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Ginger-Pigeon Pea Intercropping: An Analysis of Compatibility and Productivity in Nigeria

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Abstract
Ginger (*Zingiber officinale*) and pigeon pea (*Cajanus cajan*) are important crops with significant economic and nutritional value. Intercropping has emerged as a sustainable agricultural practice with the potential to enhance resource use efficiency and improve crop yields, particularly for smallholder farmers in developing regions. Intercropping these two crops offers potential advantages, such as efficient land use, enhanced biodiversity, and improved soil health. This review analyzes the compatibility and productivity of ginger-pigeon pea intercropping systems under agroforestry systems, focusing on their growth patterns, nutrient requirements, and mutual interactions. It evaluates how these crops influence each other's yield and the overall productivity of the system, taking into account factors like competition for light, water, and nutrients. The review explores the environmental benefits, such as increased nitrogen fixation by pigeon peas and its role in improving soil fertility for ginger growth, while both crops display reduced water competition due to their differing root depths. The pigeon pea also offers partial shade, protecting ginger from excessive heat and promoting rhizome development. The analysis of productivity shows that ginger-pigeon pea intercrops often yield higher total output compared to monocultures, with a Land Equivalent Ratio (LER) exceeding 1.2, indicating better resource utilization. However, successful implementation of this system requires careful management to avoid competition for light and nutrients, as well as addressing labour intensity and market access challenges. Despite these constraints, ginger-pigeon pea intercropping holds significant potential to improve food security, promote sustainable agriculture, and provide economic benefits to smallholder farmers.
Keywords: Ginger, pigeon pea, intercropping, compatibility and productivity

Introduction

Agricultural productivity in Nigeria, as in many developing countries, is often constrained by limited access to land, degraded soils, and erratic rainfall patterns. These challenges are further compounded by the effects of climate change, which have intensified droughts, floods, and temperature fluctuations, threatening the livelihood of millions of smallholder farmers (Ayanlade *et al*., 2018). In response to these challenges, intercropping has been identified as a promising agricultural practice that can improve land-use efficiency, enhance soil fertility, and boost crop yields. Intercropping, the practice of growing two or more crops simultaneously on the same field is a well-established agronomic strategy that is aimed at optimizing the use of available resources such as light, water, and nutrients. It also offers multiple ecological

benefits, including improved biodiversity, soil health, and pest management (Lithourgidis *et al*., 2011).One such intercropping system with potential in Nigeria is the combination of ginger (Zingiber officinale) and pigeon peas (Cajanus cajan), two crops that are widely grown in the country for their economic and nutritional value. Nigeria is one of the largest producers of ginger in Africa, with the crop playing a significant role in the country's export economy (Olatunji *et al*., 2012). Ginger is cultivated primarily in the Middle Belt region, particularly in Kaduna, where it thrives due to the favourable agro-climatic conditions. However, ginger is a high-input crop, requiring considerable amounts of nutrients, particularly nitrogen, for optimal growth. This makes it an expensive crop to cultivate, especially for smallholder farmers who often lack access to fertilizers (Aliyu and Jayeoba, 2019). On the other hand, pigeon pea, a drought-tolerant leguminous crop, is commonly grown in the northern and central regions of Nigeria, providing a crucial source of protein in local diets. Its ability to fix atmospheric nitrogen into the soil makes it an ideal companion crop in intercropping systems, where it can enhance soil fertility and reduce the need for chemical fertilizers (Okigbo and Greenland, 2014). Intercropping ginger with pigeon peas offers a strategy to optimize resource use and improve productivity in Nigeria's smallholder farming systems. The complementary nature of these crops, with ginger being a shallow-rooted tuberous crop and pigeon peas a deep-rooted legume, reduces competition for nutrients and water. Moreover, pigeon pea's nitrogen-fixing ability helps replenish soil nutrients, benefiting the ginger crop and enhancing overall soil health (Chikoye *et al*., 2018). This is particularly important in Nigeria, where soil degradation due to poor farming practices and over-reliance on monocropping has led to declining agricultural productivity in many regions (Adediran *et al*., 2020). In addition to agronomic benefits, the ginger-pigeon pea intercrop system holds socio-economic potential for smallholder agroforestry farmers in Nigeria. By diversifying crop production, farmers can mitigate risks associated with crop failure, ensure food security, and increase their income from the sale of both crops. Ginger is highly valued in local and international markets, while pigeon peas provides nutritional security and can be used for fodder or sold in domestic markets (Ibeawuchi *et al*., 2015). The success of an intercropping system largely depends on the compatibility of the component crops in terms of their growth habits, nutrient needs, and resource competition. Ginger, being a low-growing crop with significant below-ground biomass, occupies the soil without heavily shading the companion plants. In contrast, pigeon peas grows taller, allowing it to capture sunlight without directly competing with ginger for light, while its deep root system can tap into different soil layers for water and nutrients (Ouma and Jeruto, 2010). This complementary growth habit reduces interspecific competition, thereby improving the overall productivity of the intercrop system. This intercropping system could also play a role in addressing Nigeria's pressing food security challenges by increasing yields without the need for costly inputs. Recent studies have shown that ginger and pigeon peas, when grown together, can lead to improved yields of both crops under certain environmental conditions. Research by Amujoyegbe *et al.* (2019) indicated that intercropping these crops can enhance resource use efficiency, particularly in nitrogen uptake and water use. Additionally, pigeon peas role in improving soil structure through nitrogen fixation and organic matter contribution can create a favourable microenvironment for ginger growth (Singh *et al.*, 2021). Despite these potential benefits, the success of the ginger-pigeon pea intercropping system in Nigeria depends on several factors, including planting density, timing, and the specific environmental conditions of different agroecological zones. Additionally, while the intercrop can improve resource use efficiency, challenges such as competition for water during drought periods and management of pests and diseases must be carefully considered (Sanginga and Woomer, 2009).This review seeks to explore the compatibility and productivity of ginger-pigeon peas intercropping in Nigeria, and focuses on the potential for enhancing sustainable agroforestry practices and improving food security in the face of climate change and resource constraints. This review aims to analyze the compatibility and productivity of the ginger-pigeon peas intercrop system. It examines the key factors that influence the growth and yield of both crops in an intercropping setup, including planting density, resource competition, and environmental conditions. By synthesizing current research findings, this review provides insights into how this intercropping system can contribute to sustainable agricultural practices, particularly in regions facing land and resource constraints.

Potentials of Ginger Pigeon Pea Intercrop System in Nigeria

The ginger-pigeon pea intercrop system in Nigeria has demonstrated significant potential for improving productivity, both in terms of crop yields and resource efficiency. The complementary nature of these two crops enhances the use of available resources like soil nutrients, water, and sunlight, leading to a more productive and sustainable farming system. The system leverages the biological interactions between ginger

and pigeon peas to maximize output while minimizing input costs.

Increased Total Crop Yield

One of the key advantages of intercropping ginger and pigeon peas is the potential to achieve higher total crop yields compared to monocropping. Pigeon pea, as a legume, fixes atmospheric nitrogen into the soil, making it available for use by ginger, which has a high nutrient demand. This natural nitrogen input reduces the need for synthetic fertilizers, lowering costs while improving yields. Studies on legume-based intercropping systems have shown that nitrogen fixation can increase the productivity of non-legume crops grown in the same field (Sanginga *et al.*, 2003). Moreover, the land equivalent ratio (LER) of intercropping systems often exceeds 1, indicating that the combined productivity of two crops in an intercrop system is higher than if they were grown separately. According to Mead and Willey (1980), LER values higher than 1 suggests that the intercrop system makes more efficient use of land resources, leading to higher overall productivity. In ginger-pigeon pea systems, this translates into increased yield per unit area, which is critical for smallholder farmers who have limited access to arable land.

Efficient Use of Soil Nutrients

The ginger-pigeon pea intercrop system enhances nutrient use efficiency due to the complementary rooting patterns of the two crops. Pigeon pea has a deep root system, which allows it to access nutrients from deeper soil layers, while ginger has a shallow root system that absorbs nutrients from the topsoil. This complementary nutrient uptake reduces competition between member crops and ensures that soil nutrients are utilized more efficiently (Ahlawat *et al.,* 2005). Additionally, the biological nitrogen fixation by pigeon peas enriches the soil with nitrogen, which is beneficial for ginger, especially in nutrient-poor soils. This natural enrichment reduces the need for chemical fertilizers and helps maintain long-term soil fertility. Research on legume intercrops has shown that the incorporation of legumes like pigeon peas can improve the yield of subsequent non-legume crops by up to 30% (Chikowo *et al*., 2004).

Improve Water Use Efficiency

Water is a critical resource for agricultural productivity, particularly in regions of Nigeria that experience irregular rainfall patterns. The ginger-pigeon peas intercrop system improves water use efficiency by ensuring that water resources are used more effectively. Pigeon peas deep roots tap into water reserves deeper in the soil profile, while ginger relies on moisture from the upper layers of the soil. This vertical root differentiation reduces competition for water between the two crops and ensures that the available moisture is fully utilized (Kumar Rao *et al*., 2000). Improved water retention due to the increased organic matter from pigeon pea decomposition further contributes to the system's productivity. The organic matter enhances the soil's ability to retain moisture, reducing water stress for the crops during dry periods and improving overall yields.

Pest and Disease Management

Intercropping systems are known to reduce the incidence of pests and diseases due to increased biodiversity in the cropping system. The presence of pigeon peas alongside ginger creates a more complex environment that can disrupt the life cycles of pests and reduce the spread of diseases that might otherwise affect monocultures (Kumar *et al,* 2003; Doss, 2018). This natural pest suppression leads to healthier crops and higher productivity, as farmers are less reliant on chemical pesticides that can harm the environment and affect crop health. Furthermore, pigeon pea acts as a barrier crop, potentially protecting ginger from pests such as aphids and thrips, which are known to damage ginger. This protection contributes to higher yields by ensuring that ginger plants grow with fewer pest-related interruptions.

Resilience to Environmental Stress

The ginger-pigeon pea system enhances the farm's resilience to environmental stress, including drought and soil degradation. Pigeon peas are drought-tolerant and can survive in dry conditions, providing farmers with a stable crop even in periods of low rainfall. Its deep roots also help improve soil structure and reduce erosion, ensuring the land remains productive over time (Sikiru *et al.* 2017; Saxena, 2008). By combining ginger, which thrives under adequate moisture, with pigeon pea, which is more drought-tolerant, farmers, can hedge against variable weather conditions, ensuring that at least one crop will perform well under less-than-ideal circumstances. This increased resilience contributes to stabilized productivity over multiple growing seasons, reducing the risk of crop failure.

Economic Efficiency

The increased productivity of ginger-pigeon pea intercrops also translates into economic benefits for farmers. By growing two crops on the same piece of land, farmers can diversify their income sources and reduce economic risk. Pigeon pea, in addition to its agronomic benefits, is a valuable cash crop with multiple uses, including use as food, fodder, and even firewood in rural communities (Joshi *et al*., 2001).

Ginger, on the other hand, is a high-value crop with strong demand in local and international markets. The combination of these two crops allows farmers to benefit from the market value of both, increasing their overall income. Moreover, the reduced need for chemical inputs, such as fertilizers and pesticides, lowers production costs, improving the cost-benefit ratio of the farming system.

Soil Conservation and Erosion Control

Soil erosion is a major environmental challenge in many parts of Nigeria, particularly in areas with heavy rainfall or sloping terrain. The ginger-pigeon pea intercrop system helps combat this by promoting soil stability. Pigeon pea, with its deep taproot system, binds the soil, reducing the risk of erosion, especially during Nigeria's rainy season. Its deep roots break up compacted soil layers and improve soil structure, allowing for better water infiltration and reducing surface runoff (Asadu *et al*., 2014; Ume and Nta, 2007). Furthermore, ginger provides ground cover that protects the soil from direct exposure to rain and wind, reducing erosion. The combined root systems of the two crops work together to maintain soil integrity and prevent nutrient-rich topsoil from being washed away, a critical factor for maintaining long-term soil fertility and agricultural productivity.

Organic Matter Contribution and Soil Fertility

The pigeon pea plant contributes significantly to increasing soil organic matter through leaf litter and root decay. As pigeon pea residues decompose, they add valuable organic matter to the soil, which improves soil fertility and enhances the carbon sequestration capacity of the land. Organic matter improves soil structure, increases water-holding capacity, and boosts the population of beneficial soil organisms such as earthworms and microbes, which play vital roles in nutrient cycling (Sanginga *et al*., 2003).The addition of organic material also increases the soil's ability to store nutrients and water, making the farming system more resilient to droughts and reducing the need for chemical fertilizers, which can harm the environment.

Biodiversity Enhancement

Intercropping systems like ginger-pigeon pea promote agro-biodiversity, which is essential for the health of ecosystems. By cultivating two different species together, the system supports a wider variety of plant and animal species in the ecosystem compared to monoculture systems. Increased biodiversity promotes the presence of beneficial insects such as pollinators and natural predators of pests, reducing the reliance on chemical pesticides that can harm wildlife and contaminate water bodies (Olawuye *et al.,* 2019). Additionally, diverse cropping systems help to create habitat complexity, supporting more varied forms of life, including birds, small mammals, and microorganisms. The inclusion of pigeon peas in the system provides shelter and food for a range of species, thus contributing to the overall ecological balance and sustainability of the farming landscape.

Climate Change Mitigation

The ginger-pigeon pea intercrop system contributes to climate change mitigation by reducing greenhouse gas emissions and increasing the potential for carbon sequestration. Pigeon pea, being a legume, fixes nitrogen from the atmosphere into the soil, reducing the need for synthetic nitrogen fertilizers. Synthetic fertilizers are a major source of nitrous oxide, a potent greenhouse gas. By lowering fertilizer use, this intercropping system helps to reduce agricultural emissions (Lal, 2004). Furthermore, the organic matter contributed by pigeon pea helps sequester carbon in the soil, offsetting some of the carbon dioxide emissions associated with agriculture. Soil carbon sequestration is a key strategy for mitigating climate change, and intercropping systems that promote healthy soil structure and organic matter content are an important part of this strategy.

Water Conservation

Water management is a critical environmental issue in Nigeria, particularly in regions where water scarcity is becoming more frequent due to changing climate patterns. The ginger-pigeon peas intercrop system contributes to water conservation through its complementary root structures. Pigeon peas deep roots draw water from deeper layers of the soil, while ginger's shallow roots utilize moisture closer to the surface. This efficient use of water reduces competition between the crops and ensures better moisture retention in the soil (Kumar Rao *et al*., 2000). Moreover, the increased organic matter in the soil resulting from pigeon pea decomposition improves the soil's water-holding capacity, reducing the need for irrigation and helping crops to withstand periods of drought. This natural improvement in soil moisture retention makes the intercrop system more resilient to erratic rainfall and helps conserve water in agricultural practices.

Reduction in Chemical Input Use

One of the most significant environmental advantages of the ginger-pigeon pea intercropping system is the reduction in chemical inputs, particularly synthetic fertilizers and pesticides. Pigeon pea's nitrogen-fixing ability reduces the need for chemical nitrogen fertilizers, which are often associated with groundwater contamination and soil degradation when overused

(Okigbo *et al*., 2014; Okeniji, 2014). Additionally, the natural pest control provided by the diversity of crops in the system lowers the reliance on chemical pesticides, which can have harmful environmental consequences, including the destruction of beneficial insects and the contamination of ecosystems. By lowering the use of synthetic inputs, the intercropping system not only reduces pollution and soil degradation but also protects local water resources from runoff containing harmful chemicals.

Improved Land Use Efficiency

In Nigeria, where agricultural land is often scarce and degraded, the ginger-pigeon peas intercrop system promotes sustainable land use. By growing two crops on the same plot of land, farmers can maximize the productivity of their available land without expanding into ecologically sensitive areas such as forests or wetlands. This efficient use of land reduces the pressure to clear additional land for agriculture, helping to conserve natural ecosystems and protect biodiversity (Tadessa *et al* 2020). Furthermore, intercropping helps maintain soil fertility and structure, allowing farmers to use the same piece of land for longer periods without exhausting its productive capacity. This reduces the need for shifting cultivation, a practice that can lead to deforestation and habitat loss in Nigeria's more fragile ecosystems.

Reduction in Soil Degradation

The ginger-pigeon peas intercropping system is important for combating soil degradation, a common issue in many farming areas of Nigeria due to over-cultivation, deforestation, and poor farming practices. The cover provided by pigeon peas reduces the impact of heavy rainfall on bare soil, preventing soil compaction and degradation. Moreover, the deep roots of pigeon pea break up hardpan layers in the soil, improving aeration and reducing compaction, which is vital for maintaining soil health and fertility (Hamza and Anderson, 2005). By enhancing soil structure, this intercropping system prevents the decline in soil quality that can lead to desertification, a growing threat in some regions of Nigeria.

Weed Suppression

One of the key challenges in ginger cultivation is weed management, as weeds compete with ginger for nutrients, water, and light, ultimately reducing yields. Pigeon pea, with its tall stature and dense foliage, provides effective ground cover, reducing the amount of sunlight reaching the soil surface and thus suppressing the growth of weeds. This natural weed suppression reduces labour and the need for herbicides, making the system more environmentally friendly and cost-effective for farmers (Mafongoya *et al*., 2006

Challenges Faced By Smallholder Farmers in Adopting Ginger –Pigeon Pea Intercrop System in Nigeria

The adoption of the ginger-pigeon pea intercrop system by smallholder farmers in Nigeria presents several challenges, despite its numerous benefits in terms of productivity, environmental sustainability, and economic returns. These challenges stem from socio-economic, agronomic, and infrastructural constraints that limit the widespread uptake of this farming system.

Lack of Awareness and Knowledge

One of the major challenges for smallholder farmers is the lack of awareness about the benefits of intercropping systems like ginger-pigeon peas. Many farmers are accustomed to traditional monocropping practices, and they may be unfamiliar with how intercropping works or the specific techniques required managing the system efficiently. The absence of adequate extension services and training programs further compounds this issue. Smallholder farmers often lack access to agricultural education that could help them understand how to optimize the use of land, manage intercrops effectively, and adopt better pest and disease management practices (Oladele, 2011). Without this technical knowledge, they may be reluctant to shift from familiar cropping systems to intercropping.

Limited Access to Quality Seeds

For successful adoption of the ginger-pigeon peas intercropping system, farmers need reliable access to quality seeds for both crops. However, seed availability is a common problem for smallholder farmers in Nigeria, especially in rural areas. While ginger seed rhizomes are often expensive and difficult to obtain, pigeon pea seeds are not widely distributed, limiting farmers' ability to start or scale up intercropping practices (Agwu, 2004). Additionally, the high cost of quality ginger rhizomes poses a significant barrier, as many smallholder farmers cannot afford to purchase them every planting season. This financial burden discourages farmers from experimenting with new crop systems like Intercropping.

Labour-Intensive Nature of Intercropping

The ginger-pigeon pea intercrop system can be labour-intensive, especially during the planting, weeding, and harvesting stages. Smallholder farmers, who often rely on family labour, may find it difficult to manage the extra work required for intercropping compared to monocropping. The need to plant two different crops,

manage their growth cycles, and ensure that one crop does not overshadow the other adds complexity to the farming process (FAO, 2017). Given the high demand for labour in smallholder systems, where mechanization is rare, the additional time and effort required for intercropping may deter farmers from adopting the practice. Furthermore, many smallholder households already face labour shortages, as family members may be involved in non-agricultural activities or migrate to urban areas for work.

Land Tenure Issues

Land tenure is a critical issue in Nigeria, particularly for smallholder farmers, many of whom do not have secure access to land. Land fragmentation and insecure land tenure discourage long-term investments in sustainable farming practices like intercropping. Farmers who do not own the land they cultivate may be hesitant to adopt systems that require more complex land management, fearing that they could lose access to the land before reaping the benefits of the new practice (Doss, 2018). In regions where land is divided into small, scattered plots, farmers may also struggle to implement intercropping systems efficiently. The small size of the land may not be sufficient to support the cultivation of both ginger and pigeon peas in quantities large enough to justify the effort and cost.

Market Access and Price Fluctuations

Smallholder farmers face challenges related to market access and the fluctuating prices of both ginger and pigeon pea. Ginger, though a valuable cash crop, is subject to volatile price changes, particularly in the global market. This makes it difficult for farmers to predict their income, leading to uncertainty about whether investing in ginger production will be profitable (Soyinka *et al.,* 2016). Pigeon pea, on the other hand, has limited market demand in some regions of Nigeria, which reduces the incentive for farmers to grow it. Without stable and accessible markets, smallholder farmers may not see the financial viability of intercropping these two crops. Furthermore, the lack of storage and processing facilities means that farmers often have to sell their produce immediately after harvest, when prices are typically low.

Inadequate Agricultural Inputs

Access to inputs, such as fertilizers, pesticides, and organic matter, is often limited for smallholder farmers in Nigeria. The ginger-pigeon peas intercrop system, although more sustainable, still requires some input for optimal productivity. Pigeon pea fixes nitrogen in the soil, but ginger may still need supplementary fertilizers, particularly in degraded soils where nutrient levels are low. However, the high cost of these inputs can be prohibitive for many smallholder farmers (Adegbite *et al* 2021). Moreover, the limited availability of organic fertilizers and lack of support for sustainable farming practices further reduce the farmers' ability to adopt intercropping systems that rely on natural inputs for soil fertility enhancement and pest management.

Climatic and Environmental Constraints

Nigeria's diverse agro-ecological zones present climatic challenges that can affect the performance of the ginger-pigeon pea intercrop system. While ginger prefers well-drained soils and moderate rainfall, pigeon peas is more drought-tolerant and can grow in drier conditions. However, in regions with excessive rainfall or prolonged droughts, it may be difficult to manage both crops effectively, as one crop could suffer while the other thrives (Lal, 2004). In areas prone to extreme weather conditions, such as floods or droughts, smallholder farmers may prioritize more resilient mono-crops over intercropping systems that could be harder to manage under adverse conditions. This limits the appeal of intercropping as a risk-reduction strategy for smallholders in vulnerable areas.

Extension Services and Government Support

The lack of government support and inadequate extension services further hinder the adoption of intercropping systems. Extension agents play a critical role in disseminating information and providing technical support to farmers, but in many rural areas of Nigeria, these services are either underfunded or non-existent (Oluwatusin, 2008). Without access to government-backed programs or initiatives that promote intercropping practices, smallholder farmers are left to rely on traditional knowledge, which may not include insights into modern intercropping techniques. Furthermore, the absence of financial incentives, such as subsidies or credit facilities tailored to smallholder farmers, reduces their ability to invest in innovative cropping systems.

Cultural Practices and Traditional Farming Methods

Many smallholder farmers in Nigeria are deeply rooted in traditional farming methods, often passed down through generations. These farmers may view intercropping as complex or unconventional, compared to the more straightforward practice of monocropping. The ginger-pigeon pea intercrop system requires a departure from these ingrained methods, necessitating the adoption of new planting schedules, crop management techniques, and harvesting practices. Resistance to change is a common challenge, particularly in communities where farming practices are tied to cultural identities. Overcoming these

cultural barriers requires community engagement and demonstration projects that show the benefits of intercropping through tangible results. However, this approach requires investment in rural extension services and farmer education, which are often lacking (Adesina and Baidu-Forson, 1 995).

Post-Harvest Challenges

Post-harvest management is a critical issue for smallholder farmers, especially in intercropping systems where two different crops are harvested at different times. Ginger and pigeon peas have different post-harvest requirements, such as drying, processing, and storage. The lack of adequate infrastructure, such as drying facilities, storage units, and processing centres, creates challenges for farmers trying to maximize the value of both crops. Without proper post-harvest management, farmers may experience significant losses, reducing the potential profitability of the intercropping system. This issue is particularly problematic for ginger, which is highly perishable and requires careful handling to maintain its market value. Post-harvest losses due to poor infrastructure and improper handling can reach up to 40% in some regions of Nigeria (Olayemi *et al*., 2012). Additionally, pigeon pea requires proper storage to avoid spoilage, pests, and fungal infections.

Uncertainty in Yield Performance

While the ginger-pigeon pea intercrop system has shown potential for higher productivity, yield performance variability poses a challenge. The success of the intercrop system depends on factors such as soil fertility, climate, and the farmer's ability to manage the crops efficiently. Smallholder farmers, who often have limited control over these factors, may experience inconsistent yields from one season to the next, discouraging them from adopting the system (Sanginga and Woomer, 2009). Moreover, the interaction between the two crops can sometimes result in competition for resources like water, nutrients, or light, particularly if the crops are not managed properly. If pigeon pea grows taller than expected or if ginger does not receive adequate nutrients, the overall yield of the intercrop system can suffer. This unpredictability creates risks for smallholder farmers, who rely on stable yields for both household consumption and income generation.

Limited Financial Support and Credit Access

Smallholder farmers in Nigeria often face limited access to credit and financial support, which can hinder the adoption of innovative farming systems like intercropping. The costs associated with purchasing quality seeds, inputs, and tools necessary for intercropping can be prohibitive for farmers with low incomes. Many smallholder farmers rely on personal savings or informal lending systems, which may not be sufficient to cover the upfront costs of implementing an intercrop system. Without formal credit facilities or government subsidies aimed at supporting sustainable agricultural practices, smallholder farmers are less likely to take the financial risk involved in transitioning to intercropping (IFPRI, 2010). Government and NGO programs that provide financial incentives, access to credit, and input subsidies could help to alleviate this barrier.

Fragmented Agricultural Markets

In addition to challenges with market access, smallholder farmers often operate within fragmented agricultural markets, where middlemen and informal market structures dominate. These fragmented markets make it difficult for farmers to sell their produce at fair prices or access profitable supply chains for both ginger and pigeon peas. Middlemen often take a large share of the profit, leaving farmers with minimal returns, which reduces the incentive to invest in intercropping systems that require higher initial costs (Ayinde *et al*., 2010). Moreover, many smallholder farmers lack access to market information on the prices of crops like ginger and pigeon peas, which can fluctuate significantly. This information asymmetry prevents farmers from making informed decisions about when and where to sell their produce. Without reliable market access, the financial benefits of the intercrop system may not be fully realized.

Inconsistent Government Policies

The inconsistency in government agricultural policies also affects the adoption of the ginger-pigeon peas intercrop system. While some policies promote sustainable agriculture and intercropping, others focus more on large-scale monocropping or export crops, leaving smallholders without the necessary support to experiment with diverse cropping systems. Inconsistent policy direction creates uncertainty for farmers about which practices to adopt, especially in the absence of long-term governmental support for intercropping initiatives (Oluwatayo *et al*., 2019). For example, while ginger is considered a high-value export crop, pigeon peas may not receive the same level of policy attention. This policy imbalance can discourage farmers from growing pigeon peas despite its benefits to soil health and nutrient cycling. Additionally, subsidy programs that favour single-crop systems further limit the incentive to adopt more diverse cropping systems.

Lack of Cooperative Structures

Smallholder farmers often lack strong cooperative structures, which are crucial for sharing resources,

accessing bulk purchasing of inputs, and improving market access. In an intercrop system where multiple crops are grown, cooperatives can help farmers pool their resources, share knowledge, and increase their bargaining power in markets. However, the absence of robust agricultural cooperatives in many regions of Nigeria limits the collective action needed to support the adoption of complex systems like the ginger-pigeon pea intercrop. Without this form of social organization, farmers may feel isolated in their efforts to implement new farming methods and may struggle to scale up their operations (Alkali, 2006).

Conclusion

The ginger-pigeon pea intercrop system presents a promising agricultural practice in Nigeria, especially for improving land use efficiency and promoting sustainable farming. By intercropping ginger with pigeon peas, farmers can enhance soil fertility, reduce pest and disease incidence, and boost overall crop productivity. Pigeon pea, being a legume, contributes to nitrogen fixation, enriching the soil and reducing the need for synthetic fertilizers, which is both economically and environmentally beneficial. This intercrop system aligns with the goals of climate-smart agriculture, as it enhances resilience to climate variability and provides a diversified income source for farmers. Pigeon pea's drought tolerance complements ginger's moderate water needs, making the system well-suited to regions with erratic rainfall patterns. Additionally, the intercrop provides a dual harvest, offering both food (pigeon pea) and a high-value cash crop (ginger), improving farmers' livelihoods and food security. However, to fully optimize the benefits of this system, further research is needed to establish the ideal planting patterns, spacing, and management practices that will maximize yields and resource use efficiency. Extension services should also focus on training smallholder farmers on best practices to ensure the successful adoption of the ginger-pigeon pea intercrop system in Nigeria. Therefore, the ginger-pigeon pea intercrop system has the potential to improve the sustainability of agriculture in Nigeria by enhancing productivity, conserving soil fertility, and supporting food security efforts. With appropriate support, it could be a key strategy for smallholder farmers adapting to the challenges of climate change and resource constraints.

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