

IMPROVING PEST CONTROL OF VEGETABLE CROPS: LEVERAGING ARTIFICIAL INTELLIGENCE, INNOVATION AND CREATIVITY TO ENHANCE NIGERIAN ECONOMY.

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Abstract

Pest infestations pose a significant threat to vegetable crop production in Nigeria, leading to substantial yield losses, reduced farmer income, and food insecurity. Traditional pest control methods, often relying heavily on synthetic pesticides, present environmental and health concerns. 1 This article explores the transformative potential of integrating Artificial Intelligence (AI), innovative technologies, and creative approaches to revolutionize pest management in Nigerian vegetable farming. By enabling precision agriculture, early detection, targeted interventions, and sustainable practices, these advancements can significantly reduce crop losses, boost productivity, enhance food quality, and ultimately contribute to a more robust and resilient Nigerian economy. The researchers recommended that (i)since lack of comprehensive and standardized agricultural data (pest incidence, weather, soil data) is a significant hurdle for training robust AI models. There is need to establish national agricultural data collection centers and initiatives to encourage data sharing among farmers and researchers. (ii)Due to shortage of skilled personnel in AI, data science, and precision agriculture technologies there is need for the development of specialized training programs, vocational schools, and university curricula focusing on agri-tech. (iii)Due to high cost of technical equipment, the initial investment in AI and advanced technologies can be expensive for smallholder farmers therefore government should encourage subsidies, credit facilities, and the promotion of cooperative farming models to share technology costs. Encouraging local manufacturing of components to reduce import costs.

Keywords: Artificial Intelligence, environmental degradation, pesticide residues, 4R-based pest management strategies, smart farming.

Introduction

Agriculture has been one of the stronghold of Nigerian Economy, supplying the food and food products for the teaming population. Nigerian agricultural sector according to Saidu & Tafa (2016) has faced numerous challenges including neglect due to the dominance of oil industry. Low yield in agriculture has caused food insecurity and high cost of crops. Vegetable crops as one of the agricultural produce contribute immensely in the Nigerian agricultural sector by providing essential nutrients, employments and income for many households. Kariyanna & Sowjanya (2024) stated that insect pest is well known as one of the major global sources of agricultural damage. Agricultural pest poses persistent threat accounting to much yield loss annually posing significant threat to agri-food production, resulting in average worldwide crop yield losses of 40% depending on the crop (Junaid and Gokce, 2024)

Solutions to this menace of pest by prevention and management can lower agricultural losses (Ahmed & Hussain, 2018). The conventional approach to pest control in Nigeria often involves the indiscriminate use of chemical pesticides. Though pesticide gives immediate relief to pest control, the practice has raised concerns about environmental degradation, pesticide residues in food, development of pest resistance to pesticides and other health hazards to farmers and consumers. The losses attributable to insect pests undoubtedly have the potential to be aggravated if unchecked, especially with dramatic climate events such as unusual rainfalls or severe drought, which may result in increased pest populations (Ofuya, 2003). The urgent need for sustainable and efficient pest management strategies in Nigeria is undeniable. This article posits that the synergistic application of Artificial Intelligence (AI), innovative technologies, and creative problem-solving can provide a paradigm shift in vegetable crop protection, moving beyond reactive chemical interventions to proactive, data-driven, and environmentally conscious solutions. Such a transition holds immense promise for enhancing agricultural productivity, improving food quality, and strengthening the overall Nigerian economy.

There is an undeniable urgent need for sustainable and efficient pest management strategies using artificial intelligence and other innovative technologies to transform pest control in Nigerian vegetable farming.

Vegetable crops and insect pest

According to Zhang, 2018 insect pests are the major causes of crop yield losses around the world though pest management plays a critical role in providing food security and farming income. It was also estimated that global losses in vegetable production amounts to 27.7% of which 8.7% is attributable to insect pests that have the potential to cause more losses if unchecked (Ofuya, 2003). James, Atcha-Ahowe, Godonou, Baimey, Goergen and Sikirou R (2010) outlined vegetables cultivated abundantly among farming communities in Nigeria. These includes the commonly cultivated vegetables cultivated for their edible fruits (fruit vegetables): Vegetable crops are cultivated abundantly in Nigeria among farming communities. The commonly consumed vegetables include those cultivated for their edible fruits (fruit vegetables): *Trichosanthes cucumerine* L. (snake gourd), *Abelmoschus esculentus* (L.) Moench (okra), *Solanum melongena* L. (eggplant or garden egg), *Capsicum frutescens* L. (chilli pepper), *Capsicum annum* L. (sweet chilli pepper), *Lycopersicon esculentum* L. (tomato), *Cucumis sativus* L. (cucumber), *Citrullus lunatus* (Thumb.) (watermelon) and *Citrullus colocynthis* (L.) Schrad (egusi melon). Vegetables grown for their edible leaves and succulent shoots (leaf vegetables) include *Amaranthus hybridus* L. (green amaranth), *Celosia argentea* L. (plumed cockscomb or silver cockscomb), *Cucurbita maxima* Duchesne (squash), *Cucurbita pepo* L. (field pumpkin) *Telfaria occidentalis* Hook.f. (fluted pumpkin), *Hibiscus sabdariffa* L. (roselle), *Corchorus olitorius* L. (Jew's mallow), *Basella alba* L. (Indian spinach), *Crassocephalum bialfrae* S. Moore (worow), *Talinum triangulare* (Jacq.) Willd. (Water leaf) and *Vernonia amygdalina* Delite (bitter leaf). *Brassica oleracea* L. (cabbage) and *Lactuca sativa* L. (lettuce) are introduced leafy vegetables that are increasingly being cultivated in West Africa. Root vegetables include *Daucus carota* (Hoffm.) (carrot), *Allium cepa* L. (onion), *Allium sativum* L. (garlic), *Zingiber officinale* Roscoe (ginger) and *Curcuma longa* L. (turmeric).

These vegetables being cultivated in different geographical areas of the country were being affected by many pest among which are presented on the table 1 below from the studies of the following authors; Nigerian Federal Ministry of Agriculture and Natural Resources and the Overseas Development Administration of the British Government (1996), Daramola (1984), Annual report on horticulture (1988), Umeh, Kuku, Nwanguma, Adebayo and Manga (2002), Banjo, (2006), Fasunwon and Banjo, (2010), Imam, Yusuf and Mukhtar (2010), Anjorin, Jolaoso and Golu.,(2013), Alao , Adebayo and Olaniran,(2016), Suleiman,(2016), Agwu , Odo , Ekeh , Attamah, Uwagbae and Eze, (2018), Odewole, Adebayo, Olaniran, Akanbi and Olusegun.,(2018), Nair (2019), Uchechukwu (2020) and Dimkpa(2021)

Table 1. Major insect pests of some vegetable crops in Nigeria.

Vegetable Crop	Insect Pest		
	Common Name	Scientific Name	Damage
<i>Abelmoschus esculentus</i> (Okra)	Flea beetles	<i>Podagrica</i> spp.	Adults cause leaf holing
	Cotton Leafworm	<i>Spodoptera litoralis</i> Boisduval	Larvae feed on leaves leading to reduced yield
	Cotton Stainer Bug	<i>Dysdercus</i> sp.	Nymphs and adults attack fruits causing shrivelling and seed loss.
	Giant Coreid Bug	<i>Anoplocnemis curvipes</i> Fabricius	Nymphs and adults feed on new growth and developing fruits.
	Cotton Bollworm	<i>Helicoverpa armigera</i> Hubner	Larvae bore into buds and fruits, causing loss
<i>Solanum melogena</i>	Stem Borer	<i>Euzophera sharmotana</i> Rougeot	Larvae bore into fruits, causing loss.
(Eggplant)	Egg Fruit Borers	<i>Daraba laisalis</i> Walker	Larvae bore into fruits causing loss aided by

Vegetable Crop		Insect Pest	
	Common Name	Scientific Name	Damage
<i>Capsicum</i> spp. (Peppers)	Whitefly	<i>Bemisia tabaci</i> Gennadius	pathogenic attack. Transmits Pepper Veinal Mottle Virus (PVMV) that can reduce yield
	Peach-potato Aphid	<i>Myzus persicae</i> Sulzer	Insect feeding distorts young leaves and shoots. May transmit PVMV.
	Medfly	<i>Ceratitis capitata</i> Wiedermann	Larvae damage fruits and predispose them to fungal attack.
<i>Lycopersicon esculentum</i> (Tomato)	Fruit Borer	<i>H. armigera</i> Hubner	Larvae bore into fruits causing damage and predisposes them to fungal attack.
	Whitefly	<i>B. tabaci</i> Gennadius	Nymphs and adults feed on the underside of leaves, transmit viruses
	Cotton Leafworm	<i>S. litoralis</i> Biosduval	Larvae eat leaves, reducing leaf cover and yield
	Variegated grasshopper	<i>Zonocerus variegatus</i> Linnaeus	Defoliation by nymphs and adults
<i>Cucumis sativus</i> (Cucumber)	Crucifer flea beetle	<i>Phyllotreta cruciferae</i> Goeze	Defoliator

Vegetable Crop		Insect Pest	
	Common Name	Scientific Name	Damage
	Spotted Cucumber beetle	<i>Diabrotica undecimpunctata</i> Howardi Barber	Defoliator
	Hadda Beetle	<i>Epilachna vigintioipunctata</i> Fabricius	Adults and larvae feed on plant leaves
	Skeletonizing Leaf Beetles	<i>Monolepta</i> spp.	Skeletonises leaves
	<i>Citrullus lunatus</i> (Watermelon) Pumpkin Flies	<i>Dacus bivitattus</i> (Bigot) <i>D. brevistylus</i> Bezzi	Larvae feed around the developing seeds in the fruit. Attack is usually followed by secondary rots.
<i>C. colocynthis</i> (Egusi melon)	Melon Fly	<i>Bactrocera cucurbitae</i> Coquillett	Larvae bore and eat into fruits, often destroying young fruits. Fruits are contaminated with frass and secondary attack by bacteria and fungi facilitated.
	Ladybird Beetle	<i>Epilachna</i> spp.	Adults and larvae attack and skeletonise leaves.
	Cotton Aphid	<i>Aphis gossypii</i> Glover	Adults and nymphs suck sap reducing growth and may transmit viruses.
<i>Amaranthus</i> spp. (Green Amaranths)	Green Stink Bug	<i>Nezara viridula</i> Linnaeus	Adults feed on flowers and

Vegetable Crop		Insect Pest	
	Common Name	Scientific Name	Damage
			seed heads, causing discoloration, shrivelling and premature drying of seeds, and reducing seed yield and viability
	Cotton Stainer Bug	<i>Dysdercus supersitiosus</i> Fabricius	Same as for Green Stink Bug
	Stink Bug	<i>Aspavia armigera</i> Fab.	Adults and nymphs suck leaf sap leaving clear spots on leaves
	Variegated grasshopper	<i>Z. variegatus</i> F.	Eats up foliage, reducing yield.
	Maize moth	<i>Spoladea recurvalis</i> F	Larvae feed on and skeletonise leaves, resulting in yield loss
	Leaf Webber	<i>Psara bipunctalis</i> Fabricius	Larvae cause webbing and damage to leaves, resulting in yield loss.
<i>Corchorus olitorius</i> (Jew's Mallow)	Flea Beetles	<i>Podagrica</i> spp.	Adults attack leaves creating numerous small holes
	Leafworm	<i>Acraea</i> spp.	Larvae skeletonise leaves.
	Grasshoppers	Various species	Adults and nymphs feed on foliage.

Vegetable Crop		Insect Pest	
	Common Name	Scientific Name	Damage
<i>Hibiscus sabdariffa</i> (Roselle)	Whitefly	<i>B. tabaci</i> (Genn.)	Feed on leaf tissue and may transmit viruses
	Cotton Aphid	<i>A. gossypii</i> Glover	Adults and nymphs suck plant sap and may transmit viruses.
	Flea Beetles	<i>Podagrica</i> spp.	Leaf holing
	Spiny Bollworm	<i>Earias insulana</i> (Boisd.)	Larvae feed on swollen calyces and capsule wall of fruits.
	Leafhopper	<i>Empoasca</i> spp.	Xylem feeding insects and may transmit several destructive pathogens
<i>Vernonia amygdalina</i> (Bitterleaf)	Bitterleaf weevil	<i>Lixus camerunus</i> Kolbe	Stem tunnelling and galling and lodging caused by larvae.
	Grasshopper	<i>Zonocerus</i> spp.	Adults and nymphs feed on leaves.
	African mole cricket	<i>Gryllotalpa africana</i> Palisot de Beauvois	Feed on stems at and below ground level
	Coreid bug	<i>Anoplocnemis curvipes</i> Fab.	Adults and nymphs feed on young shoots
<i>Brassica oleracea</i> (Cabbage)	Cabbage Aphid	<i>Brevicoryne brassicae</i> L.	Adults and nymphs feed on sap and cause stunted and distorted growth; leaves

Vegetable Crop		Insect Pest	
	Common Name	Scientific Name	Damage
<i>Daucus carota</i> (Carrots)	Variegated Grasshopper	<i>Z. variegatus</i> L.	disfigured with exuviae and sooty moulds. Nymphs and adults defoliate plants
	Cotton Leafworm	<i>S. littoralis</i> Biosd.	Larvae defoliate plants
	Diamondback Moth	<i>Plutella xylostella</i> L.	Larvae defoliate plants
	Carrot root fly	<i>Psila (Chamaepsila) rosae</i> Fabricius	Holes in the centre of the carrot root. The outside of the carrot will have black blemishes, usually in rings around the carrot's root.
	Aphids	Several species	Distort foliage, stunt growth and can kill young plants.
<i>Allium cepa</i> (Onions)	Turnip moth	<i>Agrotis segetum</i> Denis & Schiffermuller	Larvae (caterpillars) damage edible roots.
	Onion Thrips	<i>Thrips tabaci</i> Linderman	Adults and nymphs feed on plant sap, causing white spots on the leaves; infested plants may wilt and die.
	Cotton Leaf Worm	<i>S. littoralis</i> Biosd.	Larvae defoliate plants, causing a reduction in

Vegetable Crop		Insect Pest	
	Common Name	Scientific Name	Damage
<i>Zingiber officinale</i> (Ginger)	Crickets	Various species	bulb size and weight. Eat up bulbs
	Shoot Borer	<i>Conogethes punctiferalis</i> Guenee	Bores holes in pseudostem. Frass is thrown out of the holes and central shoot becomes yellow and withers.
	Rhizome Flies	<i>Colabata</i> spp.	The larvae bore into the rhizome and feed on it.
	Leaf Roller	<i>Udaspes folus</i> Cramer	Larvae feed and fold the leaves. Can result in complete defoliation.
<i>Curcuma longa</i> (Turmeric)	Rhizome Scale	<i>Aspidiella hartii</i> Cockerell	They suck sap from rhizomes and cause them to shrivel and dry up
	Shoot Borer	<i>C. punctiferalis</i> Guen.	Larvae bore into rhizomes and feed on it.
	Leaf Roller	<i>U. folus</i> Cramer	Larvae cause leaf folding and feed within.
	Yam Scale	<i>Aspidiella hartii</i> Cockerell	The scales damage the rhizomes both in field and storage.

Pest control of vegetable crop

Pest control is very important in vegetable crop production for better yield. Right pest identification which is the precise recognition of pest species, its developmental stages and population dynamics in any agricultural environment is very important. For effective pest management, there should be accurate pest identification so as to ensure that control measures adhered to targets the correct species. Misidentification can lead to ineffective pest control, unnecessary use of pesticides and disruption of beneficial insects that are friendly to farmers mistaking them as harmful. For accurate and effective identification there should be an understanding of pest behavior, activity pattern and the agroecology which determines how they interact with crops and respond to environmental conditions.

Artificial intelligence (AI) in vegetable crop pest control

According to Omankwu, Etuk and Musa, (2024) Crop monitoring is crucial for maintaining high yields and ensuring food security. AI models, particularly those based on deep learning, have been effective in identifying early signs of stress in crops. AI models successfully predicted pest outbreaks earlier than traditional methods, allowing for timely interventions, which led to a reduction in pesticide use. Accurate pest recognition and identification serve as the essential foundation for implementing precise 4R-based pest management strategies (4R- right identification, right method, right timing and right action). Gong and Diao (2025) stated that AI which leverages computational power to mimic human behavior encompasses a variety of techniques, including machine learning, computer vision, and robotics, which are applied to various agricultural tasks. For instance, AI-driven models can predict crop diseases before they spread, optimize irrigation schedules based on real-time data, and analyze soil quality to guide fertilization (Kamilaris & Prenafeta-Boldú, 2018). These applications not only enhance productivity but also promote sustainable farming by reducing resource use and environmental impact.

AI presents a promising opportunity to improve pest identification through the use of computer vision and ML, this is because AI-powered systems can effectively analyze high-resolution images from online databases, accurately distinguishing harmful pest from beneficial species with impressive precissions (Yang and Qiu, 2024). AI offers transformative potential to address the limitations of pest management methods making them more efficient, scalable and targeted. Integration of AI into biological pest control, researchers and farmers can optimize the deployment and monitoring of natural enemies, ensuring their successes in diverse agricultural contexts.

Yang, Jin,, Jiang, Lu and Wen (2025) highlights AI-driven pest control technologies which includes (i) Computer vision and image recognition, the AI-powered image recognition can identify specific pests and diseases from images of crop leaves. Applications can be deployed on smartphones to assist farmers in real-time. (ii) Machine learning for predictive analytics where machine learning algorithms can analyze historical data (e.g. pest outbreak patterns, weather conditions) to forecast pest infestations enabling proactive interventions. (iii) Internet of Things (IoT) and Smart Sensors. IoT-enabled devices can monitor environmental conditions such as humidity and temperature which are the factors that influence pest behavior and send alert to farmers. (iv) Drones and Remote Sensing. Drones equipped with multispectral

cameras can scan large farms for signs of pest activity, allowing targeted pesticide application and reducing costs.

Benefits of AI in pest control

- **Increased Crop Yields and Food Security:** Reduced pest damage directly translates to higher yields, ensuring a more stable and abundant supply of vegetables, thereby enhancing national food security.
- **Higher Farmer Income:** Increased yields, coupled with reduced reliance on expensive and harmful chemical pesticides, will boost farmers' profitability and improve their livelihoods.
- **Enhanced Food Quality and Safety:** Minimized pesticide use will lead to healthier, residue-free vegetables, meeting consumer demands for safe food and potentially opening up export opportunities.
- **Reduced Healthcare Costs:** Lower exposure to harmful chemicals will lead to improved health outcomes for farmers and consumers, reducing healthcare burdens.
- **Environmental Sustainability:** Reduced chemical runoff protects soil and water resources, preserves biodiversity, and contributes to a healthier agricultural ecosystem.
- **Job Creation:** The development, deployment, and maintenance of AI and innovative pest control technologies will create new employment opportunities in the agricultural technology sector.
- **Economic Diversification:** A more resilient and productive agricultural sector contributes to diversifying the Nigerian economy beyond oil.
- **Attraction of Investment:** Demonstrating success in adopting advanced agricultural technologies can attract foreign and domestic investment into the agricultural sector.
- **Reduced Post-Harvest Losses:** Improved pre-harvest pest control can contribute to reduced post-harvest damage, increasing the overall value of agricultural output.

Innovations and pest control in vegetable crops

In the transition and upgrading of modern agriculture, intelligent technologies play a crucial role in enhancing agricultural precision and efficiency, driving the transition towards sustainable and smart farming (Gong & Diao (2025)

The development and application of smart agricultural machinery and agricultural robots have significantly advanced the automation and intelligence of vegetable production. Yan, Feng, Lin, Huang and Tong (2022) developed grafting robotics technology that combines machine vision and automation, considerably enhancing the efficiency and survival rate of vegetable crop grafting. Paradkar, Raheman and Rahul, (2021) designed an automated metering device for vegetable transplanters, enabling precise transplanting of vegetable seedlings and advancing vegetable cultivation towards higher efficiency and precision. Furthermore, the design and implementation of smart agricultural robots like the automated harvester Vegebot (Birrell, Hughes, Cai and Iida 2020), the intelligent weed control system (Zhang, Miao, Li, He and Sun 2022), and the growth monitor Terra Sentia have significantly decreased the reliance on manual labor and resources.

Precision agriculture management is a technology-driven approach to agricultural management (Monteiro, Santos and Gonçalves, 2024). Firstly, in terms of environmental monitoring and control, Lestari, Khan, Pertiwi and Muslim, (2024) utilized CNN algorithms to classify vegetable pests, validating their high accuracy through cross-validation. Additionally, Internet of Things (IoT)-based intelligent pest management systems for precision agriculture are continuously improving (Ahmed, Marwat, Brahim, Khan and Khan, 2024).

Vegetable production of Nigerian economy

The vegetable market in Nigeria is projected to generate significant revenue, with growth expected to continue making it a profitable venture. Vegetable crops are produced in different agro-ecological zones through commercial and small scale farmers both as source of income as well as food. Dawit (2004) stated that the production vegetables vary from cultivating a few plants in the backyards for home consumption up to a large scale production for domestic and export markets. According to Tsegay, (2010), recently despite the ups and down observed, the demands for vegetable especially for export is increasing. Vegetable crops grown in many parts of the country contribute significantly to income security and the nutritive diet of many households. Adeolu and Taiwo (2009); Giroh, (2010), in their different works outlined vegetable crops cultivated in most Sub Saharan Africa mainly by small scale farmers most states in Nigeria as tomatoes, okra, pepper, cabbage etc. Global production of fruits and vegetables tripled from 396 million MT in 1961 to 1.34 billion MT in 2003 (International Institute of Tropical Agriculture, 2005) and Nigeria ranked 16th on the global tomato production scale, accounting for 10.79 percent of Africa's and 1.2 percent of total world production of tomatoes (Weinberger and Lumpkin, 2007).

Conclusion

The future of vegetable crop production in Nigeria hinges on a proactive and technologically advanced approach to pest control. By strategically integrating Artificial Intelligence, fostering innovation, and embracing creative solutions, Nigeria can move towards a more sustainable, efficient, and profitable agricultural sector. This paradigm shift will not only safeguard vital vegetable crops but also empower farmers, enhance food security, protect public health, and contribute significantly to the nation's economic prosperity. The journey requires concerted efforts from government, research institutions, private sector players, and most importantly, the farming communities themselves, to cultivate a future where technology and tradition harmoniously work towards a thriving agricultural landscape. The successful implementation of AI, innovation, and creativity in vegetable crop pest control will yield significant economic benefits for Nigeria:

Recommendation

The researcher after assessing the improvement of pest control of vegetable crops using AI and innovation in enhancing Nigerian economy came up with the following recommendations;

1. The problem of infrastructural deficiencies that is limited internet connectivity, unreliable power supply, and inadequate digital infrastructure in rural areas pose significant barriers.

Government needs to invest more in rural broadband and renewable energy solutions for agricultural communities.

2. Lack of comprehensive and standardized agricultural data (pest incidence, weather, soil data) is a significant hurdle for training robust AI models. There is need to establish national agricultural data collection centers and initiatives to encourage data sharing among farmers and researchers.

3. Due to shortage of skilled personnel in AI, data science, and precision agriculture technologies there is need for the development of specialized training programs, vocational schools, and university curricula focused on agri-tech.

4. Due to high cost of Technical equipment, the initial investment in AI and advanced technologies can be expensive for smallholder farmers therefore government should encourage subsidies, credit facilities, and the promotion of cooperative farming models to share technology costs. Encouraging local manufacturing of components to reduce import costs.

5. Farmers resist the use of new technologies due to lack of understanding or skepticism. Government should embark on extensive farmer education and extension services, demonstration farms showcasing successful implementations, and peer-to-peer learning initiatives.

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