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Research Article

Termite Damage to Economic Trees in Benue State, Nigeria: Termite Diversity and Nature of Attacks, Economic Cost of Control and Plantation Owners' Knowledge and Perception

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Abstract

The emerging economic losses in orange, palm fruits, mango and cashew production due to termite infestation is threatening food and social security in communities in Nigeria where these crops are major cash crops and significant income earner. This study was therefore designed to identify farming practices that create ideal conditions for termite proliferation, evaluate the species diversity and abundance of termites affecting economic trees, determine the financial cost of termite infestation on economic trees in order to develop an integrated strategies for their management. Kwande, Ushongo, Ogbadibo and Oju Local Government Areas which are termite hotspots and fruit-producing Local Government Areas in Benue State were purposively selected. A total of 120 orchards were selected and trees were randomly inspected for physical evidence of termites' infestation. A structured questionnaire to investigate plantation owners' knowledge, attitudes, and practices in relation to termite infestation was administered to 402 plantation owners and farmers. Focus Group Discussions, direct field observations, were also conducted in each community and termite samples were collected from infested trees. A total of 2,458 economic trees were inspected across the four study locations, 572 (23.7%) showed visible signs of termite infestation. Cashew trees had highest infestation rate with 37.1% showing evidence of termite infestation. The Genus *Macrotermes* were the most predominant termites infesting trees with *M. bellicosus and M. malaccensis.* Orange and mango were predominantly cultivated in Kwande and Ushongo, palm trees were the major economic trees in Ogbadibo. There was a significant association between location of study and types of economic trees ($\chi^2 = 218.323$; $p = 0.000$). There was no significant association between signs of termite infestation and location of plantations ($\chi^2 = 30.107$; $p = 0.090$). There was a significant difference in pesticide application compared to other control methods ($\chi^2 = 33.565$; $p = 0.014$). Farmers termite-related perceptions are significantly influenced by local experience and indigenous knowledge resulting to ineffective control efforts. Our finding justifies the need to build the capacity of farmers and deploy more effective integration of termite control options to mitigate the impact of termite-related fruit production losses in Benue State, Nigeria.

Keywords

Economic Trees, Termite Diversity, Perception and Practices, Economic Cost

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1. Introduction

Termites are a significant component of soil macrofauna biomass ranging from 70-110 kg/ha in savanna ecosystems and approximately 20.5 kg/ha in forest biomes [12]. Their activity accelerates organic matter breakdown, promotes nutrient cycling, enhances soil structure, and facilitates secondary productivity. They also serve as keystone decomposers particularly in tropical and subtropical ecosystems [18]. In some rural societies, they are also consumed as an accessible source of animal protein [25]. Termites are essential members of the soil ecosystem and are found throughout the world [5]. They are the most important fauna in nutrient recycling, improving soil fertility and serving as food sources for other animals. On the other hand, termites are highly destructive and polyphagous pests of crop plants, which damage green foliage, seedlings, forests, pasture, wooden structures, fibers including household cellulose-based materials, and postharvest stored products.

Despite these ecological benefits, termites are becoming a significant menace to agricultural production of tree crops and other economic trees in Africa. They often cause major losses to humans by damaging anything that particularly consists of cellulose, such as books, stored timbers, wooden structures, stored grain products, crops, standing trees and forests [11]. It is estimated that termites cause a noteworthy economic loss of more than 40 billion USD annually worldwide [8, 10, 26]. They damage the agricultural and horticultural crops directly (through feeding on the bark and underlying tissue) and indirectly (the damaged plants become susceptible to pathogenic microbes) resulting in plant death [29, 26].

The financial implications of termites' control in plantations and economic losses arising from their infestation of economic trees in Sub-Saharan Africa are estimated to cost hundreds of million dollars annually. In 2021, the estimated direct and indirect annual economic losses resulting from termite-related activities in cocoa, mango, teak and cashew plantations was about 23.5 million US dollars [11, 10, 17]. Although considerable progress has been made in developing control strategies (such as cultural, biological, botanical and chemical approaches) globally, integrated management of termites in plantations is still a great challenge because of mixed cropping and emerging environmental concerns about pesticides residues on fruits.

In Nigeria, 86 termite species have been recorded, spanning 38 genera that include both mound-building and drywood termites [16, 1, 22]. Species such as *Macrotermes*, *Microtermes*, and *Odontotermes* are known to cause widespread damage to seedlings of various crops, while others, including *Ancistrotermes*, *Allondotermes*, and *Pseudacanthotermes*, inflict localized but significant harm to forest trees, rangelands, cultivated crops, and other natural resources [13, 8].

The emerging economic losses in orange and cashew due to termite infestation is threatening food and social security in communities in Nigeria where these crops are major cash crops and significant income earner. Until recently the economic consequences of termite infestation on economic trees have not been given required research attention. Termites are responsible for economic losses in orange, mango, cashew and cocoa especially in newly planted orchards where they severely damage or weaken the cuttings resulting in poor stands establishment and poor yield [8, 22, 26] (Djuidev et al., 2017, Oyedokun et al., 2023, Siapo et al., 2024). Both old and young trees which are grown from stem cuttings respectively are constantly attacked by *Amitermes*, a predominantly root feeding species. *Ancistrotermes, Macrotermes, Odontotermes* and *Pseudocanthotermes* are also involved in damaging the maturing and fruiting, as well as by hollowing out stems at ground level [10]. Termite damage to trees commences at seedling stage and increases at the arrival of senescence [11].

In Nigeria, agriculture is predominantly practiced by smallholder farmers who often lack access to modern pest control technologies. Consequently, many rely on traditional methods with varying levels of ineffectiveness. Common indigenous termite control practices include the application of wood ash, physical destruction of termite tunnels, mound destruction and pesticides [16, 30, 29]. Despite the huge amounts of damage to economic trees, plantation owners continue to grapple with unsustainable local practices and escalating termite damages. The first step towards the development of successful termite management strategies adaptable to farmers' needs is an understanding of their current practices and perceptions [30, 31, 13].

Mango and orange production in Benue State, Nigeria, holds significant economic value, contributing to both local livelihoods and the broader agricultural economy. Over 10,000 farmers engage in orange cultivation, with some managing plantations exceeding 7000 trees in local government areas such as Ushongo, Vandeikya, and Konshisha [15]. Similarly, mango and palm tree farming is prevalent, with both local and improved varieties cultivated across the State. However, the sector faces challenges, including substantial harvest losses due to termites' infestation in plantations, unfortunately the financial losses arising from termite infestation has never been quantified in the State. Studies on similar fruits elsewhere in West Africa has however estimated losses in 13.5 million US dollars [8, 27, 22]. Termite damage can be severe, with infestations leading to hollow trunks and weakened tree structures, making them susceptible to collapse. Such damage disrupts the movement of water and nutrients, leading to plant death or poor yield.

Documenting and preserving indigenous knowledge on termite management practices is therefore imperative. This knowledge base can inform the design of integrated termite management strategies tailored to local ecological and socio-economic conditions [13]. Notably, the economic cost of termite infestation in Nigeria remains grossly underestimated [1, 20-22]. To mitigate the impact of termites on agricultural productivity and rural livelihoods, it is essential to assess ter-

mite diversity, species abundance, and infestation severity across agroecological zones. Such studies can support the development or refinement of integrated control measures, bolster traditional methods, and promote practices that enhance plant vigor and resilience against termite attack [10, 28, 5, 11, 8].

The economic cost of termite infestation in Nigeria is grossly underestimated [20-22], there is necessity to link termite-related damages with financial losses arising from rejection in damaged timber and reduction in plantation yield. Furthermore, the inclusion of termite control expenditures in plantations has become necessary in order to appreciate socio-economic losses [27, 10]. This study was therefore designed to identify farming practices that create ideal conditions for termite proliferation, evaluate the species diversity and abundance of termites affecting economic trees, determine the financial cost of termite infestation on economic trees in order to develop multi-sectorial integrated strategies for their management. This information can complement the more current approach used in stakeholders understanding of the dynamics of termite communities and implications in the fruit-production economy.

2. Materials and Methods

2.1. Study Area

The study was conducted in Benue State, located in the north-central region of Nigeria. Benue State covers an area of approximately 33,955 km^2 and lies between latitudes 6.5 °and 8.5 ° N and longitudes 7.47 ° and 10 ° E. According to the Köppen climate classification, the state falls under the tropical savanna climate (Aw), characterized by a distinct wet and dry season. The rainy season spans April to October, with annual rainfall ranging between 1,000 and 2,000 mm. The dry season extends from November to March, with average annual temperatures fluctuating between 23 ℃ and 37 ℃. The State is leading ranks as the leading producers of mango, orange and palm oil in Nigeria and holds significant economic value, contributing to both local livelihoods and the broader agricultural economy. Over 100,000 farmers engage in orange, mango and palm cultivation, with some managing orange plantations exceeding 20,000 trees in local government areas such as Ushongo, Vandeikya, and Konshisha and palm plantation of more than 15,000 trees in Ogbadibo [15].

2.2. Sampling Design and Farm Selection

Four termite hotspots and fruit-producing Local Government Areas (LGAs) were purposively selected, the LGAs were Kwande, Ushongo, Ogbadibo and Oju. A total of 120 orchards and plantations were selected, with 30 from each LGA using a household randomization approach [21, 22], in each orchard trees were randomly inspected for termite infestation.

2.3. Ethical Approval and Consent to Participate

This study was approved by the Research and Ethics Committee of the Benue State University (approval number CREC/RS/003), in accordance with country regulations. Informed consent was obtained verbally before participation. Participants were anonymized and personal information was stored according to Nigerian regulations.

2.4. Structured Questionnaire Survey

A structured questionnaire was designed to investigate plantation owners' knowledge, attitudes, and practices (KAP) in relation to termite infestation. The questionnaire was administered to 402 plantation owners and farmers randomly selected across the study sites. The questionnaire was designed to investigate socio-demographic, termites' knowledge and practices, termite-related expenditure and management strategies. The administration of the questionnaire ensured that women, men and young people were adequately represented. Inclusion criteria included a minimum of 10 years of plantation owners' residency within the community.

2.5. Participatory Rural Appraisal (PRA)

Focus Group Discussions (FGDs), direct field observations, and semi-structured interviews were also conducted in each community. Three FGDs were done in each study community comprising separate groups of 12-15 men, women and young people. PRA activities followed the methodology of [30]. Due to the multi-ethnic composition of the study communities, local interpreters were recruited to facilitate communication and were selected by mutual agreement with community leaders of each village. The FGDs, direct observations and semi-structured interviews focused on perceptions and ranking of termite pests of economic importance and crop susceptibility, local names and means of termite identification, factors influencing termite behavior and infestation and traditional management strategies. A matrix ranking exercise was conducted in each community to rank termite pests in relation to other prevalent agricultural pests.

2.6. Laboratory Analysis and Curator Services

The indications of termite attacks on trees recorded in the present study included galleries (trails of termites covered by soil, termite nests on/or around the base of trees, termite mounds within the plantation or orchard. Termites were collected from trees and/or partially destroyed mounds with a metal spatula and preserved in a vial with 70% ethanol and labeled with the location ID number and other relevant data. Interviews were conducted with the owners of the plantations to collect data on the plantation history, method of termite control and termite-related financial expenditure, and perceived economic losses arising from infestation. The termites collected were sent to the National

Insect Mesum at Ahmadu Bello University Zaria for identification. Photographs of the infested wood structures and mud tubes were taken using a cannon camera.

2.7. Data Analysis

Descriptive statistics and bar charts were produced using Microsoft Excel version 2016 presentation of data and visualization were performed using simple percentages and statistical analysis were calculated using the total number of responses obtained in each specific question. Similarly, categorical data deriving from multiple-choice questions or frequency-based responses were also analyzed using a Chi-square test. To assess whether the damage caused by termites was more severe based on location in order to have a comprehensive and robust understanding of the interrelationships among key variables and practices.

3. Results

3.1. Demographic Characteristics of Respondents and Owners of Plantations

Overall, the respondents were predominantly male, Tiv, moderately educated, and with substantial experience in managing economic trees, they were mostly middle-aged, with the largest number aged 51 years and above (39.5%), followed by those aged 41–50 years (30.3%). Males dominated the sample (73.2%), while females accounted for 26.8%. Regarding education, more than one-third of the respondents had secondary education (37.7%), followed by those with no formal education (33.5%), primary education (17.1%) and tertiary education (11.7%). In relation to years of experience in managing economic trees, most respondents had between 11–15 years of experience (38.2%), followed by those with 6–10 years (21.8%) and 16–20 years (20.6%). (Table 1). A total of 2,458 economic trees were inspected across the four study locations, 572 (23.7%) showed visible signs of termite infestation. Cashew trees had highest infestation rate with 37.1% showing evidence of termite infestation. The Genus *Macrotermes* were the most predominant termites infesting trees with *M. bellicosus and M. malaccensis* collected from orchards and plantations in the study locations (Table 2).

Table 1. *Socio-demographic Information of Respondents.*

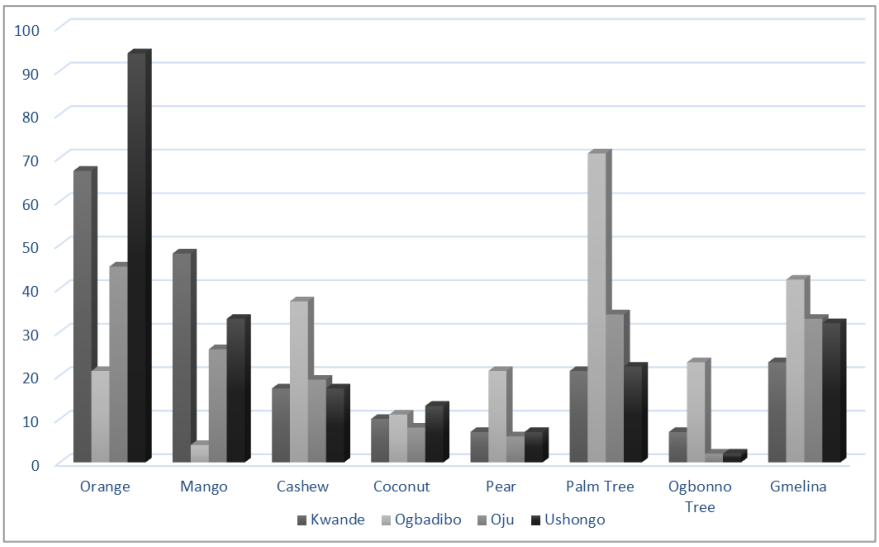
Variable	Frequency	Percentage (%)
Age		
Below 20 years	7	1.7
21–30 years	26	6.5
31–40 years	89	22.1
41–50 years	122	30.3
Above 51 years	159	39.5
Gender		
Male	295	73.2
Female	108	26.8
Educational Status		
No formal Education	135	33.5
Primary	69	17.1
Secondary	152	37.7
Tertiary	47	11.7
Ethnicity		
Tiv	199	49.4
Idoma	102	25.3
Igede	102	25.3

Variable	Frequency	Percentage (%)
Local Government Area		
Kwande	98	24.3
Ogbadibo	102	25.3
Oju	103	25.6
Ushongo	100	24.8
Years of Experience in Managing Economic Trees		
0–5 years	25	6.2
6–10 years	88	21.8
11–15 years	154	38.2
16–20 years	83	20.6
Above 21 years	53	13.2
Total	403	100.0

Table 2. *Economic trees and termites species infesting them in study locations.*

Common names of trees	Scientific names	Number of trees inspected	Number with evidence of infestation (%)	Common termite presentation	Termite species collected
Mango	*Mangifera indica*	547	122 (22.3)	Mud tubes, dried branch, termite hole on stem, termites nest on tree	*Microtermes bellicosus, Reticulitermes lucifugus, Amitermes evucifer*
Moringa	*Moringa oleifera*	127	31 (24.4)	termite hole on stem, Mud tubes	*Microtermes bellicosus*
Cashew	*Anacardium occidentale*	210	78 (37.1)	Mud tubes, dried branch	*Macrotermes malaccensis,*
Tropical almond	*Terminalia catappa*	75	12 (16.0)	termite hole on stem, Mud tubes,	*Microtermes bellicosus, Reticulitermes lucifugus, Odontotermes pauperans*
Orange	*Citrus sinensis*	617	179 (29.00	Mud tubes, dried branch, termite hole on stem,	*Microtermes bellicosus,*
Coconut	*Cocos nucifera*	89	23 (25.8)	Mud tubes, termite hole on stem	*Microtermes bellicosus, Reticulitermes lucifugus, Odontotermes pauperans, Amitermes evucifer*
African Pear	*Dacryodes edulis*	89	17 (19.1)	Mud tubes,	*Eutermes parvulus, Amitermes evucifer*
Palm Tree	*Elaeis guineensis*	376	54 (14.3)	termite hole on stem, Mud tubes,	*Microtermes bellicosus, Reticulitermes lucifugus, Odontotermes pauperans*
Ogbonno Tree	*Irvingia gabonensis*	117	14 (11.9)	Mud tubes, dried branch, termite hole on stem,	*Eutermes parvulus Microtermes bellicosus*
Gmelina	*Gmelina arborea*	211	42 (19.9)	Mud tubes, dried branch, termite hole on stem,	*Reticulitermes lucifugus, Microtermes bellicosus*
Total		2,458	572 (23.7)		

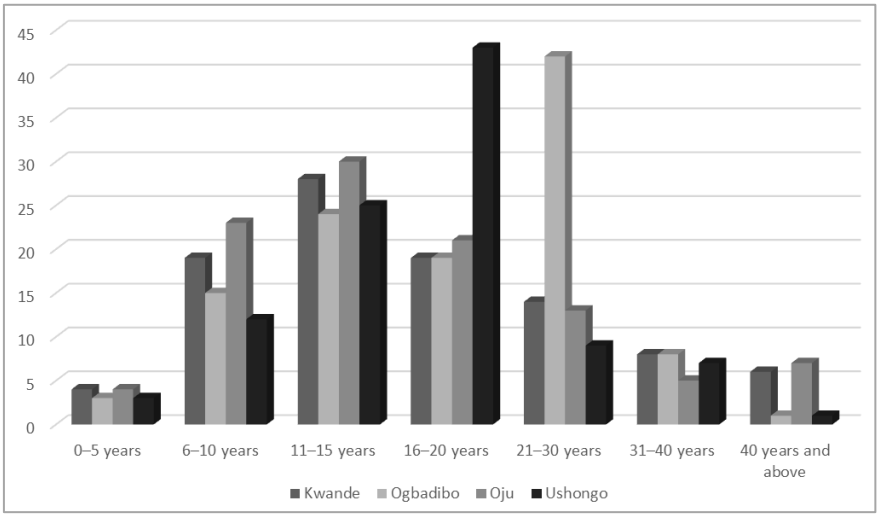
Oranges were the most common economic trees accounting for 57.1%, followed by mango 43.2% and palm trees 37.6% respectively. While orange and mango were predominantly cultivated in Kwande and Ushongo, palm trees were the major economic trees in Ogbadibo. There was a significant association between location of study and types of economic trees (χ^2 = 218.323; p = 0.000) (Figure 1).



χ^2=218.323; P=0.000

Figure 1. *Predominant economic trees managed by respondents in study location.*

Majority of respondents reported the mean age of orchards as within 16–20 years, accounting for 125 (31.0%). This was followed by 11–15 years at 107 (26.6%) and 6–10 years at 69 (17.1%). Kwande (31.1%) and Ushongo (28.9%) had relatively more plantation of orange and mango aged 21–30 years. In contrast, Ogbadibo accounted for a higher share of palm tree plantations within 21–30 years category (33.6%). Chi square analysis indicates a statistically significant association between age of economic trees and study areas (χ^2 = 32.134; p = 0.021) (Figure 2).

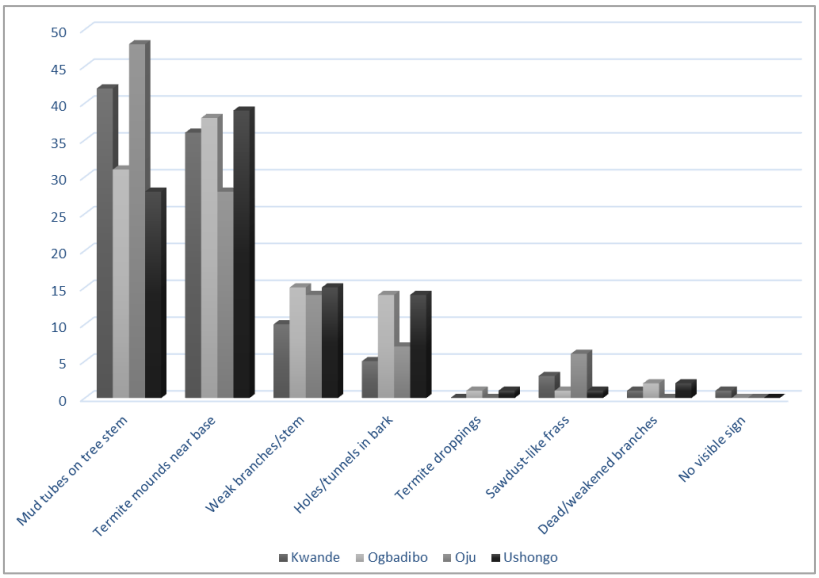


χ^2=32.134; P=0.021.

Figure 2. *Mean age of plantations of economic trees in study location.*

The most commonly observed sign of termite infestation was mud tubes on tree stems as reported by 149 (37.0%) respondents. This was followed by termite mounds near the base of trees (35.0%), weak branches or stems arising from

termite injuries (13.4%), holes or tunnels in tree bark (9.9%). While mud tubes were most frequently seen on cashew and orange trees in Ogbadibo (27.8%) and Ushongo (27.8%), termite mounds at the base of trees or on branches were seen on mango trees. There was no significant association between signs of termite infestation and location of plantations (χ^2 = 30.107; p = 0.090) (Figure 3).

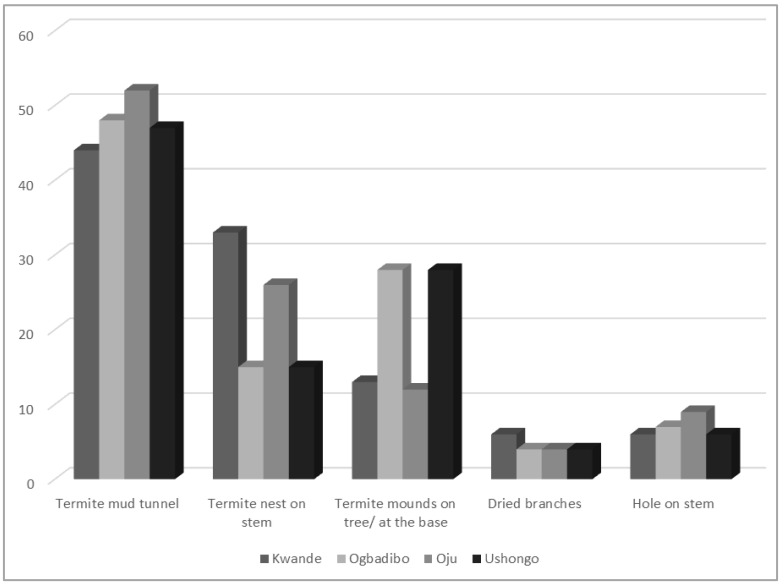


χ^2=30.107; P=0.090

Figure 3. *Signs of termite infestation on economic trees during field sampling.*

3.2. Level of Termite Infestation on Economic Trees in Study Area

The most frequently reported evidence of termite infestation was the presence of termite mud tunnels on stem; this was noticed in 46.4% of infested trees. Termite mound was the second most sighted indicator (22.1%), predominantly observed in Kwande (37.1%) and Oju (29.2%). (χ^2 = 31.604; p = 0.024) (Figure 4). The various signs of termites' infestations on trees encountered during this study are presented in Figures 5-12.



χ^2=31.604; P=0.024

Figure 4. *Evidence of the level of termite infestation on economic trees at different study locations.*

Figure 5. *Stem of palm tree severely injured by M. bellicosus in Ogbadibo, Benue State, Nigeria.*

Figure 6. *Stem of Ogbonno Tree severely injured by M. bellicosus and Reticulitermes lucifugus in Ogbadibo, Benue State, Nigeria.*

Figure 7. *Termite mound at the base of a palm tree at the edge of a plantation in Oju, Benue State, Nigeria.*

Figure 8. *Termite mound at the base of a Gmelina tree in a cassava farm in Oju, Benue State, Nigeria.*

Figure 9. *Stem of African Pear tree severely injured by M. bellicosus and M. malaccensis in Kwande, Benue State, Nigeria.*

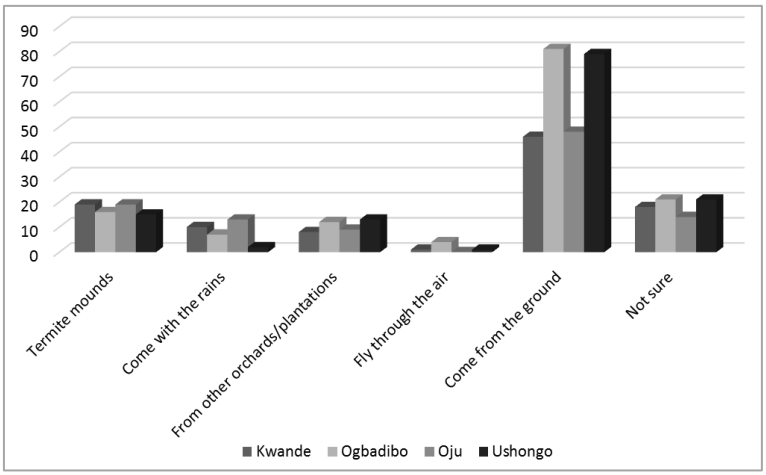
Figure 10. *Hole made by Microtermes bellicosus on the stem of Mango tree in Kwande, Benue State, Nigeria.*

Figure 11. *Termite mound at the base of African pear tree in Ushongo, Benue State, Nigeria.*

Figure 12. *Stem of Tropical almond severely injured by M. malaccensis and Reticulitermes lucifugus in Ushongo, Benue State, Nigeria.*

3.3. Termite-related Perceptions and Practices by Respondents

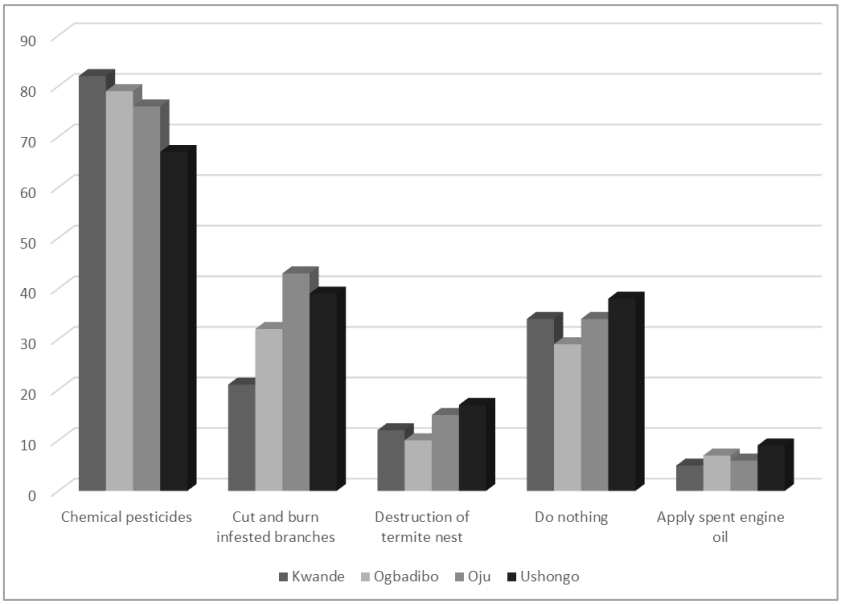
A total number of 381 (94.5%) of respondents reported that economic trees in their villages were infested by termites, while only 22 (5.5%) reported no infestation. Oju LGA reported highest termite infestation of (25.5%) followed closely by Ogbadibo (24.9%) while Kwande (24.9%), and Ushongo recording slightly fewer cases (24.7%). Infestation rates across LGAs were not statistically significant (χ^2 = 1.565; p = 0.667). The majority of respondents (63.0%) indicated that termites come from the ground, followed by termite mounds (17.1%). Ogbadibo (31.9%) and Ushongo (31.1%) recorded the highest reports of termites coming from the ground, while Kwande and Oju both reported the highest share for termite mounds (27.5% each). Chi-square test (χ^2 = 68.182; p = 0.000) shows a statistically significant association between respondents' residence and the knowledge of sources of termite infestation (Figure 13).



χ^2=68.182; P=0.000

Figure 13. *Perceived sources of termite infestation by respondents.*

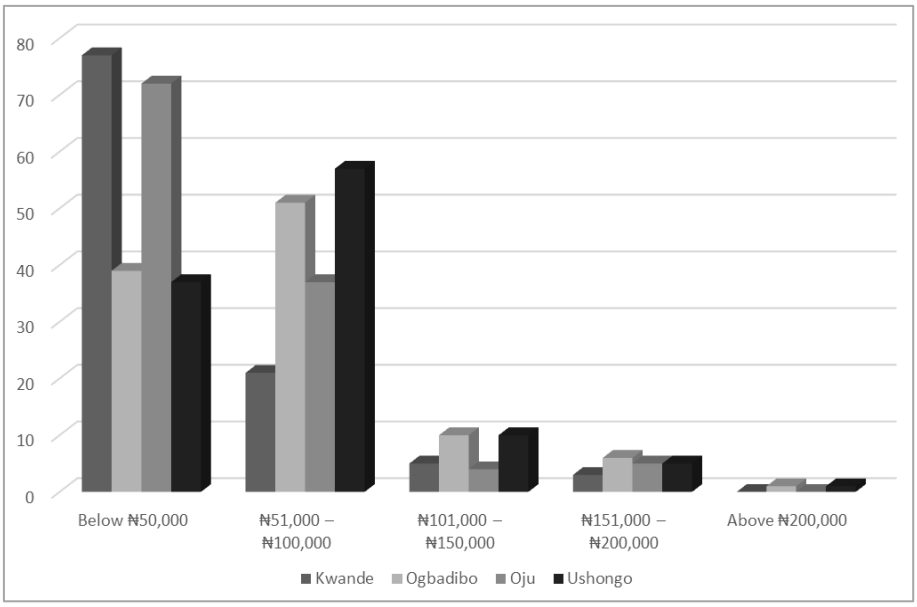
Findings indicate that the most commonly reported method of termite control was the use of chemical pesticides (77.9%). This was followed by cutting and burning affected branches and do-nothing approach. The use of chemical pesticides was high in all LGAs this led to a significant difference between method of control and location (χ^2 = 33.565; p = 0.014). Figure 14).



χ^2 = 33.565; p = 0.014

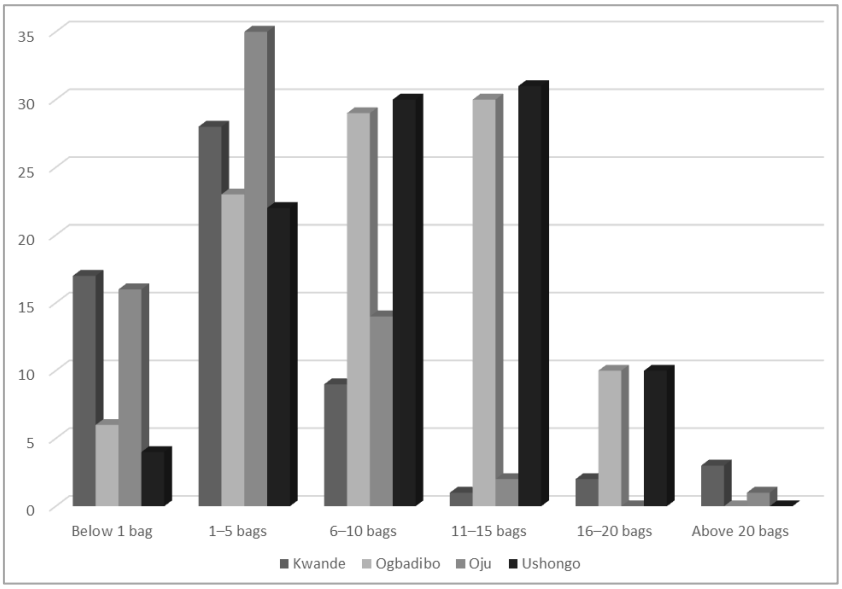
Figure 14. *Methods of termite control deployed by respondents.*

Most respondents reported that they control termites on their plantation once a year (39.2%), while 27.8% reported that they conduct control activities twice a year. Ogbadibo (38.0%) and Ushongo (38.6%) recorded the highest share of annual control, while Kwande (36.6%) and Oju (33.0%) reported more frequent biannual control. There was a statistically significant association between respondents' LGA of residence and the frequency of termite control ($\chi^2 = 133.174$; $p = 0.000$). Termite control frequency and expenditure have serious financial burden, 55.8% of respondents reported spending below ₦50,000 on termite control. This was followed by 32.5% who spend between ₦51,000–₦100,000. Kwande (34.2%) and Oju (32.0%) had the highest number of respondents spending below ₦50,000, while Ogbadibo (35.1%) and Ushongo (35.9%) recorded more respondents in the ₦51,000–₦100,000 category. Chi-square test ($\chi^2 = 58.617$; $p = 0.000$) shows a significant association between respondents' LGA of residence and their expenditure on termite control (Figure 15).



$\chi^2 = 58.617$; $p = 0.000$

Figure 15. *Reported termite control expenditure by respondents.*

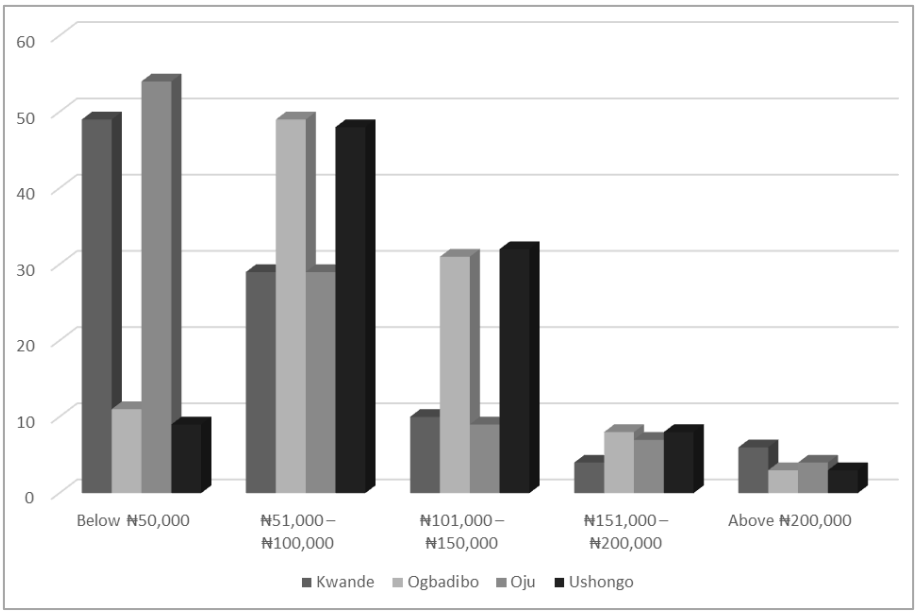


$\chi^2 = 178.466$; $p = 0.000$

Figure 16. *Estimated bags of fruit produce lost as result of termite activities.*

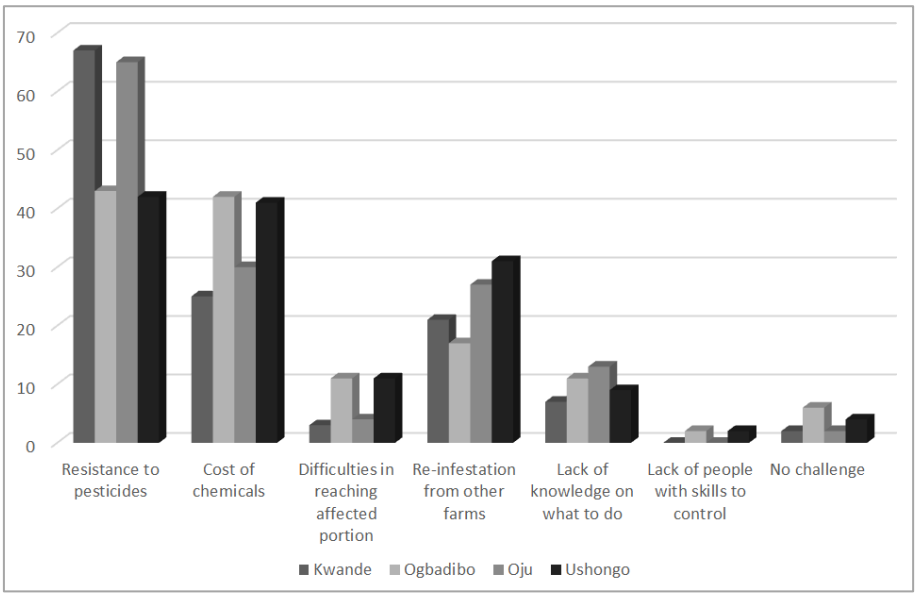
In order to have comprehensive estimate of financial losses resulting from termite-related infestation, respondents were asked to estimate number of bags of oranges, cashew and mangoes lost yearly, 26.8% reported losing between 1–5 bags annually, followed by 20.3% who lose 6–10 bags and 15.9% who lose 11–15 bags. Oju and Kwande reported higher proportions of losses within the 1–5 bag and 1–5 basket categories, while Ogbadibo and Ushongo reported more losses within the 6–15 bag range, indicating greater levels of damage (χ^2 = 178.466; p = 0.000) (Figure 16).

The estimated termite-related financial losses reported by owners of orchards and plantations across LGAs shows that 38.5% lose between ₦51,000 ₦100,000, followed by 30.5% who lose below ₦50,000. Kwande and Oju had more respondents who reported losses below ₦50,000 category, whereas Ogbadibo and Ushongo had respondents who lose between ₦51,000 ₦100,000 and ₦101,000 ₦150,000 categories respectively. There is a statistically significant association between respondents' location and the financial losses suffered due to termite infestation (χ^2 = 92.837; p = 0.000). (Figure 17).



χ^2 = 92.837; p = 0.000

Figure 17. *Estimated termite -related financial losses from sale of fruits.*



χ^2 = 36.115; p = 0.007

Figure 18. *Challenges encountered by respondents during termite control.*

The most frequently reported challenge in termite control encountered was resistance to chemical pesticides with 53.8%, followed by the high cost of chemicals (34.2%) and difficulty in reaching infested portions of the trees (7.2%). Termite resistance to pesticides was most prevalent in Kwande (30.9%) and Oju (30.0%), while the cost of chemicals was reported more in Ogbadibo (30.4%) and Ushongo (29.7%). (χ^2 = 36.115; p = 0.007) (Figure 18). While 87.1% of owners of orchards and plantations were of the opinion that termite infestation is a very severe problem across the LGAs in Benue State, their assessment of the current control practices indicates that 44.9% were unsure of the effectiveness of their efforts while 24.8% reported that their control efforts was ineffective (χ^2 = 181.048; p = 0.000). There was a significant association between educational status respondents and correct knowledge of termite infestation (χ^2 = 13.266; p = 0.004), however, there was no significant association between age, gender, ethnicity, years of experience in orchard/plantation management and knowledge of termite infestation (p < 0.05). (Table 3)

Table 3. *Association between Socio-demographic Characteristics and Knowledge of Termite Infestation.*

Variable	Termite Infestation		χ^2	P-Value
	Yes (%)	No (%)		
Age				
Below 20 years	5 (71.4%)	2 (28.6%)	9.401	0.052
21–30 years	26 (100.0%)	0 (0.0%)		
31–40 years	84 (94.4%)	5 (5.6%)		
41–50 years	117 (95.9%)	5 (4.1%)		
Above 51 years	149 (93.7%)	10 (6.3%)		
Gender				
Male	278 (94.2%)	17 (5.8%)	0.197	0.657
Female	103 (95.4%)	5 (4.6%)		
Educational Status				
No school	130 (96.3%)	5 (3.7%)	13.266	0.004
Primary	69 (100.0%)	0 (0.0%)		
Secondary	142 (93.4%)	10 (6.6%)		
Tertiary	40 (85.1%)	7 (14.9%)		
Ethnicity				
Tiv	190 (95.5%)	9 (4.5%)	0.763	0.683
Idoma	95 (93.1%)	7 (6.9%)		
Igede	96 (94.1%)	6 (5.9%)		
Local Government Area				
Kwande	95 (96.9%)	3 (3.1%)	1.565	0.667
Ogbadibo	95 (93.1%)	7 (6.9)		
Oju	97 (94.2%)	6 (5.8%)		
Ushongo	94.0%)	6 (6.0%)		
Years of Experience in Managing Economic Trees				
0–5 years	25 (100.0%)	0 (0.0%)	2.010	0.734
6–10 years	83 (94.3%)	5 (5.7%)		

Variable	Termite Infestation		χ^2	P-Value
	Yes (%)	No (%)		
11–15 years	145 (94.2%)	9 (5.8%)		
16–20 years	79 (95.2%)	4 (4.8%)		
Above 21 years	49 (92.5%)	4 (7.5%)		
Total	381 (94.5%)	22 (5.5%)		

4. Discussion

This study shows high infestation of termites in orchards and plantations across the study locations and this infestation can strongly affect yield with resultant yield losses. The overall infestation rate of 23.7% reported in this study indicate that termites are becoming serious pest of economic trees. Similar infestation rates have been reported elsewhere in Nigeria [9, 22] (Elechi et al., 2022, Oyedokun et al., 2023) and other countries [27, 17, 5] (Sonko et al., 2020, Kissi et al., 2022, Debelo 2020). Some of these studies attributed the rising infestation rates of termites to deforestation. This can also be applicable to our study locations where forests are shrinking at an unprecedented rate and depriving termites of their alternative habitat and food resources, consequently they are finding refuge in man-made plantations. Other anthropogenic effects such as urbanization, and a higher demand for timber increases pressure on remaining trees and can disrupt termite habitats, leading to a shift in their focus onto managed plantations and other economic trees [5, 10] (Debelo, 2020, Fajar et al., 2021). Though some studies are attributing the emerging termite crises to climate change which creates more favorable dry, savannah-like conditions across the African continent.

Termite species encountered in these locations seem to be widespread in Nigeria and other west African countries. *Microtermes bellicosus, M. malaccensis and Odontotermes pauperans* were the most predominant species collected from infested trees. This finding corroborates earlier studies [22] in cashew, [8] and [17] in cocoa, [1] in Gmelina, [3] in *Azadirachta indica*, and [27] in mango. Members of the Genus *Microtermes* have also been reported in teak plantations in Indonesia [10]. The wide distribution of these species can be attributed to abundance of dietary resources all year round and development of specialization to specific dietary resources. The three major species are known for their foraging galleries made of soil sheeting on plant surfaces as observed in this study. These galleries are used to cover the biomass of the plants being consumed. Species like *Microtermes* in particular are known for attacking trees from their roots and tunneling to the stem with the leftover cavity filled in by soil [10].

Termite damage to tree bark has often been underestimated and not considered when determining the overall productivity of the tree. Tree barks are vital since they protect the phloem layer, which is the vascular tissue in charge of transporting and distribution of organic nutrients. Termite-related scratches or damage on the bark can damage the tender phloem layer, which can cause tree death or open a pathway for tree diseases. Termites consume the cellulose in tree tissues like stems, roots, and branches, which disrupts the movement of water and nutrients, weakening the tree and potentially leading to its death [19]. Overall, the trunk damage done by termites observed in this study are severe with stem distortions of varying degrees. These damages could be responsible for the perceived low productivity and losses reported by plantation owners. Further studies may be necessary to directly link termites-related damages to fruit tree productivity and other economic implications. Though there are abounding evidences to indicate annual losses in termites-infested tree, Termites especially *Amitermes evucifer* distinctly infested the dead parts of the trees through soil inter-phase mostly stem bark resulting to dead branches [3, 18]. In addition, Termite infestation in fruit trees has also led to significant losses including reduced fruit yield, tree death, and damage to structural integrity [9]. These damages can be more severe, especially in monocultures as seen in orchards in Benue State.

Palm produce like palm oil and palm wine, oranges and mango are major agricultural commodities in Benue state, Nigeria. These crops are products of strategic importance for economic and social development, as well as an important instrument in the fight against poverty. Oranges, mango and palm oil sale accounts for 30% of the farmers' earnings [7]. Nigeria is the leading producer of mango in West Africa [27] and Benue State is the leading producers of mango in Nigeria. These fruits trees employ about 700,000 farmers and provide a livelihood for around 1.5 million people in Benue State alone [15]. The remarkable productivity of these plants is significantly compromised by the presence of termite and other pests. Termites are one of the major scourges of tropical agriculture and agroforestry, damages caused by termites are considerable, and costs of control are estimated at over 22 billion euros each year [30, 29, 13].

4.1. Economic Cost of Termites' Infestation and Control

Management of termites are difficult to manage due to their dynamic living strategies, most of the species live in underground nests with ramification of galleries, so it is rather difficult to locate and reach them. One of the major challenges faced by farmers in Benue State is the difficulty in reaching the location of the termite nest which are sometimes built on top of trees. The economic cost of termite control in plantations varies but includes expenses for preventative measures like pesticide application and other cultural control measures. The cost of losses from damage if infestations are not controlled could be enormous. Factors influencing the final cost include the size of the plantation, the severity of the infestation and the type of control [10]. Current choice of termite control in our study locations is heavily skewed towards application of pesticides, the over reliance on pesticides by farmers in Benue State pose a possible risk for pesticide residue. There has been a growing concern from the international community on high levels of pesticide residue in fruits imported from Africa. Over $362 million worth of Nigeria's food exports are rejected overseas because of pesticide residues [14], while back home, millions of people unknowingly consume chemicals that are already banned elsewhere. In addition to pesticide residue, the reinfestation of orchards after pesticides application is providing a cause for concern. There are emerging research inquiries on whether termites are developing resistance to pesticides [4, 23] On the other hand, a significant number of plantation owners do not deploy any form of control for lack of capacity and knowledge of what to do. The justification to adopt any type of control is guided by anticipated profit and reducing the spread of infestation within the plantation.

4.2. Termites-related Knowledge and Practices

Despite the significant roles of termites in tropical ecosystems and the damage they cause mainly to crops and forestry, farmers' perception and management of termites is influenced by traditional norms, local experience and indigenous knowledge. Some of their control practices are based on erroneous perceptions and too cumbersome to be applied on a large scale. For instance, farmers in parts of Bauchi State in Northern Nigeria use a mixture of cow urine and pepper against termites on their farms [13]. Our finding indicate that farmers have sufficient knowledge of termite ecology, however there are areas in which farmers' knowledge is deficient and their control practices are ineffective. The implication for this is to exploit the traditionally effective control measures while encouraging the adoption of more effective measures. Farmers in Benue State have moderate tolerant attitude towards termites' infestation in their orchards, this corroborates findings in [24] in East and Southern Africa. The application of various ineffective indigenous control practices is the reason why majority of farmers assessed their current control efforts as ineffective. [6] reported that insights on farmers' perception may also provide the bases for addressing the needs and constraints of farmers. The prospects of integrating indigenous termite control practices into integrated termite management programmes looks promising because it can limit the use of pesticides and focus on using locally available materials with insect repellant properties. These practices may be promoted not only for the benefit of the people but also for maintaining agricultural sustainability and ecological balance [2].

To mitigate the effect of termite damage on trees, there is a need for periodic destruction of termite mounds in and around orchards. Others have recommended clearing and exposing termite galleries and runways to outside disturbances, which discourages termites from expanding their foraging areas [10]. This study justifies the need to build the capacity of farmers to deploy more effective integrated control practices.

5. Conclusion

We investigated termite diversity, infestation rates on economic trees and plantation owners' practices and perception in a major fruit producing State in Nigeria. Three predominant species *Microtermes bellicosus, M. malaccensis and Odontotermes pauperans* were collected and termite assemblages on plantations progressively increased with plantation age. We discovered varying degree of stem damages resulting from termite infestation with consequent reduction in yield and additional expenditures invested control activities. We also found an overwhelming reliance on pesticides to control termites' infestation with an appreciable number not deploying any control effort for lack of technical capacity. Furthermore, our results indicated that termite attacks on trees results in financial losses to farmers thereby threatening food security and jeopardizing socio-economic development. We also observed that farmers termite-related perceptions are significantly influenced by local experience and indigenous knowledge resulting to some ineffective control efforts.

6. Recommendation

The outcomes of this study justify the need for comprehensive farmer training programmes on sustainable termite management to improve productivity and promote environmentally friendly pest control practices focusing on education and utilization safer control options. There is also the need for further studies to determine the economic cost termite infestation on specific economic trees in order to attract more interventions.

Abbreviations

FGD	Focus Group Discussion
LGA	Local Government Authority
TETFUND	Tertiary Education Fund

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Conflicts of Interest

The authors declare no conflicts of interest.

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