number of larvae and percentage leaf area damaged in 2024 and 2025

Treatment (% w/v)	Incidence (%)		No. of larvae/plant		Leaf Area Damaged (%)	
	2024	2025	2024	2025	2024	2025
Untreated (control)	12.16 ^a	11.71 ^a	3.76 ^a	3.84 ^a	62.58 ^a	61.60 ^a
<i>J. curcas</i>	9.60 ^b	8.86 ^b	2.82 ^b	3.01 ^b	57.61 ^b	58.21 ^b
<i>K. senegalensis</i>	5.91 ^c	5.83 ^c	2.71 ^c	2.59 ^c	37.87 ^c	37.76 ^c
<i>B. aegyptiaca</i>	3.20 ^{cd}	3.37 ^{cd}	1.45 ^{cd}	1.52 ^{cd}	34.51 ^{cd}	34.59 ^{cd}
<i>A. indica</i>	2.31 ^d	2.33 ^d	0.78 ^d	0.77 ^d	20.45 ^d	19.98 ^d
Lambda-cyhalothrin 2.5EC	2.13 ^d	2.08 ^d	0.43 ^d	0.42 ^d	20.33 ^d	20.11 ^d
SE±	2.78	2.81	0.55	0.47	19.66	17.11

Mean values followed by the same letter are not significantly different at 5% level of probability by Student Newman Keuls Test (SNK).

Results presented in Table 1 showed that there was significant difference among the treatments. *Azadirachta indica* extract applied had significantly the higher maize plant height and higher number of leaves both in 2024 and 2025 cropping seasons followed by *B. aegyptiaca* and *K. senegalensis* compared to *Jatropha curcas* leaf extract. However, Lambda- cyhalothrin 2.5 EC had significantly the highest plant height and number of leaves which were at par with neem leaf extract at 20 % w/v in both years (Table1).

Mean stem girth ad leaf area in both years showed that

A. indica leaf extract (NLE) applied at 20% w/v were significantly higher and statistically similar with that of Lambda-cyhalothrin 2.5 EC (Table 2) followed closely by *B. aegyptiaca* and *K. senegalensis* applied at 20 % w/v while *J. curcas* at 20 % w/v had the lowest stem girth and leaf area in both years in the study area.

Table 3 showed that percentage maize fall armyworm incidence, number of larvae/plant and percentage leaf area damaged in both 2024 and 2025 were significantly ($p<0.05$) the lowest in plots treated with NLE followed closely by *B. aegyptiaca* (BLE), *K. senegalensis* (MLE)

Table 4. Effect of different plant leaf extracts on maize grain yield parameters in 2024 and 2025

Treatment	Cob weight (kg)		No. of seeds/Cob		Seed weight/Cob		Grain yield (t/ha)	
	2024	2025	2024	2025	2024	2025	2024	2025
Control	9.51 ^d	9.53 ^d	291.69 ^d	291.66 ^d	51.95 ^d	51.81 ^d	2562.11 ^d	2562.13 ^d
<i>J. curcas</i>	12.71 ^{cd}	12.72 ^{cd}	297.44 ^{cd}	293.86 ^{cd}	57.64 ^{cd}	56.79 ^{cd}	2661.00 ^c	2663.19 ^c
<i>K. senegalensis</i>	15.38 ^c	14.94 ^c	300.31 ^c	301.21 ^c	78.13 ^c	77.89 ^c	3701.33 ^{bc}	3811.16 ^{bc}
<i>B. aegyptiaca</i>	17.96 ^b	18.06 ^b	311.91 ^b	313.07 ^b	88.92 ^b	88.89 ^b	4013.33 ^b	4022.10 ^b
<i>A. indica</i>	24.05 ^a	24.10 ^a	376.90 ^a	375.84 ^a	97.90 ^a	98.39 ^a	4633.33 ^a	4701.05 ^a
Karate 2.5EC	26.03 ^a	25.99 ^a	403.65 ^a	401.07 ^a	104.22 ^a	103.83 ^a	4698.11 ^a	4691.20 ^a
SE±	41.08	43.10	123.38	126.27	82.17	84.62	233.65	296.12

Mean values followed by the same letter are not significantly different at 5% level of probability by Student Newman Keuls Test (SNK)

and *J. curcas* (JLE) applied at 20 % w/v while control (untreated) plots had the highest percentage maize fall armyworm incidence, number of larvae/plant and percentage leaf area damaged in both 2024 and 2025 during the study. However, plots treated with Lambda-cyhalothrin 2.5 EC had the least and were at par with plots treated with NLE at 20% w/v.

The effect of the different plant extracts on maize fall armyworm was presented in table 4. It revealed that NLE applied had significantly ($p<0.05$) improved maize cob weight, number of seeds/cob, seed weight and maize grain yield in the study area in 2024 and 2025 cropping seasons when compared with the other plant extracts. Lambda-cyhalothrin , a synthetic insecticide used as a standard check was found to be at par with NLE (Table 4).

DISCUSSION

The present study established the insecticidal ability of plant extracts which can be attributed to their phytochemical constituents found in it which possess insecticidal activities against fall armyworm (Oboho *et al.*, 2020; Zain *et al.*, 2022).The effects of plant extracts on maize fall armyworm (FAW) were found to be effective and promising in reducing the incidence, infestation and damage of the crop. It was also found that good and appropriate application of the correct concentration of plant leaf extracts had improved the vegetative and reproductive performance of SAMMAZ 52 maize in the study area in 2024 and 2025. Among the plant leaf extracts, it was found that maize treated with NLE had significantly ($p<0.05$) increased the plant height, number of leaves/plant and leaf area followed closely by *B. aegyptiaca* (BLE), *K. senegalensis* (MLE) and *J. curcas* (JLE). *Jatropha curcas* performed significantly lower than other extracts due to lower concentration of saponins, alkaloids, tannins and flavonoids (Jumare *et al.*, 2023). The studies revealed that NLE application boosts maize yield attributes such as stem girth, leaf area, cob weight, number of seeds/cob, seed weight /cob and maize grain yield during the two cropping seasons in the study area. The NLE was found to have significantly reduced the percentage incidence of fall armyworm, the number of

larvae/plant and leaf area damaged. The effectiveness of NLE was equally good and at par with Lambda-cyhalothrin 2.5 EC on the maize fall armyworm. This result indicates that NLE is effective and potent enough for managing maize fall armyworm due to the presence of azadirachtin and higher concentration of saponins, alkaloids, tannins and flavonoids (Ujah, *et al.*,2021) compared to the other plant extracts. This finding agreed with that of Silva *et al.*, 2015; Akhigbe *et al.*; 2019; Birhanus *et al.*, 2019).

The effects of the NLE , BLE and MLE on FAW indicate that they were effective in reducing the percentage incidence of fall armyworm, the number of larvae/plant and leaf area damaged. The decrease in the incidence, infestation, and damage of maize crops treated with NLE showed that the material was toxic and effective against fall armyworm (Asefa and Ayalew, 2019; Babendreier *et al.*, 2020). In another study, Martinez *et al.*, 2017 also found that ethanolic extracts of botanicals are effective and toxic on the food and development of FAW. This is because the NLE toxicity affects the feeding of the larvae on the maize leaves and also affect the development of the different larval instars of FAW on maize (Anyim *et al.*,2020). FAW can cause serious damage to maize that are not control and caused colossal loss of up to 80% damage (IITA, 2016; Wilson, 2017).

Among the plant leaf extracts used, NLE was found to be more effective in reducing the incidence, leaf damaged and the population of the larvae of FAW compared to other plant extracts and untreated maize. This implies that NLE applied at 20 % w/v was effective and efficient for the control of maize fall armyworm (*S. frugiperda*). Fall armyworm larvae damage maize crops by defoliation (Kumela *et al.*, 2018;Akhigbe *et al.*,2021; Makgoba *et al.*,2021). Hugo *et al.* (2020) reported that if maize crops are not protected with effective materials, maize crops damage by the second and third larval instars, the damage may be more serious and massive than other cereal crops. Akhigbe *et al* (2021), Siazemo and Simfukwe (2020) reported that the application of both botanical and synthetic insecticides at the right time will give the needed control of maize FAW while application of wrong plant product at the wrong time will not be effective against the pest and may even cause pest resistance and resurgence (Hatcluson and Cira, 2017).

The increased in cob weight, seed number, seed weight and grain yield that were treated with NLE implies that this treatment was appropriate, effective and efficient for the control of *S. frugiperda* on maize in both years in the study area (Kamsiime et al., 2019; Tanyi et al., 2020; Kamunhukamwe et al., 2022). This also implies NLE is good for optimum maize grain production in the study area. The higher values recorded under Lambda-cythaothrin 2.5EC having the same superscripts indicate that NLE and standard check Lambda-cythaothrin 2.5EC are at par with each other in terms of controlling *S. frugiperda* in the study area (Birhanus et al., 2018; Bateman et al., 2018; Tulashie et al., 2021). However, the lowest yield performance values recorded under the other plant extracts means that they are not quite adequate and effective for maize fall armyworm control and thus not appropriate for optimum maize production.

CONCLUSION

This present study showed that fall armyworm (*S. frugiperda*) is a serious major insect pest of maize. It is a major constraint to maize production in the study area. The insecticidal activities of the four plant leaf extracts against maize fall armyworm (*S. frugiperda*) were revealed during 2024 and 2025 cropping seasons in the study area. The most active, effective and friendly plant extract was found to be NLE followed closely by BLE, MLE and JLE in that order. The NLE applied before the reproductive phase of maize reduced the incidence, leaf damaged and number of fall armyworm larvae. It also improved the maize crop height, number of leaves/plant, stem girth, cob weight, number of seeds/cob, seed weight and grain yield compared to the other treatments. The study demonstrates the high potency and efficacy of the neem leaf extract as well as environmentally, friendly, alternative of cheap, locally available and affordable plant in the study area. We suggest that further studies be conducted on the screening of other indigenous and available plants as alternatives to synthetic insecticides at different concentrations for the control of fall armyworm in the study area.

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