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Author Affiliation:
[1]Department of Biological Sciences, Faculty of Biosciences, Federal University Wukari, Taraba State, Nigeria.
[2]Department of Crop Production and Protection, Faculty of Agriculture, Federal University Wukari, Taraba State, Nigeria.

***Corresponding author:**
Okrikata Emmanuel,
Department of Biological Sciences, Faculty of Biosciences, Federal University Wukari, Taraba State, Nigeria.
Email: okrikata@fuwukari.edu.ng

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Marketers' Perceptions on Economic Impact and Management Responses to Scale-like Hemipterous Pest Infestation in Wukari, Nigeria

Okrikata Emmanuel[1]*, Agere Hemen Ityodugh James[1], Adepoju Isaiah Olusesan[2], Isa Richard Terkuma[1]

ABSTRACT

Scale-like hemipterous pests are important postharvest insect pest that impacts yam quality, marketability, and profitability in Nigeria. Information on marketers' perceptions of their economic impact and management responses is limited. This study was thus designed to determine yam marketers' perceptions on economic losses, and management practices associated with scale insect infestation on yams in Wukari Yam Market, Taraba State, Nigeria. A survey (cross-sectional) was conducted between March and June 2026. Structured pre-tested questionnaires were administered through face-to-face interviews of 255 randomly selected yam marketers from an estimated population of 700 active marketers using the Yamane sample size formula. Economic losses were estimated from reductions in market prices of infested tubers relative to healthy tubers. Most respondents were male, economically active, and had more than five years of trading experience. Nearly all respondents (97.65%) believed that scale insect infestation reduced the economic value of yam tubers. The major perceived effects were shrinkage/weight loss (84.31%), dry and fibrous tissues (77.00%) and reduced food value (55.29%). Average price reductions of 19.69%, 48.84%, and 74.37% was recorded on lightly, moderately, and heavily infested tubers, respectively. More than half (51.59%) of the respondents believed that infestation shortened storage life. Synthetic insecticides were the predominant management option, being used by 95.29% of respondents, with an average monthly control expenditure of ₦18,525±24,427.59. Alternatives such as botanicals, wood ash, and sun-drying were not commonly used. Overall, scale insect infestation was found to be perceived as a serious socioeconomic challenge that goes beyond biological damage to substantial postharvest losses. We thus recommend the promotion of integrated pest management strategies which encompasses improved storage technologies, and safer alternative control measures to suppress scale insect induced postharvest losses and to improve the profitability and sustainability of yam marketing in the study area.

Keywords: Biological damage, Infestation, Marketing, Postharvest loss, Yam Scale insects.

1. INTRODUCTION

Yam (*Dioscorea* spp.) is a major tuber, food, and cash crop in West Africa which plays an important role in food security, income generation, rural livelihoods, and cultural traditions. It is also a major source of dietary carbohydrates, minerals, vitamins, and medicinal compounds for millions of people (Korada *et al*., 2010; FAOSTAT, 2023). Recent FAOSTAT (Food and Agriculture Organization Corporate Statistical Database) data reveals that annual yam production globally exceeds 88 million metric tonnes and Nigeria is the largest producer (FAO, 2024). In 2024, Nigeria produced about 65.3 million metric tonnes of yam. This output accounts for over 60% of global production which reinforces the crop's strategic importance to Nigeria's rural livelihoods and food systems (FAO, 2024).

Yam production and marketing face numerous pressures (biotic and abiotic) that reduce quality, market value, and profitability. Of these, Postharvest losses remain a major constraint (Adejo, 2017; Ajayi *et al*., 2021). Postharvest deterioration arising from insect pests, pathogens, poor handling practices, and inadequate storage facilities has been shown to cause substantial qualitative and quantitative losses (25% to 85%, depending on storage duration, environmental conditions, and pest pressure) with a resultant income reduction for value-chain actors (Adejo, 2017).

Of the major postharvest insect pests of yam, scale-like hemipterous pests (used broadly for the Coccoidea complex that includes armored scales, particularly *Aspidiella hartii* - Diaspididae, and mealybugs, including species of *Planococcus* - Pseudococcidae) have been reported to be a serious threat to the storage, quality, and marketability of yam tubers (Goergen *et al*., 2010; Salerno *et al*., 2018). They feed on tuber tissues through their piercing-sucking mouthparts. Heavy infestations result in shriveling, desiccation, reduced tuber weight, delayed sprouting, and increased susceptibility to secondary infections, resulting in reduced consumer acceptance and lower market prices (Korada *et al*., 2010; Salerno *et al*., 2018). A study carried out in Nigeria shows that yam scale insect infestation can cause up to a 36-50% reduction in the market value of yam stored, which leads to significant economic losses for yam producers, and traders (Ajayi *et al*., 2021).

Yam infestation with scale insect involves more than just a biological effect. Agricultural markets are inherently quality markets in which the customer's preferences and the prices are determined by the product's appearance, size, freshness and physical integrity. Therefore, deterioration related to infestation may have an impact on marketability through decreasing consumer demand, decreasing selling prices, increasing sorting and handling costs, and storage time. These effects are of particular importance to the traders, and marketers who may bear a significant economic risk due to postharvest quality losses (Fuglie, 2008). Previous studies have examined the prevalence, biology, and management of scale-like hemipterous pests. However, less attention has been given to the experiences, and perceptions of the marketers who are key intermediaries between production and consumption systems.

Assessing the marketers' perceptions is critical as it influences the decisions they make on adoption of pest management practices such as willingness to invest in improved storage technologies, and responses to market risks. Studies that have investigated these issues using a perception-based approach have demonstrated that awareness and understanding of pest problems can have a significant impact on the effectiveness of the pest control interventions. Furthermore, there is a lot of practical knowledge about pest occurrence, quality degradation, consumer preferences, and economic losses that cannot be fully captured by biological assessment (Umar *et al*., 2021). Hence, understanding marketers' perceptions of yam scale insect infestation will help to identify barriers to effective management and to accepting interventions.

Wukari Local Government area of Taraba State in Nigeria is known for enormous yam production, and the central Yam market in Wukari is a prominent yam trading centre. This is because the market plays a strategic role in regional yam supply by attracting wholesalers, retailers, transporters, and consumers from different parts of the country. Given the importance of Wukari as a major yam production, and marketing centre; infestations by scale insects could generate significant economic consequences across multiple segments of the value chain. Nonetheless, empirical data on Wukari yam marketers' perceptions of yam scale insect infestation, the magnitude of associated economic losses, and the management responses they adopt are hard to find.

While previous studies on yam scale insects focused largely on production constraints, storage practices, and biological aspects of their infestation; the perspectives of marketers' scale-like hemipterous pest infestation have apparently received little scholarly attention (Ajayi *et al*., 2021). This creates a critical knowledge gap because successful management strategies reasonably relies on understanding how market actors see the risks of pests, how they evaluate the economics, and how they react to challenges of infestation. Addressing this gap is significant in designing evidence-based interventions that can be implemented to mitigate postharvest losses, enhance yam quality, optimize market efficiency, and boost food security. Hence, this study is aimed at determining

yam marketers' perceptions on cost implication and management responses to yam scale insect infestation at Wukari yam market in Taraba State, Nigeria.

2. METHODOLOGY

Study Site

The study was conducted within March to June, 2026 in Wukari Yam Market located in Wukari Local Government Area (LGA) of Taraba State, Nigeria (Figure 1). Wukari is known as one of the major yam-producing areas in Nigeria. The Wukari Yam Market is a major yam trading centre in Nigeria because it is an important aggregation and distribution point for yam tubers sourced largely from the surrounding communities. The market attracts yam producers, wholesalers, retailers, transporters, and consumers from within and beyond Taraba State. The strategic importance of the market makes it an appropriate location for assessing marketers' perceptions on the impact of scale-like hemipterous insect infestations and their management responses.

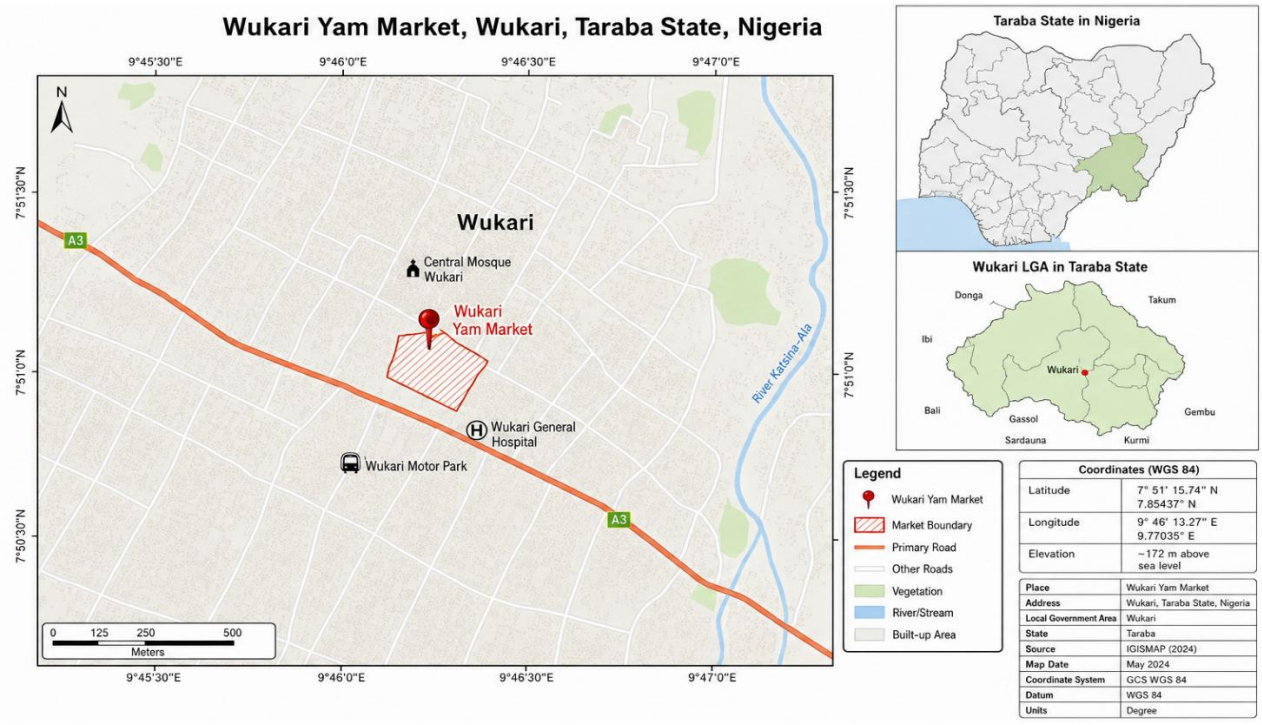


Figure 1. Map of study site (**Source:** IGISMAP, www.igismap.com, accessed on 14 July, 2026

Sample Size Determination and Sampling Technique

The target population consisted of approximately 700 yam marketers (wholesalers, retailers and commission agents) operating within the market. For inadequate of official data, the estimated 700 active marketers was determined through key informant interviews (n = 3) with marketers that have traded in the market for over 10 years supplemented by a random physical headcount conducted during peak operating hours (11am – 2pm) over 3 peak days – Mondays to Wednesdays.

The sample size (n) for the questionnaire survey was determined using the model of Yamane (1967) for a finite population:

$$n = N / [1 + N(e^2)]$$

Where:

n = required sample size,

N = population size, and

e = chosen level of precision at a 95% confidence level (0.05).

Using N = 700 and e = 0.05, a sample size (n) of 255 respondents (rounded to the nearest whole respondent) was obtained:

$n = 700 / [1 + 700 (0.05^2)]$

= 700 / [1 + 700 (0.0025)]
= 700 / (1 + 1.75)
= 700 / 2.75 = 254.545

Using a random procedure, eligible marketers (those who have participated in yam trading in the market for at least one year) who provided informed consent were approached for questionnaire interview. Where an eligible marketer declined participation, another was approached for replacement. To manage the busy market setting, respondents were approached during off-peak days (Thursdays to Saturdays), and at a time when they were less busy.

Questionnaire Design and Data Collection

Peer-reviewed structured questionnaire were administered by trained field assistants through face-to-face interviews. The interviews were however preceded by a pilot study on 25 yam marketers in neighbouring smaller markets. The feedback from the pilot study helped in the revision of some of the questions before the large-scale study commenced. The trained field assistants were proficient in English and local languages, and they used participatory Rural Appraisal (PRA) techniques (Chambers, 1994) to ensure inclusive participation. This was done by allowing respondents who had no formal education to contribute their knowledge. The field assistants visited the respondents in the market to conduct the interviews after obtaining informed consent (Figure 2).



Figure 2 A – F: Interactive sessions with Yam Marketers at Wukari Yam Market

List of Questions in the Questionnaire

Demographic Data:

1. Gender: Male [ ]. Female [ ].
2. Age: 10 - 20yrs [ ], 21 – 30yrs [ ], 31 – 40yrs [ ], 41 – 50yrs [ ], > 50yrs [ ].

3. Highest level of education:	Non-formal	[ ]
	Completed Primary school	[ ]
	Completed Secondary school	[ ]
	Completed Tertiary institution	[ ]

Marketers' Trading Experience and Sources of Yams Sold:

4. Years of yam trading experience in Wukari Market:
   1 - 5yrs [ ], 6 – 10yrs [ ], 11 – 15yrs [ ], 16 – 20yrs [ ], > 20yrs [ ].
5. Yams sold in the market are from (*Multiple responses allowed*): Wukari LGA [ ], Donga LGA [ ], Ibi LGA [ ], Takum LGA [ ], Gassol LGA [ ], Ukum LGA [ ], Jalingo LGA [ ].
   Others (Specify) _____
6. The major source of yams sold in the market is: Wukari LGA [ ], Donga LGA [ ], Ibi LGA [ ], Takum LGA [ ], Gassol LGA [ ], Ukum LGA [ ], Jalingo LGA [ ].
   Others (Specify) _____

Impact of Yam Scale Insect Infestation and Control:

7. What are the effects of infestation? (*Multiple responses allowed*).
   Dry and fibrous flesh [ ], Discoloration/whitish/brownish/light-grey substance [ ], Shrinkage/weight loss [ ], Rot [ ], Reduce market value [ ], Reduce food value [ ], Delays/Impairs sprouting [ ], Promotes sprouting [ ].
   Others (Specify) _____
8. Will you consume food prepared from infested tubers? Yes [ ], No [ ].
9. If No, why? (*Multiple responses allowed*)
   Loss of food value [ ]
   Fear of negative health impact [ ]
   Unattractive/Lacks appeal [ ]
   Others (Specify) _____
10. If ten tubers of yams, of a particular size, cost ₦10,000, how much will such yams cost if:
    a. It were lightly infested with scale insects ₦_____
    b. It were moderately infested with scale insects ₦_____
    c. It were heavily infested with scale insects ₦_____
11. Do infested tubers last as long in storage as healthy ones? Yes [ ], No [ ], Not sure [ ].
12. How do you control scale insect infestation during storage?
    No control measure taken [ ], Use of synthetic insecticides [ ], Sun-drying [ ],
    Use of botanicals/plant based insecticides [ ], Others (specify) _____
13. If you use control measures, what is the average cost of control/month? ₦ _____

General Comments

14. Over the years, is the infestation increasing? Yes [ ], No [ ].
    Reason:- _____

Marketer's Comments _____

Data Analysis

The data were analyzed using descriptive statistics (mean, frequencies and percentages). The economic losses associated with lightly, moderately and heavily infested tubers were expressed in naira (₦), and percentages on the basis of the selling price of ten un-infested tubers that cost ₦10,000.

3. RESULTS

Socio-demographic Characteristics of Marketers in Wukari Yam Market

Most (70.20%) of the respondents were males. Most of the respondents were economically active, with ≈ half (49.80%) within the 31-40-years age category. Next, was the 41-50 years category (27.8%). While a few yam marketers (1.57%) were 10 and 20 years of age, those that were > 50 years in age constituted 11.4% of the population. Yam marketing in the study area involves individuals with varying

educational backgrounds, as 17.65% of the respondents had tertiary education, and 30.20% and 30.59% had secondary and primary education, respectively. Approximately 21.57% of respondents had no formal education (Table 1).

Table 1. Socio-demographics of respondents as categorized by gender, age and highest level of education (n = 255)

Variable	Category	No. of Respondents	Percentage of Response
Gender			
	Male	179	70.20
	Female	76	29.80
Age			
	10 – 20 years	04	1.57
	21 – 30 years	24	9.41
	31 – 40 years	127	49.80
	41 – 50 years	71	27.84
	> 50 years	29	11.37
Highest educational level			
	Non-formal	55	21.57
	Primary school	78	30.59
	Secondary school	77	30.20
	Tertiary institution	45	17.65

Marketers' Trading Experience and Sources of Yam Supply

Table 2 shows that of the 255 respondents, only 50 constituting 19.61% had < 6 years trading experience. Majority of the respondents had substantial experience in yam trading. While 16.08% of the respondents had between 11 and 15 years of trading experience, about half (50.20%) had been in the yam business for 6 -10 years.

Yam supplies originated from Wukari and a number of surrounding Local Government Areas. However, Wukari LGA constituted the major source of marketed yams, with all respondents identifying it as their principal supply source. Other important supply LGAs included Ukum (45.10%) and Ibi (38.82%), while Donga, Takum, Jalingo and Gassol contributed relatively smaller proportions of marketed yams (Table 2).

Table 2. Marketers' trading experience and sources of Yams Sold in Wukari Market (n = 255)

Variable	Response	No. of Respondents	Percentage of Response
Marketers' trading experience			
	1- 5 years	50	19.61
	6 – 10 years	128	50.20
	11 – 15 years	41	16.08
	16 – 20 years	27	10.59
	> 20 years	09	3.53
Sources of yams sold[1]			
	Donga LGA	60	23.53
	Gassol LGA	08	3.14
	Ibi LGA	99	38.82
	Jalingo LGA	20	7.84
	Takum LGA	21	8.24
	Ukum LGA	115	45.10
	Wukari LGA	255	100
Major source of yams sold			
	Donga LGA	-	-

	Gassol LGA	-	-
	Ibi LGA	-	-
	Jalingo LGA	-	-
	Takum LGA	-	-
	Ukum LGA	-	-
	Wukari LGA	255	100

[1]Multiple responses allowed

Perceived Impact of Yam Scale Insect Infestation

Results in Table 3 shows that 97.65% of respondents reported that infestation diminished the economic value of yam tubers. Similarly, while 77.00% observed dry and fibrous flesh, 84.31% reported shrinkage/weight loss, apparently suggesting substantial adverse effects on tuber quality and marketability. More than half of the respondent (55.29%) believed that infestation suppressed food value of yam tubers while others believed that the impact of infestation includes delayed/impaired sprouting (39.61%), discoloration (23.14%), and rot development (34.51%).

Table 4 shows that 39.04% of the respondents reported that they would not consume infested tubers and most (69.39%) these cited reduced food value as the reason. The severity of infestation were believed to substantially reduce the selling price of yam tubers as lightly infested tubers were perceived to have a 19.69% price reduction (average selling price of ₦8,031.37). Moderately infested tubers; a 48.84% reduction in monetary value (average selling price of ₦5,115.69). The highest losses were reported in heavily infested tubers, which sold for an average of ₦2,562.75, representing a 74.37% reduction in market value. These findings apparently suggest a negative relationship between infestation severity and financial returns (Table 5). Infestation is widely believed to reduce the storage life of yam tubers as more than half of the respondents (51.59%) reported that infested tubers did not store as long as healthy tubers. While, 28.17% believed that infested and healthy tubers had similar storage duration, 20.24% were uncertain (Table 6).

Table 3. Perceived effects of yam scale insect infestation on yam quality and value (n = 255)

Effect[1]	No. of Respondents	Percentage of Response
Delays/impairs sprouting	101	39.61
Discoloration	59	23.14
Dry and fibrous flesh	197	77.00
Reduced food value	141	55.29
Reduced market value	249	97.65
Rot	88	34.51
Shrinkage/weight loss	215	84.31
Promotes sprouting	-	-

[1]Multiple responses allowed

Table 4. Willingness to consume infested yam tubers (n = 255)

Variable	Response	No. of Respondents	Percentage of Response
Will you consume infested tubers?*			
	Yes	153	60.96
	No	98	39.04
Reasons for non-consumption[1]			
	Reasons		
	Fear of health effects	32	32.65
	Reduced food value	68	69.39
	Unattractive appearance	23	23.47

*The total number of respondents is < 255 because 4 respondents did not provide response to the question; [1]Multiple responses allowed

Table 5. Monetary losses associated with different levels of infestation (Using mean selling price of 10 healthy tubers = ₦10,000; n = 255)

Level of infestation	Mean±SD selling price (₦)	Price reduction (₦)	Loss (%)
Lightly infested tubers	8,031.37±830.64	1,968.33	19.69
Moderately infested tubers	5,115.69±1,081,04	4,884.31	48.84
Heavily infested tubers	2,562.75±1,008.81	7,437.25	74.37

Table 6. Effect of infestation on storage longevity (n = 255)

Response*	No. of Respondents	Percentage of Response
Do not last as long as healthy tubers	130	51.59
Last as long as healthy tubers	71	28.17
Not sure	51	20.24

*The total number of respondents is < 255 because 3 respondents did not provide a response to the question

Adopted Control Measures and Perceptions of Long-term Infestation Trends

Table 7 shows that synthetic insecticides were the predominant management strategy used by 95.29% of the respondents. Other control methods were substantially less common and included sun-drying (8.24%), wood ash application (5.49%), combinations of wood ash and botanicals (5.10%), and botanical treatments alone (4.71%). Washing powder was rarely used (1.18%), while only 2.75% of the respondents reported not using any control measure. Expenditures incurred in managing scale insect infestations on yams varied widely among respondents (ranging: ₦3,000 to ₦100,000 per month). This indicates considerable variability in management intensity and associated costs. On the average, the monthly expenditure on scale insect management on yams was reported as ₦18,525±24,427.59 (Table 8). Results in Table 9 shows that the marketers have different perceptions on changes in infestation prevalence over time. More than half (53.82%) believed that yam scale insect infestation had not increased over time, approximately one-quarter (24.10%) perceived an increase in infestation levels, and 22.09% were uncertain about long-term trends.

Table 7. Control measures used against yam scale insects (n = 255)

Control method[1]	No. of Respondents	Percentage of Response
Botanicals	12	4.71
Sun-drying	21	8.24
Synthetic insecticides	243	95.29
Washing powder	03	1.18
Wood ash	14	5.49
Wood ash + Botanicals	13	5.10
No control	07	2.75

[1]Multiple responses allowed

Table 8. Average monthly cost of yam scale insect management (n = 255)

Variable	Mean±SD monthly cost (₦)	Minimum cost (₦)	Maximum cost (₦)
Monthly cost of control	18,525±24,427.59	3,000	100,000

Table 9. Marketers' perception of long-term infestation trends (n = 255)

Response*	No. of Respondents	Percentage of Response
Increasing	60	24.10
Not increasing	134	53.82
Unsure	55	22.09

*The total number of respondents is < 255 because 6 respondents did not provide a response to the question

4. DISCUSSION

The predominance of male marketers in this study agrees with the male-dominated nature of yam marketing in many parts of West Africa, where men traditionally dominate the production and wholesale trade of yam, while women participate more actively in retail marketing. Similar gender patterns have been reported in different Nigerian agricultural value chains, where access to land, capital, and transportation apparently favors male participation (FAOSTAT, 2022). The high proportion of respondents within the economically active age group (largely, 31 – 40 years) and with several years of marketing experience (> 5 years) suggests that respondents possessed substantial practical knowledge of yam quality deterioration and market dynamics, which increases the reliability of their perceptions.

Respondents overwhelmingly believed that yam scale insect infestation reduced tuber quality and market value, with almost all respondents (97.65%) indicating that infestation diminished economic value. Importantly, however, 'scale insect infestation' is used in this study to denote a perceived Coccoidea pest complex rather than infestation by any taxonomically confirmed species. This perspective is plausible as Coccoidea comprises several insect families such as Diaspididae (armoured scales) and Pseudococcidae (mealybugs) which can co-infest occur on yam tubers and whose symptoms of infestations are superficially similar. In Benin, Goergen *et al*. (2010) documented *Aspidiella hartii* and *Planococcus* spp. on infested yam tubers, demonstrating the biological plausibility of the problem reported by respondents. However, because the present study relied on questionnaire data rather than the collection and examination of specimens, it cannot establish the identity, relative abundance, or distribution of the taxa associated with the reported symptoms. To resolve these uncertainties, a direct specimen collection and morphological identification, potentially complemented by molecular methods is required (Korada *et al*., 2010; Watson *et al*., 2021).

The perceptions expressed in this study are in tune with the biology of scale insects infestation on yams (*A. hartii*, in particular) whose feeding activities damage yam tubers by extracting cellular contents, resulting in desiccation, shrinkage, development of corky tissues, and deterioration of storage quality (Salerno *et al*., 2018; Ajayi *et al*., 2021). Studies conducted by Hahn *et al*. (1987); Jatala and Bridge (1990) and Coyne *et al*. (2018) reveal that infestation by scale insects reduces tuber appearance, market acceptability, and storage performance, resulting in considerable postharvest losses in yams. Goergen *et al*. (2010) also reported that scale insect feeding causes extensive physiological deterioration of yam tubers. These assertions are buttressed by a very high proportion of our respondents who reported shrinkage, dry fibrous tissues, and reduced food value as impacts of infestation. Apparently scale insects cause not only a reduction in nutritional and sensory value of tubers, but also impair market competitiveness as a result of feeding that causes weight loss, shriveling and necrosis of tuber tissues. The relationships between insect-induced tissue damage and economic depreciation have also been reported for a few tropical root and tuber crops (Kumar and Kalita, 2017; FAO, 2019).

A particularly interesting finding of this study was the decrease in market value as severity of infestation increased. We noted that tubers with light infestation losses roughly 1/5 of its market value while tubers with heavy infestation losses about 3/4. This is a clear economic gradient that shows the direct link between biological damage and economic losses. Economic evaluations of postharvest insect damage have been previously conducted, and the visible defects in the products have been found to have a significant impact on the decision to buy the product, with disproportionately high decreases in selling price (Kitinoja *et al*., 2011; Affognon *et al*., 2015; Ajayi *et al*., 2021). Such losses can be very disturbing to marketers who rely on yam marketing for their livelihood. Our finding agrees with that of Salerno *et al*. (2018) and Ajayi *et al*. (2021) who reported that scale insects can cause considerable damage to yams leading to 16% to 50% market-value loss.

Around 61% of our respondents said they would eat tubers if they were infested. However, a substantial proportion disagrees, mainly for perceived loss of quality and health risks. These perceptions are important as consumer confidence directly influences purchasing behavior whether or not infestation poses direct health risks. Nutritional quality is often not the most relevant criterion in purchasing decisions of agricultural products. Appearance is often more influential (Kader, 2005; FAO, 2019). As such, consumers tend reject agricultural products that are visually impaired (Behler *et al*., 2024). Over 50% of the respondents reported that infested tubers had a shorter storage period, which corroborates the reported knowledge that insect feeding predisposes stored tubers to secondary microbial invasion and causes increased moisture loss, leading to a reduced storage period, while at the same time causing rot to the tubers (Ajayi *et al*., 2021). Amusa *et al*. (2003) and Ray and Ravi (2005) reported that the mechanical injury caused by the feeding activity of insects allowed the colonization of fungi and bacteria which caused progressive deterioration during storage. This not only contributes to direct postharvest losses but also restricts marketers' ability to take advantage of seasonal price fluctuations to earn profits.

Another significant findings in this study, is the rampant usage of synthetic chemical insecticides for scale insect management by marketers. Respondents reported using a variety of products including a very few botanicals, and wood ash (traditional practice), while

an overwhelming majority (≈ 95%) reported using synthetic insecticides. This trend indicates that marketers believe synthetic pesticides are the most effective management technique, despite the rising worries about pesticide residues, exposure of workers, contamination of the environment, and the emergence of insecticide resistance. Recently, calls around the world for the adoption of Integrated Pest Management (IPM) strategies have been heightened. The aim is to integrate biological control, cultural practices, resistant cultivars, better storage methods and safer botanical pesticides in order to suppress reliance on synthetic pesticides (Sparks and Nauen, 2015; FAO and WHO, 2024). The limited adoption of alternative management strategies observed in the present study indicates considerable opportunities for extension programs to promote sustainable pest management technologies. The use of alternative suppressive strategies such as storing tubers, in sawdust, or sand has been shown to provide 86.5% and 92.3% success, respectively in India (Ajayi *et al*., 2021). Subjecting these and other alternative options to trials in the study area may be helpful. This is critical as the misuse and use of obsolete synthetic insecticides have been reported to cause yam poisoning in some parts of Kano, and Ilorin in Nigeria (Adedoyin *et al*., 2008; Adeleke, 2009).

The large difference in monthly cost of infestation management is due to differences in the intensity of infestation, the size of the trade, and personal approach to infestation management. Control costs represent extra expenses for many marketers, and further cut profit margins that are being eroded by market losses from infested crops. These direct and indirect economic losses demonstrate a wider socioeconomic impact of yam scale insect infestation in the yam value chain. Interestingly, despite the fact that over half felt that infestation had not increased over time, about a quarter felt that infestations were getting worse over time. This difference in opinions could be attributed to spatial variability of infestation pressure, difference in climatic conditions, improvement in pest management practices, or the difference in the experience of the respondents. Such discrepancies been documented in agricultural systems highlighting the need for stakeholder perceptions to be complemented by field-based surveys for determining pest dynamics more accurately (Bentley, 1994; Srinivasan *et al*., 2022).

Overall, our results indicate that scale insect infestation is an important socioeconomic constraint that affects the quality of the yam, storage efficiency, market value and the livelihoods of yam marketers. In Nigeria, especially in Wukari, strengthening IPM programmes, better postharvest storage technologies, adoption of better alternative control technologies, and extension education could significantly reduce postharvest losses, and increase the profitability and sustainability of the yam marketing system.

5. CONCLUSION

Our study showed that yam marketers are aware that scale insect infestation is a crucial postharvest constraint in the yam value chain in Wukari, Nigeria. Infestation was found to be strongly linked with the deterioration of the tuber quality, short storage life, significant loss of market value and higher management costs. It was also observed that as infestation increased, so did the economic losses. The ubiquity of synthetic insecticides highlights the need for more and safer ways of managing insects. Our overall findings indicate infestation by hemipterous scale-like insects is not only an entomological problem, but also a socio-economic constraint that has negative impact on food quality, storage efficiency, market-value and yam marketers' livelihood. Improving postharvest storage technologies, promoting safer alternative control methods, strengthening IPM programs, and enhancing extension education could substantially reduce postharvest losses and improve the profitability and sustainability of yam marketing systems in Wukari, and Nigeria in general.

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Author Contributions

Okrikata Emmanuel and Agere Hemen Ityodugh James conceptualised, developed the methodology and supervised the execution of the research. Isa Richard Terkuma prepared the draft manuscript. Adepoju Isaiah Olusesan reviewed the draft manuscript and Okrikata Emmanuel submitted the manuscript.

Informed consent

Written & Oral informed consent was obtained from individual participants included in the study.

Conflicts of interests

The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical approval & declaration

The study was done in conformity with ethical guidelines. Participation was entirely voluntary, and all respondents provided informed consent. The participants' anonymity and confidentiality were ensured, and the data obtained were utilized purely for the study. The ethical guidelines for Human Subjects are followed in the study.

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Data and materials availability

All data associated with this study are present in the paper.

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