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TABLE OF CONTENTS

EDITORIAL ADVISORY BOARD
DISCLAIMER

Exploring the Economic and Social Impacts of Rural-Urban Migration of Youths in Abuja, Nigeria 1
Samson Olayemi Sennuga, Joseph Bamidele, Adebisi Olateju Omole, Bankole Osho-Lagunju, Mary E. Iheonu and Mary Adanna Chinwuba

Diagnostic Investigation of the Potential Effect of Soil Moisture Condition in Detecting Climatic Hazards During the Crops Sowing in Cameroon 18
Thierry Gaitan Tchuenga-Seutchueng, Eun Hea, Jho, Martin Yemefack, Simon Djakba Basga

Smart IoT Rural Agricultural Innovations for Food Security through Digital Technology Transfer: Agro-Industrial Sector Reform 30
Ugochukwu Okwudili Matthew, Jazuli Sanusi Kazaure, Godwin Nse Ebong, Charles Chukwuebuka Ndukwu, Andrew Chinonso Nwanakwaugwu, and Ubochi Chibueze Nwamouh

Influence of Enhanced Efficiency Fertilization on Fall Armyworm (Spodoptera frugiperda J. E. Smith) Infestations and Agronomic Performance of Maize (Zea mays L.) 51
Abdulai, Fuseini, Badii, Kongyeli Benjamin, Kankam Frederick, and Nboyine, Asalma Jerry

Pollen Analysis and Physicochemical Characterization of Honey Samples from Owo Local Government Area, Ondo State, Nigeria 66
Essien, Benjamin Christopher and Olaniyi, Barakat Olamide

Promotion of Onion Seed Production Technologies for Improving Productivity in Upper and Middle Awash Irrigated Areas 80
Yitages Kuma Beji, Nardos Mulgeta, Ayisha Here, and Nigusse Chewaka

Data Collection Procedures for Selected Horticultural Crops Prepared for Junior Researchers 93
Yitages Kuma Beji

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Exploring the Economic and Social Impacts of Rural-Urban Migration of Youths in Abuja, Nigeria

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Abstract:
The primary driver of urban unemployment and population pressure in an emerging nation like Nigeria is the phenomena of rural-urban migration, which is primarily sparked by rural "push" forces and urban "pull" factors. This circumstance also has an impact on the healthy growth of rural and urban communities. Despite this, little research is done to assess how it would affect urban residents' quality of life and rural livelihood. To this end, this study is mainly concerned with exploring the economic and social impacts of rural-urban migration of youths, determine the socio-economic characteristics of rural-urban migrant youths in the study area, assessing the impact of rural-urban migrant youths particularly on economic aspects (employment, cost of living, urban informal sectors) in the study area, investigate the impact of in-migration of youths particularly on social services (education, housing, health and other social facilities) in the study area, and investigate the push and pull factor that influence rural-urban migration in Abuja. Questionnaires were given to 210 rural-urban young people who were chosen at random to learn about the issues. Descriptive statistics were used to analyze the participant-provided data. Youth from rural and urban migration move to cities in quest of work and to use city services and amenities. Youth migrants have put pressure on the socioeconomic as well as environmental conditions and characteristics of the study region because of the ongoing outflow of rural migrants seeking out urban basic utilities. Because of the high incidence of rural-to-urban migration, Abuja now faces issues such a housing shortage, unemployment, rising cost of living, limited access to social services, an increase in crime, the growth of urban informal sectors, and other challenges.

Keywords: Youths, rural-urban migration, pull factors, push factors

INTRODUCTION

Migration is a demographic phenomenon that involves both temporary and permanent movement of individuals from one geographical area to another. People's economic assessments of their living conditions, sociological circumstances, geographical limitations, and cultural and historical aspects are all included. According to a UNDP (2009), there are 740 million more individuals migrating internally than internationally, which totals 214 million migrant persons worldwide. Rural to urban migration is a comparatively old and widespread global phenomena among internal migrants. However, it has recently grown in importance at the international, regional, and national levels (Sennuga, et al., 2023). People have been moving from rural to urban regions as a result of the unprecedented levels of urbanization present in the majority of emerging countries, which has led to the development of slums and informal settlements. These areas frequently face developmental obstacles such as the spread of pandemic illnesses like cholera and dysentery, the availability of contaminated water, instability, subpar infrastructures, and subpar service delivery. Furthermore, this idea has connections to issues like pollution, traffic, and crime. According to Mutandwa (2011), rural to urban migration is occasionally viewed as a crucial economic option for rural adolescents, who tend to live in impoverished rural areas in developing countries.

Throughout Nigeria's migration history, the multifaceted phenomena of the country's political, economic, social, and environmental conditions and circumstances, including drought, war, political unrest, forced migrations, and poverty, have caused internal migratory flows in Nigeria during the past few decades to be forced. Small farm plots that are insufficient to feed a family have caused a spike in migration in all regions of Nigeria in recent years (Angelica et al., 2023). Although having possession of a farmland is a constitutional right for country village residents, it has grown more challenging to fulfil this right for the younger generation due to the increasing shortage of land. Particularly in the highlands of Nigeria, where population concentrations have increased significantly. The paucity of farmland in Nigeria's highlands, along with a lack of non-farm work alternatives in rural areas, has pushed youngsters away from livelihoods in agriculture and rural villages. On the other hand, youth migration to cities and towns in search of much better livelihoods, which actually offer better education, technology, and additional basic social services than rural areas, exacerbates the current issue by adding to urban unemployment and underemployment, putting more strain on inadequate housing resources, and increasing social and psychological stresses among the urban population, such as poverty, destitution, prostitution, beggaring, and clinging to life (Haruna et al., 2023).

Poverty has the greatest impact on Nigerian youth, who make up 71 percent of the total population under 30 and 45 percent of the populace under 15. According to Adamnesh, Linda and Benjamin (2014), poverty in Nigeria is characterized by a lack of access to land, a limitation of productive assets, a lack of income, a lack of food, marginalization, a lack of access to essential services like health care and education, and an inability to find job. The impoverished in rural Nigeria have recourse to migration as a means of escaping poverty. It frequently involves danger, has minimal short-term profits, could end in disaster, and exposing migrants to being exploited, arduous labour, and abuse. However, it is frequently the only viable option for investment and the only chance that some of the rural poor have to improve their lives (Ojo et al., 2022).

The majority of the nation's governmental, commercial, and industrial facilities are located in Abuja, the capital city of Nigeria. These opportunities offered a chance to draw a lot of migrants, especially young people. About 48% of the city's people, according to the 2007 Population and Housing Census, were immigrants (Dokubo et al., 2023). The city is also one of the urban areas with the fastest growth rates in the globe. The population has grown by almost three times since 1970. However, the urban area's spatial expansion has been far more significant. Over the past few decades, Abuja has grown both physically and populated. The population of the city, which had roughly 500,000 persons in 2000, was reported to be somewhat over three million in 2011 (CSA, 2011). While the declining death rate has led to the surge in population, the quick speed of rural-to-urban migration has also played a significant role.

Rural urban migration has been the subject of numerous research (Mutandwa, 2011; Benebeberu, 2012). The majority of these studies concentrate on the results of migration as seen from two angles. While migration is an essential component of boosting the economy, balancing tendencies, encouraging industrialization, enhancing income distribution, and incorporating innovations in agriculture, generalize that migration is a fundamental human right guaranteeing selecting one's destination to improve welfare and economic well-being. On the other hand, migration causes excessive urbanization, unemployment, income inequalities, ecological stress, and population mal-distribution. Generally speaking, migration from rural to urban has a number of effects on both the destination and the origin places' economies, societies, cultures, and demographics (Achukwu et al., 2023).

It is clear that the primary "pulling" factors behind the migration of significant populations from rural to urban regions are the relative advancements in various services and greater quality of life in urban areas as compared to rural areas. The rate of urbanization, or the tide of rural-to-urban migration, which is sparked by "push" forces in rural regions, is invariably faster than the capacity of new job openings and the availability of housing and other social services and amenities (Adeyemi et al., 2023). Widespread urban unemployment, cramped housing, and a severe absence of amenities for the public are some of its repercussions. Due to its proximity to one of Africa's biggest open markets, Abuja has emerged to be one of the most popular attractions for rural-urban migrants. Because of this, the city's population of migrants increased from 776,298 in 2006 (CSA, 2011) to 1,405,201 in 2016 (World Bank, 2016). It means that there should be certain actions taken to lower the rate of migration to the city, which is currently too high. Therefore, the specific objectives of the study are to:

- determine the socio-economic characteristics of rural-urban migrant youths in the study area.
- assess the impact of rural-urban migrant youths particularly on economic aspects (employment, cost of living, urban informal sectors) in the study area
- investigate the impact of in-migration of youths particularly on social services (education, housing, health and other social facilities) in the study area.
- investigate the push and pull factor that influence rural-urban migration in Abuja.

LITERATURE REVIEW

Definitions and Basic Concepts

Migration is only a process of a person moving from one place to another, according to theory. Interregional (among countries), intracontinental (between countries on the same continent), and intercontinental (between continents) scales are typically used (National Geographic Society, 2012). But migration's nature and its causes are complicated, and there isn't a consensus among academics regarding their causes. Researchers within the same subject as well as those from distinct disciplines have disagreements concerning the various factors that cause migration (Timalsina, 2011). As a result, concepts and methods for categorizing migration are additional crucial elements of migration research.

Rural to urban migration, or the movement of individuals from the countryside to cities in pursuit of opportunities, has been one of the most prominent trends in migration (National Geographic Society, 2012; Genzeb, 2022). Additionally, the usual kinds of rural-urban migration include step migration (village-town-city), circulatory (village-city-village), seasonal (migration linked to cyclical labour demand), and chain migration (where migrants follow their forebears and are helped by them in establishing an urban area) (National Geographic Society, 2012).

Review of Relevant Migration Theories and Models

Ravenstein's Law of Migration:

To demonstrate patterns in the extent and course of migration as well as shed light on migration movements in connection with opportunities and constraints, Ernest Raventein presented his "Laws of Migration" to the Royal Statistical Society as early as 1885. Improved external financial possibilities were the main driving force behind migration, according to Ravenstein's laws, which also pointed out that migration takes place in stages rather than in one long move, that population movements are bilateral, and that migration differentials (gender, social class, age, etc.) have an impact on people's mobility.

The Push and Pull Factors Approach of Rural-Urban Migration:

In accordance with the theories in which he divided the forces influencing migrants' perception into push and pull components, (Lee, 1966) developed a generic paradigm into which many different types of spatial movement can be placed (Acharya and Cervatus, 2009; Angelica et al., 2023). While the latter are favourable elements that lure migrants to destination locations in the hope of raising their standard of living, the former are negative aspects that tend to compel migrants to migrate away from origin areas.

According to Lee (1966), all migration-related factors fall into one of the following groups:

1. Factors associated with the areas of origin (Push factors)
2. Factors associated with the areas of destination (Pull factors)
3. Personal factors.

Lee asserts that push factors may outweigh pull elements in importance. Although there are push and pull variables that can cause migration, according to Lee, the predominant driving force behind migration is a blend of push and pull factors, intricately linked to the points of origin and destination being controlled by personal characteristics. The choice of whether to migrate or not can be influenced by a person's particular feelings, knowledge, and intelligence (Lee, 1966; Maisule et al. 2023).

The Nature of Rural-Urban Migration in Nigeria

Both the advantages and disadvantages of migration are revealed by studies conducted in Nigeria. On the plus side, migration helps to meet the labour needs of receiving regions, brings skills home, and is crucial in increasing household income and diversifying sources of it. According to several academics studying the impact of rural-to-urban migration, the move results in an increase in population that puts strain on urban social services in the host environment and a scarcity of farm labour that places responsibility on the individual who stayed behind (National Geographic Society, 2012; Genzeb, 2022).

Impacts of Rural-Urban Migration

Economic Impact:

The main goal of migration has frequently been economic gain. A significant asset that might be transferred to rural areas (home region or village) in the form of capital, technology, learning awareness, knowledge, trade, commodities or services, etc., is the economic benefit attained by rural migrants from the cities. According to UNESCO (2017), the benefits of migration include the influx of capital and information, as well as investments in stores and transportation, which can help make agriculture more profitable. Migrants work in all industries, primarily in the service and unorganized sectors. They primarily work in tasks which are difficult, unclean, as well as hazardous and dangerous and are undesirable to the urban populace because they are too challenging or degrading.

Demographic Impacts:

Population density across both receiving and sending regions is significantly influenced by migration. Because the vast majority of migrants are males and females in the reproductive age range, National Geographic Society (2012) noted that a surge in migration is anticipated to slow the expansion of the rural population while allowing the urban population to rise. Consequently, older age groups with lower reproduction rates may predominate in the sending rural areas. According to Mendola (2012), migration driven by population growth becomes sex- and age-selective. Since the migrants are younger than the local population at their destination, the urban area's population structure will be revitalized. Furthermore, several researches showed that the age selectivity of rural-urban migration brings more young adults to cities, which subsequently in turn boosts the crude birth rate in cities and urban areas. The age structure of the urban population in Africa is more favourable to high fertility since non-contraceptive countries tend to have age selectivity in city ward movement (UNESCO, 2017).

Impacts on Providing Urban Basic Facilities:

Migration affects urban basic services in a variety of ways, in addition to its effects on demographic and economic factors. Among the many effects of migration in urban areas, overcrowding and congestion, the burden on urban social services, rising food prices, and deteriorating air and water diseases are significant. The increase in squatter colonies in the major metropolitan centres is likely the most obvious effect of the rising urban population. Costs of living and rules makes it difficult for migrants to rent homes in cities force them to go to sub-urban areas where there are an overall absence of social services and police protection (Mendola, 2012).

Impact of Expansion of Urban Informal Sectors:

According to Deshingkar and Grimm (2005), the bulk of migrant workers find employment in the urban informal sector, which results in low productivity and little opportunities to escape poverty. But there is also substantial proof that migrants can get above poverty even if they stay in the unofficial economy. The vast majority of the newcomers to the urban labour force appeared to launch their own firms and create their own jobs. Other immigrants worked as day labourers, barbers, mechanics, carpenters, maids, personal assistants, and artisans (McCatty, 2004).

Their primary motivation for working in the informal sector is to make advantage of the limited talents they do possess to generate sufficient revenue to support their daily needs. As previously indicated, urban informal sector operations can be labor-intensive, requiring the labour of every household member who is able to work. The main motivation for participating in the informal sector is to use what limited skills they have to earn enough money to sustain their daily lives (Acharya and Cervatus, 2009). The majority of employees entering the urban informal sector are current rural migrants who are incapable to find jobs in the formal sector. Since it offers chances to those that have been unable to find job in the official sector, the informal sector is linked to the latter. Because it reduces the likelihood that a person will be unemployed once they migrate to the cities, rural-urban mobility is therefore considered as a factor of the rise of the informal sector (McCatty, 2004; Haruna et al., 2023).

Impacts on the Rise of Urban Population:

Increased urban population due to rural-urban migration leads to unplanned urban growth with inadequate social services such housing, electricity, water supply, proper sewage system, road networks, and transportation system. Population growth brought on by rural-to-urban migration undoubtedly strains already-stagnant public services. The demand for health care and education has been particularly high, resulting in overcrowded classrooms in metropolitan regions. The increase in squatter colonies in major metropolitan centres is likely the most obvious effect of the rising urban population. In general, rising urban populations have also resulted in rising urban problems. It is also difficult for the urban administration to have proper record of urban residents (Ekele et al., 2023).

Farmers are being evicted from their land as a result of unplanned urban growth, according to Alemante, Ansha and Waktola (2006). This exacerbates the lack of productivity and the inconvenience to families. When there are no jobs available, affected family members may elect to move to an urban area. As Alemante, *et al.* (2006) noted, increases in street crime, urban unemployment, and a bigger number of unskilled immigrants have a negative impact on the town's peace and security.

Conceptual Framework

The conceptual framework in Fig. 1.1 provides a concise, charted explanation of the causes and effects of rural-urban mobility. As it plainly shows, there are numerous rural push and urban pull variables for migration from rural to urban areas. The high rate of rural-urban movement in the recipients of migrants has a number of other implications. These pull and push dynamics encouraged young people to leave their hometowns and come to cities. Then they got involved in many unofficial business areas that have an impact on urban life. Migration from rural to urban areas benefits the target region as well. Migration from rural to urban areas has an impact on the social, economic, and demographic makeup of cities. However, this conceptual framework illustrates the ideal cause-effect relationship underlying rural-urban migration (Sati et al., 2023).

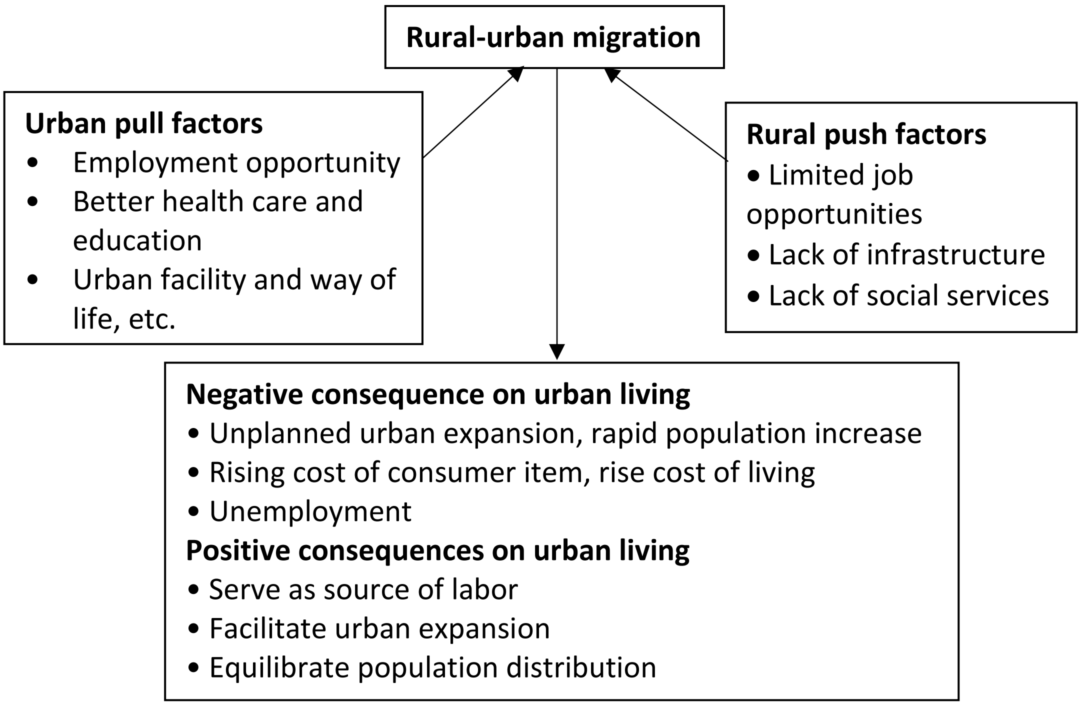

Figure 1.1: Conceptual Framework

MATERIAL AND METHODS

The Study Area

This study was conducted in Abuja, the federal capital of Nigeria and one of its Northern-Central states. It is located between Longitudes 6°45 and 7°45 East of Greenwich and Latitudes 8°25 and 8°25 North of the equator. The Federal Capital Territory has a total area of over 8,000 km², a height of about 536 m above sea level, and a population of 776,298 according to the 2006 census. Four states around it on all sides: Kogi, Niger, Nasarawa, and Kaduna. Six district councils make up Abuja: Abaji, Bwari, Gwagwalada, Kuje, Kwali, and the Abuja Municipal Area Council (AMAC). With a great deal of the northern Guinea Savannah Grassland and Middle Belt, it has a tropical southern forest climate. Due to its favourable environment, the National Capital has good agricultural land. The annual total amount of precipitation ranges from 1100 to 1600 millimetres. The dry season lasts from October to April and the wet season from April to October, with an average temperature of 290 degrees Celsius. Because of the area's elevated position and undulating landscape, the weather is moderated.

Population of the Study and Research Design

The population of this study focuses on the young people of Abuja, Nigeria who have undergone rural-urban migration. It includes individuals aged between 15-35 years old who have migrated from rural areas to urban centers within Abuja. The age range is chosen to capture the demographic most likely to engage in such migration for educational, employment, or other opportunities. The study employed descriptive research design (Genzeb, 2022) in order to explore the economic and social impacts of rural-urban migration of youths in Abuja in their real-life settings.

Sample Size and Sampling Techniques

A combination of simple random sampling and purposive sampling techniques will be employed to select respondents. This dual approach allows for both statistical rigor and targeted inclusion of individuals with specific characteristics of interest, ensuring a well-rounded and insightful study on youths who have migrated from rural to urban areas in Abuja. As previously discussed, the research begins by dividing the urban areas of Abuja into clusters based on geographical (that is, the six Area Councils) and socio-economic criteria. These clusters serve as the primary units for sampling. To introduce an element of randomness and impartiality into the sample, simple random sampling will be used at this stage. This randomization process ensures that every cluster has an equal chance of being selected, reducing potential bias. Through the simple random sampling, the selected clusters will represent a diverse cross-section of urban areas within Abuja. This approach guarantees that the sample includes participants from various parts of the city, regardless of their size or prominence. Within each of the selected clusters, a purposive sampling approach will be employed to identify specific respondents who meet the study's criteria with a sample size of 210 youths in the study area. This purposive sampling is essential for targeting youths who have migrated from rural areas to urban areas in Abuja, as it ensures that the sample reflects the population of interest.

Methods of Data Collection and Analysis

In order to accomplish the study's goals, this study utilized primary data that was acquired via the use of a structured questionnaire. The secondary data that aid in explaining where was gathered from a variety of sources in addition to the data that was gathered through questionnaires and personal observation. The study will benefit greatly from the information provided by the books on migration in the library, reports and other written data from the central statistics agency, particularly the population and housing census statistics. The surveys were examined and presented using the descriptive statistics after the pertinent data had been gathered. Additionally, tabulation, graphs, and charts are used to illustrate the results. The validity and reliability of the surveys were investigated. With aid of Statistical Package for Social Science (SPSS) version 25 the data were analyzed and the descriptive statistics were used to present the results.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Sample Respondents

Accordingly, the study's findings indicate that young male migrants make up the majority in Abuja. 61% of the participants were young boys, and 39% were young females (Table 1). It is also known that young women are more likely to migrate abroad than they are to move to the country's rural areas. While many children have engaged in the rural-urban movement, Clemens (2014) study indicated that young males and females from various ethnic groups make up the majority of migrants to Addis Ababa. According to the study's findings, which are consistent with the discussion above, the rate of migration was significantly higher for those who belonged to the age groups of (15-20) followed by (20-25) at about 52.69% and 33.33%, respectively (which indicates that youths, among others, are more migratory), and it was relatively lower for those under the age of 25 at 11.8% for 25-30 and at about 2.18% for the age group of 35 years and above (Table 1).

This study demonstrates that rural-urban migration occurs today at all educational levels. The findings indicate that 7.1% of migrants lack a high school diploma (53.4%), with 27.6% of them attending first-cycle primary school (grades 1-4) and 25.8% attending second-cycle primary school (grades 5-8). The remainder were tertiary level (college or university) students, with graduates making up 22.3% of migratory youths. 7.1% of urban-rural immigrant youths (grades 9–12) were enrolled in secondary school (Table 1). Considering the elevated rate of dropout at the conclusion of primary education courses and the substantial number of university and college graduates looking for work, this does not imply that the least educated are the most migratory; rather, it shows the overwhelming majority of primary school graduates. According to the majority of studies on rural-urban migration, those with comparatively higher levels of education had the largest propensity to move (Deshigkar and Grimm, 2005). However, CSA (1999) found that internal migrants in Nigeria made about 70% of the illiterate population.

The study's findings, which reveal that more than half (63.3%) of the migrants were single, 24.4% were married, and 12.3% were divorced at the time of their migration, lend credence to this theory. The survey confirms that most young people who moved from rural to urban areas got married there to share the responsibilities of life. In the city, nearly all of them got divorced after only a brief period of marriage, primarily as a result of women's pregnancies. Due to this reality, most divorced women end up becoming single mothers. Marital status has an impact on migration from rural to urban areas. According to many academic works, those who don't have any family responsibilities are typically more likely to migrate (Clemens, 2014; Mendola, 2012). According to Table 1, the majority of migrants (53.5%) currently make an average monthly salary of less than 12,000 naira. According to this, 17.5 and 26% of migrants, respectively, have monthly incomes of 12,001-25,000 and 25,001-45,000 naira. This could be as a result of their involvement in various formal, informal, and self-employed economic activities that allow them to earn an average monthly income.

In a rural location, land constitutes one of the most valuable resources. To guarantee the standard of living of rural people, a decent quality of cultivable land is required. A person's likelihood of moving is comparatively high if they lack access to land size and other productive assets. Along with the small size of rural farms, which is a result of the high family size to land ratio, the low quality and productivity of the land as a result of increasing pressure on it has caused division and fragmentation of operational holdings, which has pushed many rural youths to the cities in search of better employment opportunities.

Table 1: Summary of Socio-economic characteristics of respondents (n = 210)

Characteristics	Frequency	Percentage (%)
Respondents' age (years)		
15-20	109	52.69
21-25	69	33.3
26-30	23	11.83
>30	9	2.18
Sex		
Male	111	61.0
Female	99	39.0
Marital status		
Single	131	63.3
Married	51	24.4
Divorced	28	12.3
Level of Education		
Illiterate	15	7.1
Grade 1-4	58	27.6
Grade 5-8	54	25.8
Grade 9-12	36	17.2
College or university	47	22.3
Level of income		
<12,000	107	53.5
12,001-25,000	35	17.5
25,001-45,000	52	26.0
Greater than 45000	16	3.0
Farm size		
< 1 hectare	129	70.93
1-2 hectare	53	19.76
>2 hectares	28	9.31

Source: Field survey, 2023

Economic Status of Rural-Urban Migrant Youths

Employment:

The results show that 71.4% of respondents had jobs. This shows that the employment rate for young rural-urban migrants in Abuja is relatively high. It is crucial to remember that 14.3% of people were unemployed and another 14.3% were in underemployment. These statistics show that some migrants struggle to find suitable employment prospects in urban areas. This finding is in line with a study by Adamnesh *et al.* (2014) that revealed rural-urban migrant teenagers frequently struggle to get formal job due to issues like insufficient abilities and educational credentials. These issues could lead to rural-urban migrant youth unemployment or underemployment rates to increase.

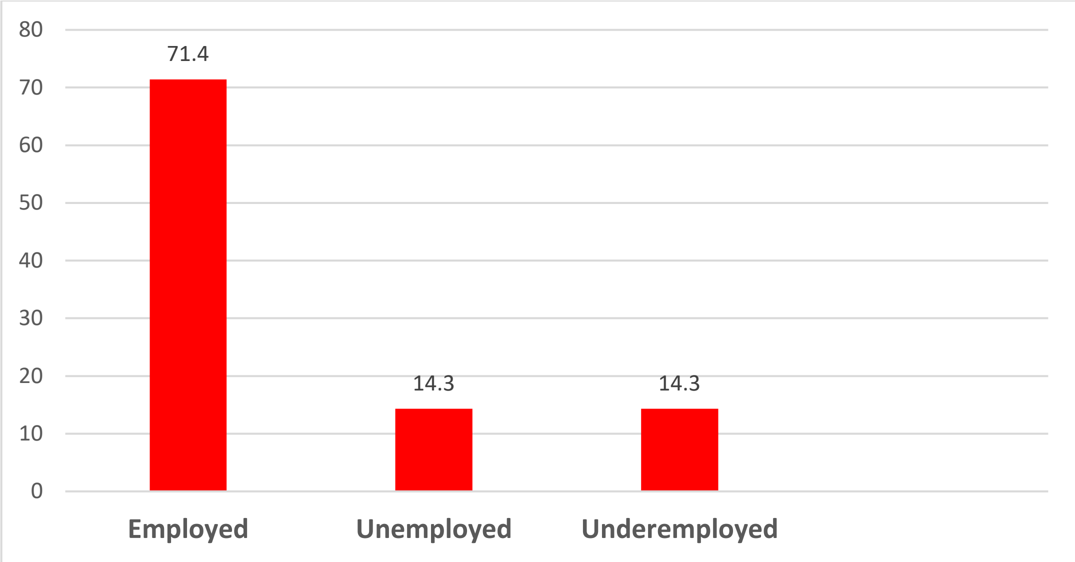

Figure 1: Employment
Source: Field survey, 2023

Cost of Living:
The outcome reveals that 28.6% of respondents indicated that their cost of living was affordable. However, a sizeable portion 47.6% said that the cost of living was moderate, and 23.8% said it was extremely expensive. These results are consistent with research on cost of living and urbanization. For instance, CSA. (2011) discovered that the cost of living is typically greater in metropolitan locations compared to rural ones. This study ascribed this to urban-related variables including increased housing costs and transit expenses, etc. Similar forces might be at work in Abuja, adding to the moderately high and extremely high cost of living those respondents noted.

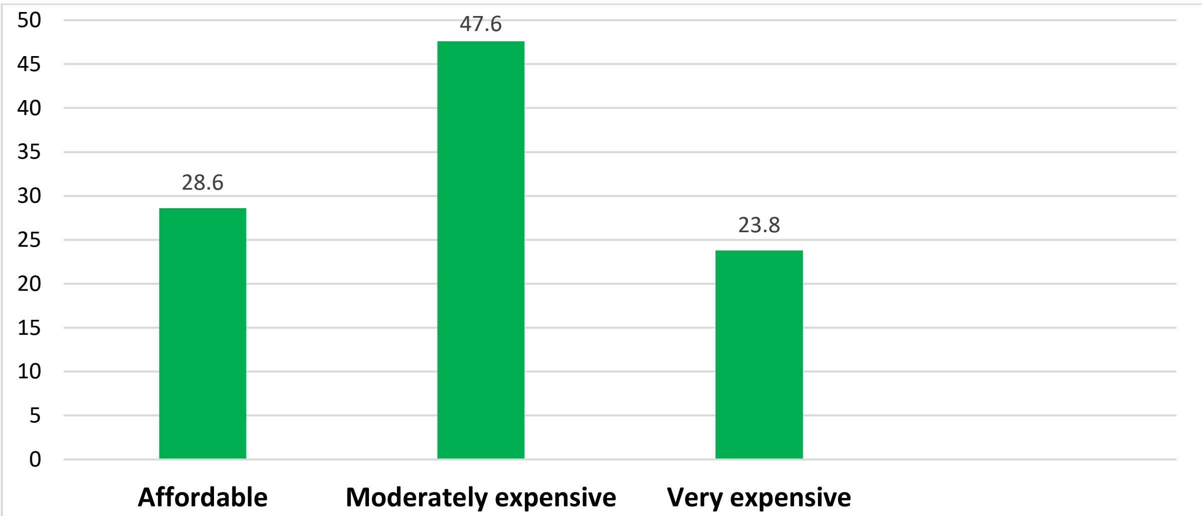

Figure 2: Cost of Living
Source: Field survey, 2023

Urban Informal Sectors:
According to the data, 57.1% of respondents actively participated in urban informal sectors such as street vending, small-scale trading, artisanal work, and other informal sectors. However, 42.9% of respondents did not work in these industries. This shows that a sizeable fraction of young rural-

to-urban migrants in Abuja engage in the informal economy, which can be a source of livelihood and income.

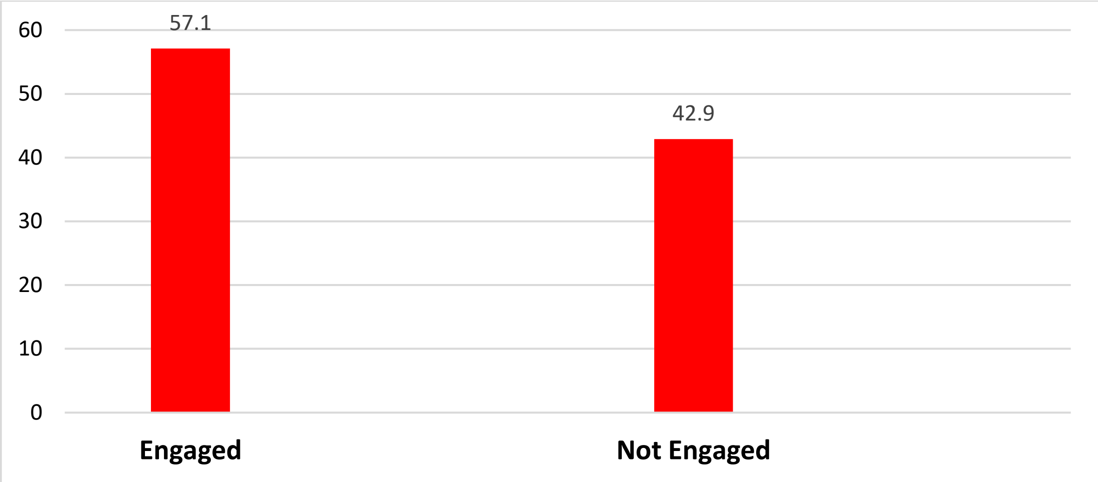

Figure 3: Urban informal sectors
Source: Field survey, 2023

Impact on Social Conditions of Abuja

Transport and healthcare services made a strong statement about the inadequacies social services were. Transport and health services became unavailable in the sub-city as a result of the significant influx of migrants. The main issue in the sub-city (41%), which is caused by the massive influx of migrant adolescents, is the inadequacy of social services. An effort was undertaken to compile data on the issues encountered by urban households (non-migrants) in order to analyze the effects of migration on city life. As a result, issues including inadequate housing, inadequate social services like education and healthcare, rising costs of living, difficulty finding a job, and competition for jobs were used as measuring sticks for the effects of migration on urban life. Information gathered through key informants indicates that there are effects of migration that the general public must deal with. The urban population grows as a result of rural-urban migration. Rural-urban migration raises the population in cities, leading to unplanned urban growth and a lack of social services like education and healthcare. a suitable road network, sewer system, and transit system. It is then followed by expansion of crimes in the area (28.4%); it also contributed for expansion informal urban sectors like Commercial sex work (22.8%). Rural-urban migrant also contributed for urban congestion (21.2%). Results also depicts that rural-urban migrants are highly involved in crimes like robbery and most women are also commercial sex workers. The rest (16.4%) respondents believe that slums and squatter settlements are results of high rate of rural-urban migration

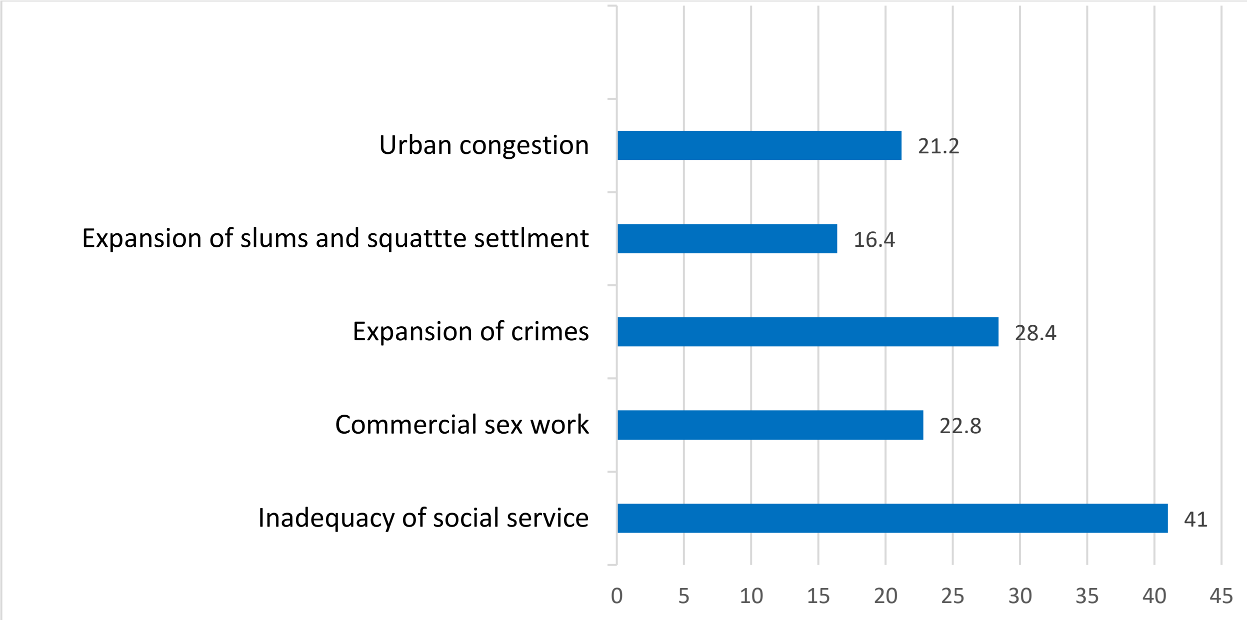

Figure 4: Impact on Social Conditions of Abuja

Source: Field survey, 2023

Push and Pull Factors

Push Factors:

With a high percentage of replies expressing concurrence or strong agreement (60 strongly agree, 80 agree), limited work opportunities appeared as the most significant push factor. The majority of respondents, as seen by the mean score of 3.71, believed that the lack of work possibilities in rural areas was a significant reason driving young people to move to urban areas. This result is consistent with previous research that highlights the significance of employment possibilities as a key factor in rural-urban migration (Mutandwa, 2011). He believed that the lack of job chances in rural areas frequently causes young people to migrate in pursuit of better employment prospects and higher earnings. Another significant push element was inadequate infrastructure. Table 2 shows that a sizable proportion of respondents acknowledged the role of infrastructure constraints, such as insufficient transportation, electricity, and water supply, in motivating rural youths to migrate. The frequencies (30 strongly agree, 50 agree) and mean score of 3.22 show this. Previous research has also emphasized how a lack of infrastructure affects people's decisions to migrate (Benebeberu, 2012).

It was determined that a lack of social services, such as healthcare, education, and public facilities, had a somewhat significant influence. The frequencies (20 strongly agree, 40 agree) and mean score of 2.95 indicate that a sizeable proportion of respondents believed that basic social services were lacking in rural areas, which led youngsters to seek out greater access to such programmes in urban settings. This outcome confirms research results that social service gaps are a major factor in encouraging rural-urban migration (Adamnesh, *et al.*, 2014). Additional push factors that respondents noted but were not particularly included in the poll are included in the "others" category. These variables may have been less prevalent or had less of an effect than the push factors indicated because of the frequencies (10 strongly agree, 20 agree) and lower mean score of 2.18. These findings suggest a wide range of additional factors that affect rural-urban migration, but their overall influence appears to be less significant than the aforementioned push factors. Individual circumstances, dreams, or cultural and social influences that affect migration decisions are only a few of the many possible variables.

Table 2: Push factors that prompt migration decisions (n=210)

Push factors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)	Mean scores	Rank order
Limited job opportunities	60	80	40	25	5	3.71	1st
Inadequate infrastructure	30	20	60	55	15	3.22	2nd
Lack of social services	20	40	80	55	15	2.95	3rd
Others	10	20	40	60	80	2.18	4th

Source: Field survey, 2023

Pull Factors:

According to Table 3, 70 respondents and 60 of them strongly agreed with the statement that a higher standard of life is a draw factor. The computed average score for this component is 3.81. These findings imply that a sizable proportion of respondents understood the possibility for higher standards of living in cities, including access to better housing, infrastructure, facilities, and general quality of life. Young people from rural areas may move to metropolitan areas in search of a higher standard of living (CSA, 2011). Table 3 shows that 80 respondents and 50 respondents strongly agreed with the proposition that higher career prospects are a pull factor. This factor's average rating is 3.71. These findings imply that a sizable proportion of respondents were aware of the allure of better economic prospects in cities, which encouraged young people from rural areas to migrate. Many people want to migrate to urban regions because they provide a variety of work options and the possibility of a greater income (Adamnesh *et al.,* 2014).

Table 3 shows that 40 respondents strongly agreed, 60 agreed and 70 remained neutral with the statement regarding the quality of education as a pull factor for rural-urban migration. The mean score for this pull factor is calculated as 3.57. This shows that a sizable proportion of respondents agreed or strongly agreed that the quality of education is a desirable feature that entices youth to migrate from rural areas to urban centres. Youths in urban regions that have access to greater educational opportunities may be able to gain important knowledge and skills that will improve their prospects in the future (Benebeberu, 2012). Access to healthcare is ranked fourth among the pull factors in Table 3 with a mean score of 3.33. These findings suggest that while some respondents acknowledged the importance of access to healthcare as a pull factor, a significant number remained neutral or disagreed. However, this indicates that while access to health care is still considered relevant, its influence may be relatively lower compared to other pull factors. Nonetheless, availability of better healthcare services in urban areas can be appealing factor for rural youths concerned about their well-being (Mutandwa, 2011).

Cultural opportunities rank fifth among the pull factors in Table 3 with a mean score of 3.05. These results imply that while a considerable proportion of respondents were neutral or disagreed, others acknowledged the draw of cultural activities in urban regions. Depending on personal preferences and priorities, the impact of cultural variables on migration decisions can vary (UNDP, 2009). A dynamic lifestyle and other cultural aspects, such as having access of a variety of social activities, may appeal to some people but may not be the main factors driving migration from rural to urban areas (Birhane, 2011).

Table 3: Pull factors that prompt migration decisions (n=210)

Pull factors	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)	Mean scores	Rank order
Quality of education	40	60	70	30	10	3.57	3rd
Better job prospects	50	80	40	20	20	3.71	2nd
Access to healthcare	30	40	90	40	10	3.33	4th
Improved standard of living	60	70	60	10	10	3.81	1st
Cultural opportunities	20	30	80	50	30	3.05	5th

Source: Field survey, 2023

CONCLUSION AND RECOMMENDATIONS

This study used a case study from the Abuja to demonstrate the socioeconomic effects of rural-to-urban migration on the social and economic conditions of urban households. Migration between rural and urban areas strains urban essential services like transportation, housing, and health care. According to the report, the majority of migrant youths are young (between 15 and 20 years old), have only completed grades 1 through 4 of primary school, and are single. It also notes that university and college graduates who are migrating due to unemployment in their home countries are also among the migrants. Youth from rural and urban migration are involved in illegal street trade, which has a negative impact on non-migrant urban inhabitants' quality of life. The issue of unemployment has been made worse by the continual influx of migrants into the Abuja, which produces too much labour. The main issues brought on by rural-urban migration are an increase in street children, an increase in commercial sex workers, an increase in criminality, and an expansion of urban informal sectors. Urban residents are particularly impacted by migration since rising food prices and job competition lead to jobs with poor pay. Cities' population densities are significantly influenced by migration. The influx of rural migrants into cities causes an unforeseen rise in population and a demand for urban resources including jobs, health care, and transportation.

In general, migrant youth enjoy better living conditions in cities than they do in rural areas, and they work hard to do so. According to the study, most migrant adolescents have fair expectations when they leave their village, and they are now typically satisfied and enjoy an enhanced level of living in urban regions. Nevertheless, despite challenges in the town, the housing issue, a lack of employment possibilities and sufficient consumption items, growing costs of living, insufficient social services, and other issues remain key issues for migrants today. However, the majority of migrants do not intend to or have any plans to go back to where they were born because they prefer to believe that things would get better. Some people, nevertheless, have intentions to relocate to other cities. Additionally, as more and more rural-urban migrants enter this city, there will soon come a point of diminishing returns where the towns will no longer be able to provide even the most basic social services to the registered citizens owing to the demand of the migrants.

According to this study's findings, rural-to-urban migration raises the urban population, leading to unplanned urban growth with a lack of social amenities like adequate health care, an effective sewerage system, road networks, and a transportation system. Transport and healthcare services made a strong statement about how inadequate social services were. Transportation and health services become inaccessible in the sub-city as a result of the significant influx of migrants. Regarding the impact of rural-to-urban migration on urban households, it contributes to sub-city poverty, unemployment, and an increase in crime. The impact of rural-urban migration on urban demographics also shows that urban residents' issues are brought on by the city's rapid population growth, which is then greatly exacerbated by rural-urban movement. The study also discovered that movement from rural to urban areas contributes to the rise of urban squatters, uncontrolled urban growth, and poor environmental management. It implies that migration from rural to urban areas contributes to environmental contamination in urban areas.

RECOMMENDATIONS

- The country's goal to reduce poverty views rural-urban migration as an unwanted occurrence. Rural-urban migration can, however, be a positive phenomenon and should be taken into account when developing a strategy to fight poverty. The plan should be created to maximise the positive effects of migration and minimise any negative effects.
- Rural-urban migration makes it easier for agriculture and industrial development to be linked, especially when it comes to shifting labour from less productive to more productive sectors. Migration from rural to urban areas is a method of structural change that promotes economic expansion. In this regard, the growth of labor-intensive industries and the strong performance of the urban economy help to strengthen the connections between rural and urban areas. As a result, policies for both urban and rural development should be consistent and supportive of one another. Additionally, migration policies ought to become ingrained in the nation's macroeconomic strategy.
- To lower the degree of open and covert unemployment as well as the chronic poverty in rural areas, the government and the private sector should promote employment possibilities in both the rural and metropolitan economies. In this sense, the government should establish infrastructure that will support private sector growth in rural areas and ensure that rural youth have access to jobs.
- To give rural youngsters raised the necessary skills to work in the agricultural industries, education strategies should include agricultural components. Rural-urban migration has greatly decreased as more rural youth participate in agricultural activities, and increased agricultural production leads to stability in the cost of consumer goods in towns and cities.
- With many young migrants from rural to urban areas of the country, Abuja transforms into a melting pot. To raise rural-urban migrant youths, decentralized urban development in regional states should be implemented. In addition, it allows rural youngsters to find employment in their communities and lessens the massive migration of migratory youths into Abuja.

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Diagnostic Investigation of the Potential Effect of Soil Moisture Condition in Detecting Climatic Hazards During the Crops Sowing in Cameroon

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Abstract:
The beginning of the sowing period in Cameroon has always been difficult to define and determine by scientists. Most of the authors analyze the state of the beginning of the sowing period in Cameroon using rainfall and temperature data. Soil moisture, which is an essential climate variable, has not been much used, even though it can be a good climate variable to monitor the seasonal agricultural drought. The present study intends to investigate the spatial and temporal patterns of agricultural drought based on soil moisture data during the beginning of the growing season (march and July). The choice of the two months was made since they are respectably defined by the Ministry of Agriculture and the agricultural research center as the periods of the beginning of sowing in Cameroon. Rainfall and soil moisture data were collected from different sources. The analysis of the data was made using descriptive and inferential statistics as well as remote sensing. The findings show that from 1950 to 2010, while the March soil moisture was decreasing, the July soil moisture was increasing. The year 1990 has been detected as the year with an exceptional soil moisture deficiency in Cameroon. Also, it has been found that the regions from Adamaoua to the south have a high variation in March soil moisture. While the Far North and the North Region have less variation in soil moisture. It can lead us to observe that in March in the area from Adamaoua to the south of Cameroon, the beginning of the growing season is more variable and unstable than in July in the north and far north regions.

INTRODUCTION

African agriculture is more vulnerable to climate change and climatic hazards because of low adaptative capacity and forecasting (Hope, 2009). This leads to food insecurity in some parts of African countries affecting livelihood of farmers mainly in rural areas. In the past, it was possible to predict seasons based on the farmer's empirical knowledge, but nowadays the beginnings and ends of the rainy seasons became less predictable due to the irregular distribution within months (Diop et al., 1996; Houndenou et al., 1998). The growing period is the time to choose when to produce crops. It is delimited by the number of days during which a specific plant or crop needs to move from germination to maturity. It can be once or twice annually. In Cameroon, the rainfall season is the appropriate period for crop production.

Most of the farmers planned their activities according to the behavior of the rainfall (raining agriculture). Samba et al. (1999) show that useful rain to start sowing is registered within two consecutive days with an amount of 20mm. These consecutive days will not be followed by a sequence of 7 days without rain for 20 days. This quantity of water is needed for the beginning of the vegetative cycle of crops. Research has been done considering mainly rainfall to explain and analyze the sowing period. Furthermore, several studies analyzed the impact of climatic hazards on agriculture in Cameroon based on the relationship between rainfall, temperature, and crop yield (Abossolo et al., 2017; Amougou et al., 2015; Feumba, 2016). However, soil moisture was less considered in climate change impact analysis in Cameroon. Recently, the World Meteorological Organization (WMO) recommended researchers the use of soil moisture when analyzing climate change impacts on agriculture because changes in soil moisture can accordingly have substantial impacts on agricultural productivity. Magha et al. (2021) assess the soil moisture characteristics of Gleysols in the Bamenda (Cameroon) wetlands and the link between soil moisture content and selected soil characteristics affecting crop production. Carsky et al. (2000) and Sugihara et al. (2016) mentioned that soil moisture limits production more than nutrient supply. Therefore, there is a need to develop innovative strategies that increase resilience of farmers in the changing conditions (Olajire et al., 2022).

It is in view of these works and the insufficiency of works on soil moisture in the analysis of climate change that the present study was oriented on the diagnostic investigation of the potential effect of soil moisture conditions in detecting climatic hazards during crop sowing in Cameroon. We assumed that soil moisture data could be an effective method of detecting climatic hazards during the early planting period in Cameroon. Soil moisture is a major determinant of the type and condition of vegetation (agriculture), so there is a need to define it as a new research axis in the agricultural research structures of Cameroon.

RESEARCH METHODS

Study Area

The study area is in the center of Africa. The country is bordered to the north by Chad, to the south by Equatorial Guinea, Gabon, and Congo, to the east by the Central African Republic, and to the west by Nigeria. Geographically, it is located between 2.0.0N and 13.00N and 9.00E and 16.00E.

The agricultural calendar, or cropping period, is the interval of time farmers use to plan their agricultural activity based on rainfall behavior. The beginning of the rainy season is considered by farmers to be the beginning of cropping season. The end of rain is considered harvest time. In Cameroon, we have two rainfall regimes (monomodal and bimodal). In the mono-modal zones, agricultural production activity is developed once a year. while in the bimodal zone it develops twice (two production cycles). The present changes in climate are such that it is possible in some monomodal areas (western highland areas) to have two crop cycles of production. Considering the dependency of agriculture on rainfall, more than half of farmers derive their resources from rain-fed agriculture, which gives the climate a central place in the agricultural production process. For example, the table below shows the calendar of maize production in Cameroon.

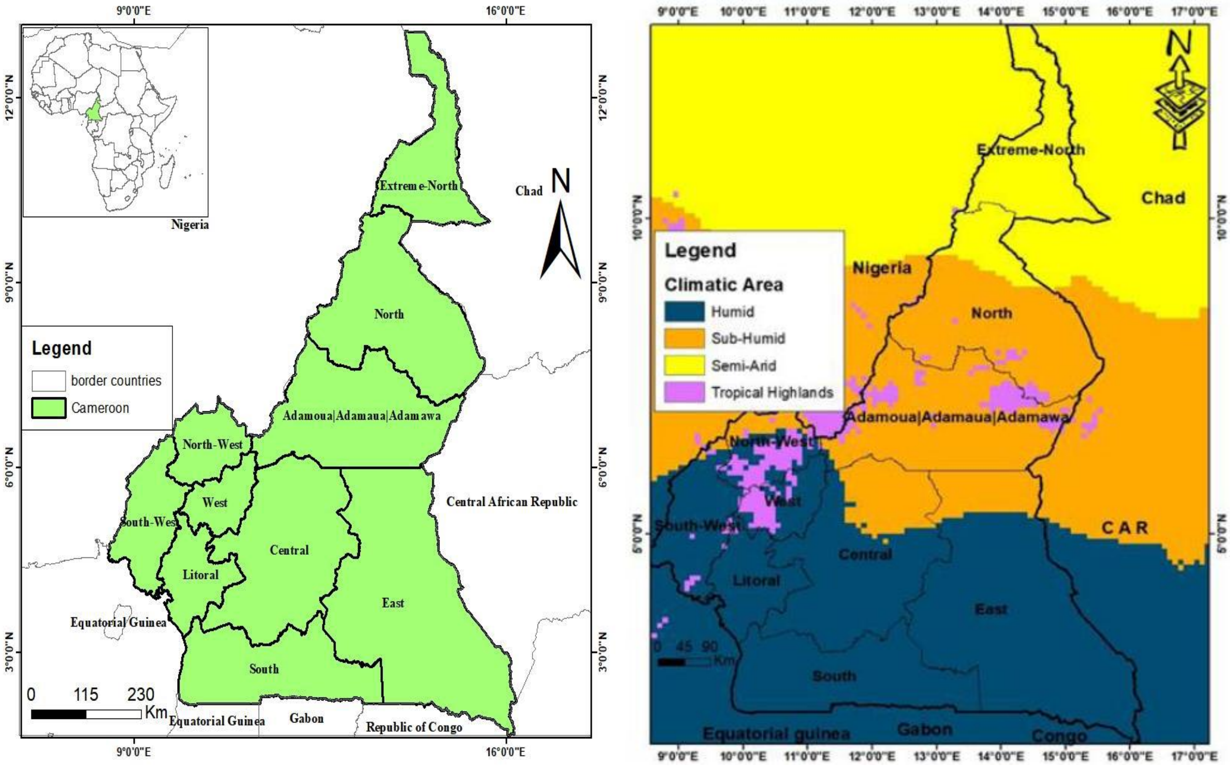

Figure 1: Cameroon in Africa and its climatic area

Table 1: Annual Length of cropping period in Cameroon

Région	Date of sowing for the first season	Date of sowing for the second season
Adamawa	May-June	-
Center	15 March-15 April	15-25 August
East	15 March-15 April	15-25 August
Far-North	July	-
Littoral	15 March-15 April	15-25 August
Nord	15June-15july	-
Northwest	Mi -April	15july- 05 August
west	Mi April	15july- 05 August
South	15 March-15 April	15-25 August
Southwest	15 March-15 April	15-25 August

Source: MINADER-Cameroon

The table presents the regions of Adamawa, Centre, East, Littoral, South, and Southwest as the regions with a cropping season starting in March. The field work and literature show that the west and northwest also begin their growing seasons in March. Even though the table shows that it begins in April. It runs from the 15th of March to the 15th of April. Those regions are in the south of the country. According to the fact that March is considered the beginning of their sowing period, it has been chosen in the present study to analyze its moisture content to find out if the month of March is suitable to start agricultural activities. The North and Far North have July as the month of the beginning of the growing season. It is the reason for the choice of the month of July in moisture analysis.

Data Collection
The lack of in situ soil moisture data over Cameroon led us to consider the satellite soil moisture product from both passive and active microwave satellites. The GLDAS monthly (March and July) soil moisture data was used. The data had a resolution of 0.25 x 0.25 degrees from 1950 to 2010. Monthly soil moisture data from GLDAS was in NetCDF format. Only July and March data were downloaded.

Data Analysis
Examining the sowing period through soil moisture can help detect some climatic constraints impacting crops. The case of July and March sowing periods has been analyzed at one dimension of 0 to 10 cm soil moisture during the years 1951, 1960, 170, 1980, 1990, 2000, and 2010. Two types of approaches were chosen to analyze the variation in soil moisture: temporal and spatial variation. The analysis of temporal soil moisture change was done through Excel 2016 software. From the NetCDF, the mean value data was extracted. The time series analysis was done to show the temporal variation in July and March soil moisture. A slope was used to determine the trends in soil moisture data. A regression analysis and level of significance for the changes in soil moisture were done.

The temporal analysis was done through GIS, which has become widely used for satellite observation and climate model data. ArcGIS is one of the dominant software packages in GIS that is appropriate for NetCDF data. This format is not a traditionally used GIS format, although it is getting popular. In this study, after downloading the different data mentioned above, we use ArcMap 10.2.1 for the analysis. In the software, we import the data, calculate the statistics of each layer, display and plot the NetCDF data, verify the extent of the layer, and export the final map and statistic data. The descriptive statistics (mean, median, standard deviation, maximum, and minimum) were done for the soil moisture of each year and for regions where sowing starts in July and March (table 1).

RESULTS

Depending on agroecological zones, Cameroon has a diverse sowing period and sowing behaviors. Each agroecological zone has a specific seasonal characteristic. July is considered as a sowing period for the North and Far North regions. While May is considered by the rest of the regions of the country (Table 1) as the period of sowing.

Temporal Variation in Soil Moisture
The time series shown in Figure 5 presents the evolution of soil moisture between 0 and 10 cm. The slope of the figure shows a decrease in soil moisture (-0.02 mm). Figure 5 depicts a significant decrease in soil moisture during the year 1990. There was a decrease in March mean soil moisture from 1980 to 1990 and an increase from 1990 to 2010. This decrease in humidity can indicate an exceptional climatic situation that Cameroon would have endured in terms of dryness.

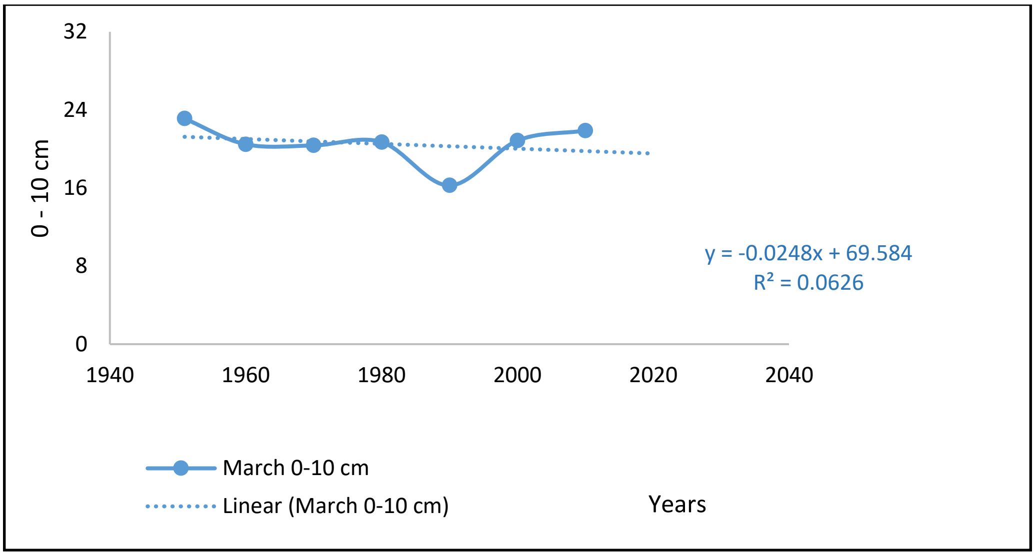

Figure 5: Monthly mean of March soil moisture at the depth of 0-10 and 100-200.

The same situation is observed in the mean soil moisture of July. The years 1970 and 1990 saw a decrease in soil moisture content. While the year 2000 saw an increase in soil moisture. A general increase in soil moisture is observed on figure 5 through the slop (0.004 mm).

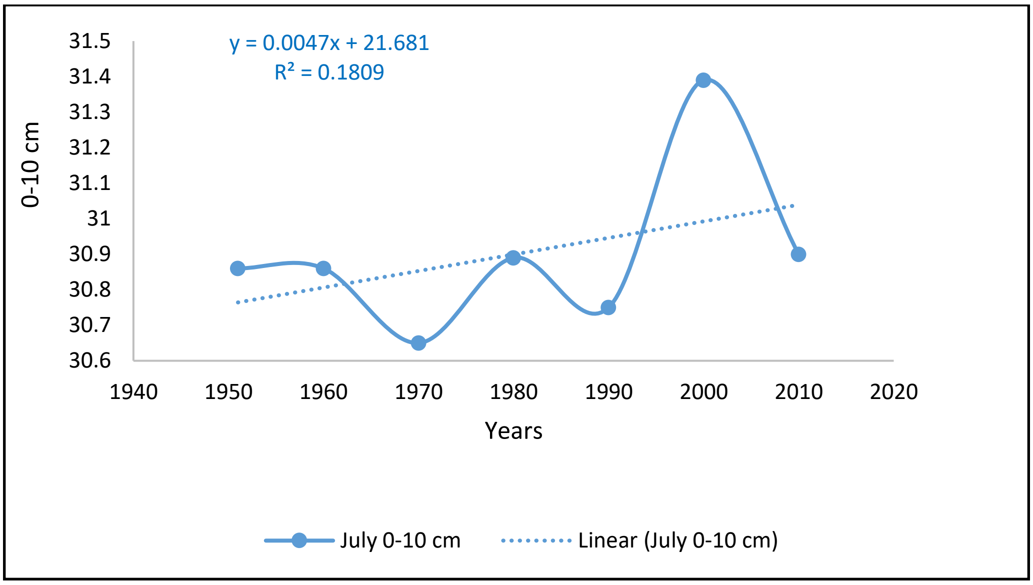

Figure 6: Monthly mean of July soil moisture at the depth of 0-10 and 100-200.

A t-test: two-sample assumption of unequal variances has been executed to see the level of variation in soil moisture at the same depth in July and March. The results have shown that the variable has a different or unequal variance. The p-value of the two-tail test is 0.0000130.05. Meaning that there is a statistically significant difference in the variation of the mean in July and March at the depth of 0–10 cm.

Table 2: t-Test: Two-Sample Assuming Unequal Variances

Months and the soil moisture depth	March	July
	0-10cm	*0-10 cm*
Mean	20.52143	30.9
Variance	4.479581	0.054733333
Observations	7	7
Hypothesized Mean Difference	0	
df	6	
t Stat	-12.8953	
P(T<=t) one-tail	0.000007	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.000013	
t Critical two-tail	2.446912	

This statistical test concludes that July and March have a significant change or variation in soil moisture. It can be too risky to sow between July and March.

Spatial Variation in Soil Moisture

The spatial analysis of the variation in soil moisture gives the value of each region. The mapping considers the moisture level from 0 to 10 cm and from 1951 to 2010. July (J) is concerned by two regions, such as the Far North and the North Region. While March (M) is concerned by the rest of the regions in Cameroon. For the year 1951, the July soil moisture mean was 30.57 mm for the two regions. The maximum is 37.13 mm, and the minimum is 20.4 mm. The sample variance is 41.30, and the standard deviation is 6.42. The descriptive analysis shows that the data are close to the mean value (30.57 mm). The March soil moisture at 0 to 10 cm shows a mean value of 29.01 mm. The maximum value of soil moisture is 38.87 mm, while the minimum is 19.15 mm. The sample variance is 54.41, meaning that there is a variation within the soil moisture value over the region of North and Far North Cameroon. The standard deviation is 7.37.

The year 1960 is characterized by decreasing mean soil moisture in July. Compared to the year 1951, the mean of the year 1960 is 27.95 mm. The maximum soil moisture is 35.18 mm, and the minimum is 20.73 mm. The sample value of the data is 27.05. This indicated low variation in soil moisture value over the Far North and the North region. The March soil moisture indicated a mean soil moisture value of 24.97 mm. The maximum soil moisture is 36.03 mm, and the minimum soil moisture is 13.92 mm. The sample variation is 63.39 mm. It shows an important variation in soil moisture amount over the south regions of Cameroon (from Adamaoua to the south region) (figure 1).

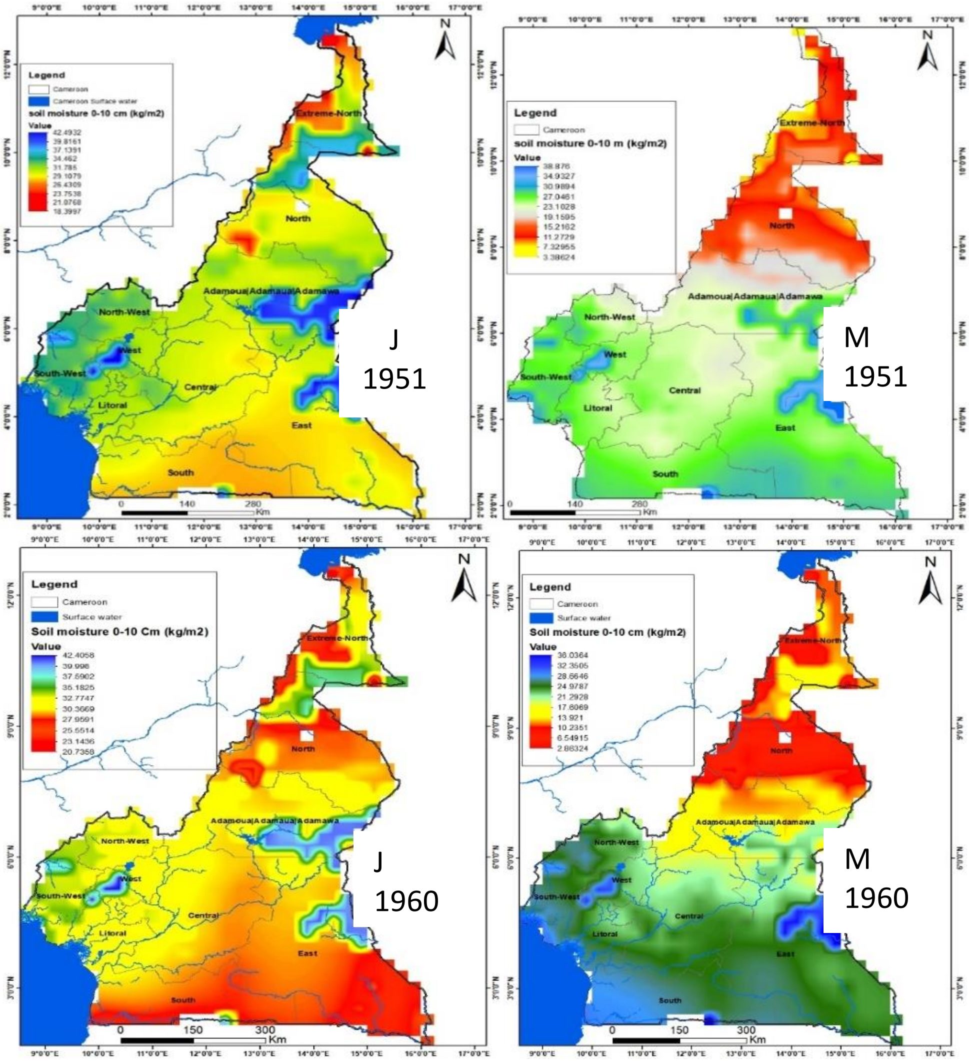

Figure 7: March and July 0-10 cm soil moisture variation from 1951 to 1960

The mean soil moisture of July 1970 for the Far North and North region was 27.97 mm. The maximum is 35.02 mm, and the minimum is 19.09 mm. The sample variance is 43.84. It indicates a low variation in soil moisture from the mean value. From Adamaoua to the south region, the March mean value of soil moisture is 24.82 mm. The maximum is 38.22 mm, and the minimum is 11. The sample variance is 133.02. In addition, the March 1980 mean soil moisture was 23.86 mm. It is lower than the mean soil moisture of 1970 (24.82). The maximum march soil moisture is 36.68 mm, while the minimum march soil moisture is 11.05 mm. The sample variance is 121.66. It shows an important variation in March soil moisture in the South regions of Cameroon. The July soil moisture mean value of 1980 was 27.12 mm. Compared to the July mean soil moisture of 1970 (27.97 mm), there is not an important change. There was a stable condition in July mean soil moisture from 1970 to 1980. The maximum soil moisture for July 1980 was 36.38 mm. The minimum soil moisture is 17.87 mm. The sample variance is 63.44 and it indicates a variation in July soil moisture in North and Far North regions of Cameroon.

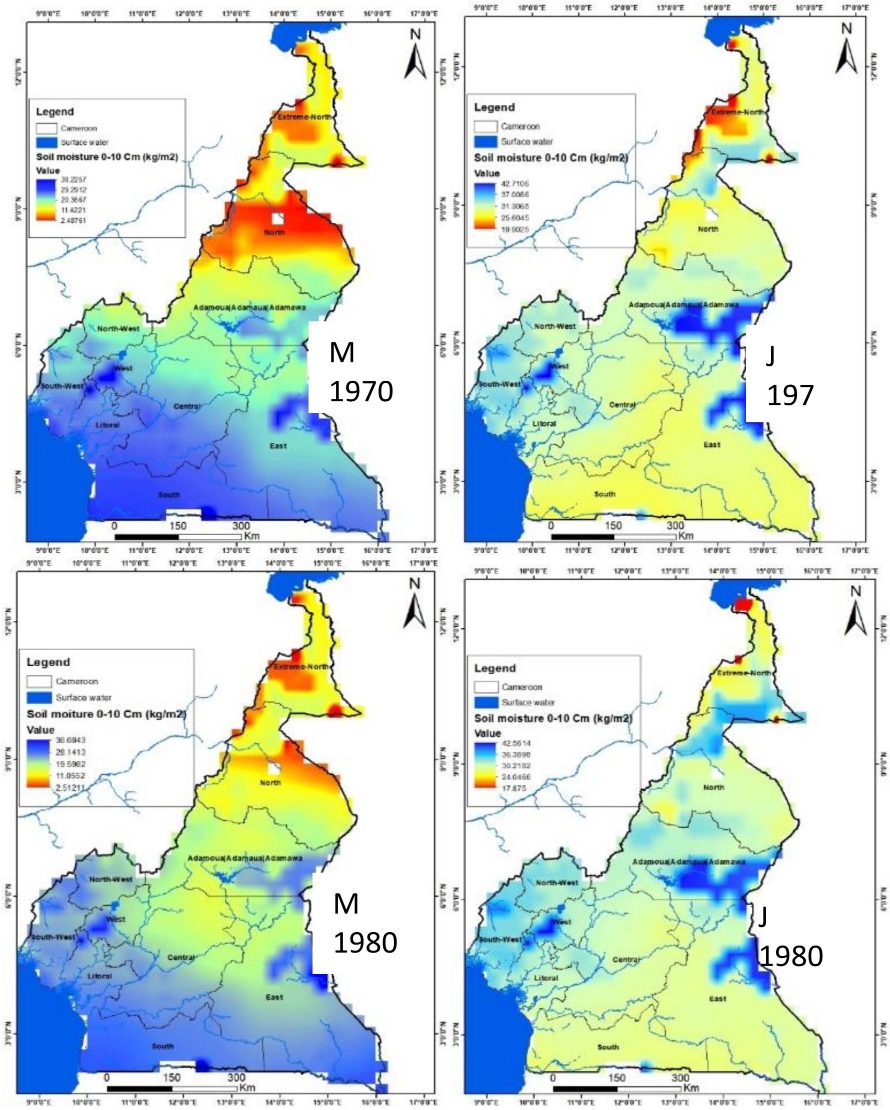

Figure 8: March and July 0-10 cm soil moisture variation between 1970 and 1980

The year 1990 is characterized by an increase in July mean soil moisture variation. The July mean value is 28.26 mm. The maximum is 36.88 mm, and the minimum is 19.66 mm. The sample variance is 54.92. In July of the year 2000, the mean value of soil moisture was increasing. Moving from 28.26 mm in 1990 to 29.13 mm in 2000. The maximum is 35.07 mm, and the minimum is 21.95 mm. The March soil moisture mean in 1990 was 19.29 mm, while it was 23.86mm in 1980. It is an important decrease in soil moisture in the south regions of Cameroon. The maximum soil moisture is 36.32 mm, and the minimum soil moisture is 2.27 mm. The sample variance is 181.17 and it is very high. It indicates an important variation in soil moisture of March. In 2000, there was an important increase in mean soil moisture in March. The mean soil moisture is 24.77mm. The maximum soil moisture is 36.85 mm, and the minimum soil moisture is 14.09mm. The sample variance (99.08) reveals an important variation in soil moisture.

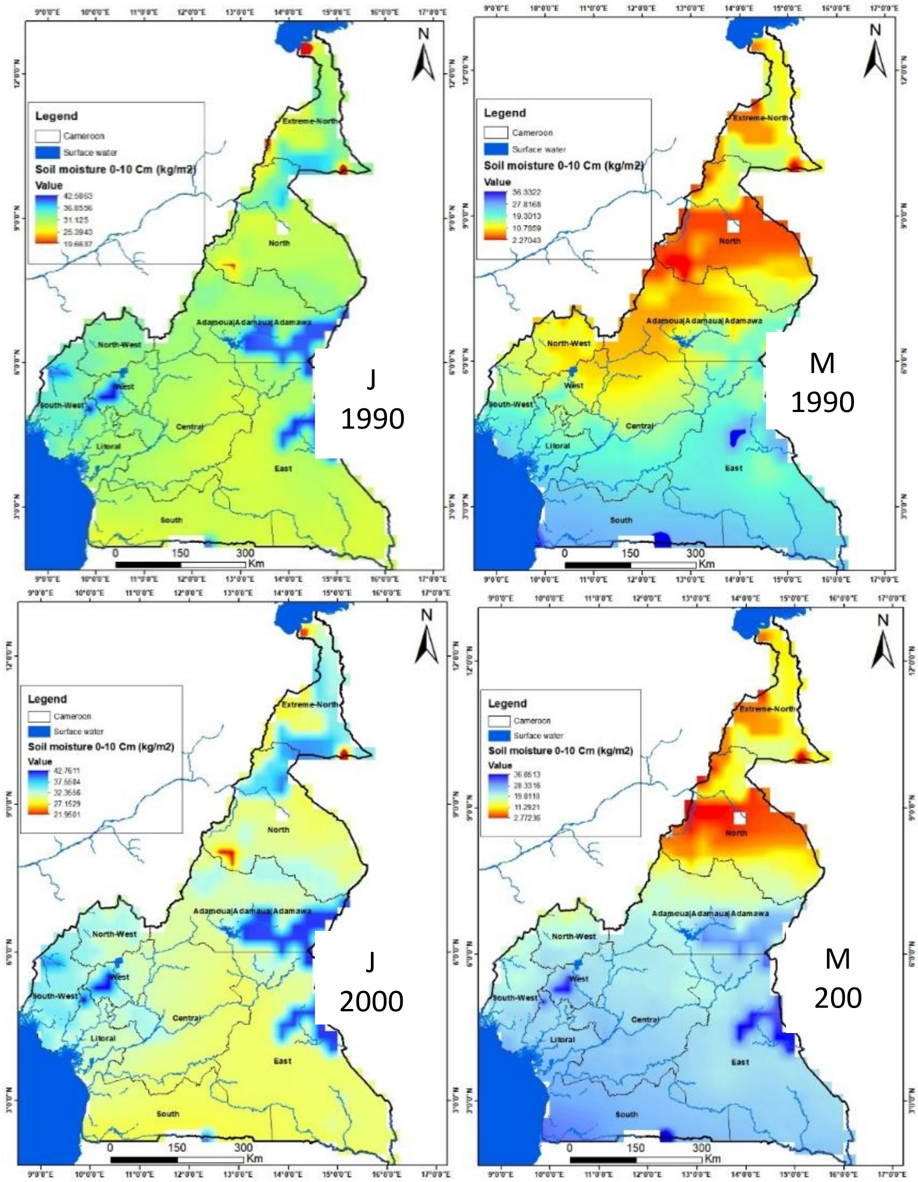

Figure 9: March and July soil moisture variation in 1990 and 2000

The mean soil moisture of March is still increasing in the south regions (from 24.77 mm in 2000 to 25.03 mm in 2010), the mean soil moisture in the north and far north regions is decreasing (from 29.13 mm in 2000 to 27.88mm in 2010). The maximum July soil moisture in 2010 was 35.06 mm, and the minimum was 21.7mm. The sample variance is 45.37 indicated the low variation in soil moisture. For March 2010, the maximum soil moisture is 35.72 and the minimum soil moisture is 17.05. The sample variance is 71.23 showing a variation in soil moisture.

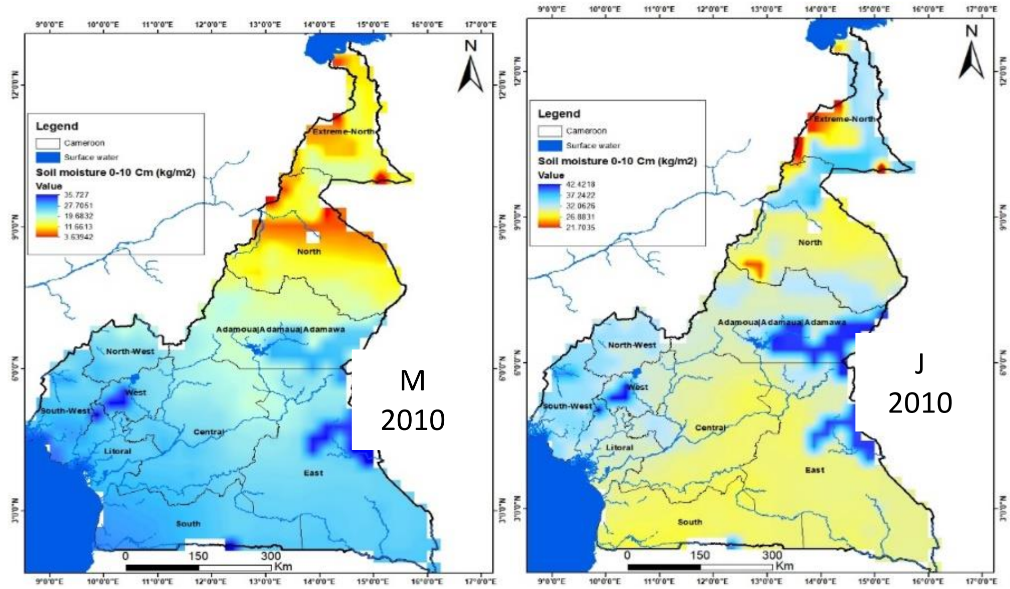

Figure 10: March and July 0-10 cm soil moisture in 2010

DISCUSSION

The present study found that 1990 was characterized by a decrease in soil moisture over Cameroon. This can be explained by a global decrease in precipitation over the country from 1970 to 1990 (Olivry et al., 1993) because of a strong positive correlation between soil moisture and precipitation (Sehler et al., 2019). Since rainfall is the source of soil moisture (Zhang et al., 2010), decreasing precipitation can lead to a deficiency in soil moisture. Tsalefac (1994) also reported that the dry years of 1982–1983 were strongly felt in the agricultural sector, not only in the Western Highlands but also in the entire country (Cameroon). The FAO/OSRO assessment of the effects of drought on food availability and the agricultural situation in 1983 indicates a 10 to 15% decline in national cereal production. It means that the decrease in soil moisture is also the result of drought impacts, which affected crop production. So, the decrease in soil moisture during March and July of the year 1990 can explain two situations, such as the dryness during those months and the decrease in rainfall. These climatic hazards have consequences for crop phenology, especially the germination phase, which coincides with the months of July and March according to the cultivation calendar. The second result of this study is that the spatial variation in soil moisture is mostly intense in the south regions and less stable in the north and far north regions. Sehler et al. (2019) explain this result with two factors, such as climatic regime and land cover. It is well known that land cover has a significant effect on soil moisture (Hillel, 1998; Rodriguez-Iturbe, 2000; Eagleson, 2002).

CONCLUSION

Overseas, this research was intended to use soil moisture for a diagnostic investigation to detect climatic hazards during the cropping period. The result indicated that, based on soil moisture, the years 1970 and 1990 have been identified as periods with an important decrease in soil moisture. March and July of the years 1970 and 1990, which are linked to sowing periods, face agricultural drought. The result shows that the mean value of soil moisture is more variable in the south regions than in the north and far north regions. This variation makes it difficult to determine the best period of sowing and can impact crop phenology. Based on this study, the Ministry of Agriculture and Rural Development in Cameroon and the Institute of Agricultural Research for Development will pay great attention to soil moisture because it is an essential tool to measure agricultural draught. The soil moisture sensor should be added to the measurement instrument for climate parameters. The association between vegetation index and soil holding capacity can be the best way to monitor soil moisture.

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Smart IoT Rural Agricultural Innovations for Food Security through Digital Technology Transfer: Agro-Industrial Sector Reform

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Abstract:
The goal of the Green Imperative programme is to use innovative Brazilian technology to mechanize agriculture, elevate farming among Nigerian rural residents, increase food security, and make farming a satisfactory occupation. The linking of Nigeria's agricultural value chain through an investment program established by the governments of Brazil and Nigeria is the country's option for improving the general agricultural innovations in the rural settlements. The Green Imperative is a south-south triangular cooperation initiative with long-term goals for food security, and is supported by the governments of Brazil and Nigeria through their respective Ministries of Foreign Affairs. The Green Imperative offers a macroeconomic strategy for generating sustainable economic growth, with a focus on investments, job creation, technology transfer and digital skills among farmers. The difficulties of the agricultural sub-sector's integration into international networks demonstrates how African countries struggle to get cutting-edge technologies and agro-innovation packages. The IoT smart technology and multi-stakeholder engagements are necessary for the growth of the green economy in order to speed up and solidify changes in consumption and agro production patterns. Implementing IoT Smart technologies for sustainable rural agriculture is a cutting-edge and innovative strategy to assist farmers, extension services, agribusiness, and policymakers in understanding innovative solutions to technology-driven food security. This study, employed survey technique, featured a sample size of 400 farmers from an extension block of the Agricultural Development Project in the Selected States of Jigawa, Katsina and Kano State in the North-Western Nigeria. In the study, IoT smart technology connectivity along the agricultural value chain will make it easier to precisely price goods, better position them on the market, and manage production better. The paper came to the conclusion that agricultural research and investment will have a significant impact on the growth of the food supply in Nigeria and Africa due to technological advancements, and that will be essential for ensuring future food security and sustainable food production through smart IoT farm management.

Keywords: Farm Mechanization, Android IoT Smart Technology, Digital Innovation, Food Security, Green Imperative, Sustainable Agricultural Economy, Extension Service and ICT for Development

INTRODUCTION

The Green Imperative is a south-south triangular cooperation effort with long-term goals for food security that is actively supported by the governments of Brazil and Nigeria through their respective Ministries of Foreign Affairs. This good practice involves numerous efforts from many sectors of activity, which combine to serve as a sustainability factor for its practical implementation. Participants include a learning institution (Getulio Vargas Foundation), an industry association (Brazilian Machinery Manufacturers Association), and banking organizations (Deutsche Bank and the Brazilian National Bank for Economic and Social Development). It is also supported with the right political commitment, a comprehensive strategy, and a clear mandate in the domains of agriculture and rural development. The project, which will last ten years, will be implemented in two stages: (a) spending more than $200 million to build 780 agricultural service centres, which will serve as hubs for training and equipment sharing to boost agricultural productivity; and (b) transferring technology from Brazil to Nigeria through procurement of agricultural equipment and inputs like tractors, planters, seeders, fertilizers, and pesticides.

For agricultural research and investment to achieve sustainable food production and food security in the future, the expansion of the food supply through technological advancements will be a key factor(Viana, Freire, Abrantes, Rocha, & Pereira, 2022). Investments in research, technology, and capacity building are needed, as well as a renewed focus on innovation, to increase sustainable agricultural productivity(Amaonwu et al.). The notion of "Greening the Economy with Agriculture " (GEA) refers to a comprehensive set of rights to sufficient food along with nutrition security in terms of food availability, access, stability, and utilization that may improve the standard of rural livelihoods while successfully managing natural resources and enhancing resilience and equity along the entire food supply chain, taking into account different nations' and individuals' particular circumstances(Musvoto, Nahman, Nortje, de Wet, & Mahumani, 2014). Managing agriculture, forestry, and fisheries in a way that satisfies a range of societal needs and desires without jeopardizing the likelihood that future generations will be able to utilize the full range of goods and services provided by terrestrial, aquatic, and marine ecosystems as part of global commons is imperative in order to achieve the goals set forth by the GEA(Weiskopf et al., 2020). As a matter of fact, the goals of GEA include:

1. Promoting regional, sub-regional, and national agricultural forums through application of a macroeconomic plan to achieve sustainable economic growth.
2. Enhancing the concepts of the "green economy" that are being presented, with a focus on financing, technology, and investment opportunities for the green sector.
3. Encourage countries to establish macroeconomic policies and mainstream them in order to facilitate the transition to a green economy.
4. By balancing domestic production, bilateral technology synergy, investment, and commerce, we can ensure that everyone will have access to food and nourishment. To that effect, everyone will have access to enough food and aid in the rural areas with sustainable economies.
5. Using traditional knowledge, scientific advancement, and technological changes to maintain healthy ecosystems that take food production into account and observe the rules of resource management.

The sample size the of current study consist of 400 rural farmers from an extension block of the Agricultural Development Project in the Selected States of Kano, Jigawa, and Katsina in the North-Western Nigeria. Four hundred (400) respondents were selected for the survey through the use of a number of pre-tested, structured questions administered in stages while using purposive and random sampling techniques. The primary statistical information for this study came from these respondents, in addition to secondary data input. The results showed that the average age of farmers in the zone was 40 years old and that they had an average of 18 years of agricultural experience. With only one or two types of formal schooling and an average family size of ten members, men made up the majority of the respondents. The respondents identified as Muslims and claimed ancestry-related access to land. Although farming was their primary source of income, they did not belong to any farmer organizations. The majority of respondents (90%) also owned a mobile phone, with 40.5% of those being ordinary phone owners. Call apps (90 percent) and SMS apps (90 percent) were both used by the majority of the farmers in the area. According to additional study, call apps are preferred by farmers over SMS for family and friend communication (90 percent), purchasing agricultural goods (80 percent), and receiving general marketing information (79 percent). Farmers generally have positive opinions of using cell phones and related technology within the agricultural supply chains in the ongoing development.

RESEARCH AIMS AND OBJECTIVES

The following objectives were sought to be accomplished in this study:

1. To provide information on the social and economic effects of rural farmers' adoption of mobile technology as part of the continuing digital agricultural revolution.
2. Analyse the effects of the adoption of mobile technologies on the agricultural productivity of the rural farmers in the chosen states of North Western Nigeria and make recommendations for appropriate action.
3. To determine the relationship between farmers and the application of technology for agricultural globalization in the ongoing Brazil-Nigeria Green initiative that focused on agricultural transformation.
4. To develop technological techniques for enhancing rural agriculture productivity that will support local food sustainability and nutritional security via private sector extension services.
5. To define the responsibilities that academic institution partnerships, public/private involvement, and bilateral technology transfer will play in enhancing rural agriculture productivity through the green imperative initiative.

RESEARCH QUESTION

The term agriculture technology describes the application of knowledge to agricultural production systems in order to increase farm productivity, profitability, and labour efficiency through various automation. In light of that, the purpose of the current study was to address the following research issues in accordance with the green imperative initiative:

1. As part of the ongoing Brazil-Nigeria Green Imperative and South-South corporation on agro-innovation for food and nutrient security, to what degree will the services of agro-extension workers be sufficient for rural agricultural technology transfer using Android IoT Smart Mobile devices?
2. Do rural farmers in Nigeria accept this technology transfer and have the skills necessary to use it effectively for agricultural management that would lead to food security?
3. How far will rural agricultural practices' adoption of new technologies be sufficient to allow for cross-border connection within the agricultural supply chain?
4. What part does the Nigeria Incentive-Based Risk-Sharing System for Agricultural Lending (NIRSAL) play in strengthening the bond between finance and agriculture?

5. What roles does south-south triangular cooperation initiative play in the long-term goals for food security?

LITERATURE REVIEW

Academically, a literature review is a piece of academic writing that shows knowledge of a comprehensible academic compilations on a particular subject in relation to other sources(Nelson & King, 2022). It is considered a literature review rather than a literature report because it also involved a critical assessment of the sources(Gusenbauer & Haddaway, 2020). A literature review is intended to help readers understand the current research and discussions that are pertinent to a particular subject or field of study and to communicate that understanding in the form of a written report. Therefore, an author can increase the understanding of the field by conducting a literature review. In this context, we categorized the literature of the current paper into three; (i) Technology Transfer (ii) Agro-Based Technology Innovation (iii.)Agro-Based Extension Services

Technology Transfer

In a calculated attempt to increase annual agricultural production of rice, soya beans, dairy products, livestock and poultry farming, the federal government of Nigeria had engaged Brazil on the transfer of agricultural technologies. In 2018, the Getúlio Vargas Foundation (FGV) and the Nigerian government signed a Memorandum of Understanding, which gave rise to the "Green Imperative Project", For the construction of the largest agricultural project on the African continent, there is need for cooperation in agricultural technology between Brazil and Nigeria(Zhou, 2022),(Alves, de Oliveira, & Motta, 2022). The initiative seeks to increase local production of essential meals for the community while giving priority to the development of sustainable, low-carbon agriculture mechanizations(Okoh, 2020). It is a top priority initiative for the Nigerian government that aims to enhance food production and decrease rural emigration, promoting social harmony that should promote environmental ecosystem sustainability. The Brazilian technology package, which includes the provision of agricultural machinery, equipment, and services, will be used in order to increase the production and quality of food produced by small-scale farmers in Nigeria in the coming year(Sims & Kienzle, 2017).

Even while technology is still viewed as a crucial component of the transition to sustainable agri-economy, international attempts to facilitate this shift in developing nations with technology have not been successful in producing the necessary results. The focus of the current research was on how to have a dialogue about international technology transfer (ITT) that encourages more fruitful international cooperation in the pursuit of sustainable development in underdeveloped countries. With an emphasis on small and medium-sized farmers and extension agents, the International Centre for Innovation and Transfer of Agricultural and Livestock Technology (CIITTA) being a group that aims to promote agriculture in developing nations(Pandey, de Coninck, & Sagar, 2022). The professional management of CIITTA oversees a wide range of activities including business management tools, social and environmental sustainability, as well as training and capacity building for all stages of the agricultural and livestock value chains, from basic production to production processing. The activities of CIITTA aim to empower young people and women through inclusive professional development, technical skill development, and access to environmentally friendly technologies. Through South-South collaboration between Brazil and developing nations in Latin America, Africa, and Central America, CIITTA facilitates technological and cultural interactions between nations. In order to guarantee the dissemination of best practices and access to new technologies in the industry, CIITTA maintains technical cooperation with the major research and technological diffusible institutions in Brazil.

Added to the mix of global technology transfer, scholarship opportunities and manpower development, the Nigeria Tertiary Education Trust Fund (Tetfund) had signed Memorandum of Understanding (MOU) with eight international institutions on research development, which include: University of Aberdeen, United Kingdom(UK), Cardiff University ,UK, University of Sheffield , UK, Durham University, UK, University of Turku , Finland, Sao Paulo Research Foundation (FAPESP),Brazil and Forum for Agricultural Research in Africa (FARA),Ghana. The object of the scholarship and collaboration include;

1. Encouraging collaboration in scientific and technological research between Nigeria and various institutions, including the nations that serve as their hosts.
2. The necessity of fortifying ties between the Nigerian scientific and other institutions' communities, including those of their host nations.
3. Supporting new venues for Nigeria and international research institutions to collaborate.
4. Fostering bilateral cooperation through encouraging cooperation in important areas of scientific research and technical manpower development.

Advances in Agro-Based Technology for Modern Agriculture

The FARA Holistic Empowerment for Livelihoods Program (HELP) aims to increase youth empowerment and livelihoods in Africa by fostering strategic human capital formation, through the Agricultural Knowledge & Innovation System (AKIS) and agribusiness(Molinari, Mena, & Ghiglione, 2022),(Kim, 2022). As a comprehensive model fueled by international collaboration, HELP creates livelihoods by relying on South-South and Triangular Cooperation (SSTC), a solidarity that build up the conventional donor-recipient relationship in which partners utilize pertinent technologies and innovations for their mutual advantages. The goal of HELP is to connect the private sector and African Agricultural Research for Development (AR4D) institutions with the necessary capacity for Science , Technology & Innovation(STI) and agribusiness to address problems in the continent's agri-food system and promote the development of the entire value chain(Swelam, Abdallah, & Salem, 2022),(Singh, Paroda, & Dadlani, 2022). Creating a strong and empowered agricultural workforce will alter the agribusiness in Africa by delivering agri-competencies, skills, innovative capacity, and knowledge to create future value chains and fit-for-purpose agricultural research.

The convocation of ARIFA, were to provide skill manpower innovative training for young African citizens on the 21st-century digital proficiencies regarding agricultural innovation, inaugurated in Brazil by FARA(Onu, Silva, de Souza, Bonatto, & da Costa, 2022). The launch of ARIFA in collaboration with Brazil Africa Forum 2019 highlighted the importance of technological innovation to increase Africa's agricultural productivity, which is at the core of the ARIFA initiative(Amaonwu et al.). This showed that without advancements in the deployment of technology in agriculture, it would be difficult for Africa to achieve food and nutrition security(Okello, Lamo, Ochwo-Ssemakula, & Onyilo, 2021). The African Union Commission and the African Union Development Agency official technical arm for matters pertaining to agricultural sciences, technology, and innovation and FARA, are the leading continental body in charge of coordinating and promoting agricultural research and development (R&D) in Africa (Singh et al., 2022). FARA is carrying out the Agricultural Research and Innovation Fellowship for Africa in order to restructure the African agri-food industry and offer the catalyst for swift agricultural transformation within ten years implementation plan(Pavageau, Pondini, & Geck, 2020). ARIFA will assist the regular admission of cohorts of graduates and agri-preneurs into the innovation systems created by FARA through Innovative Platforms (IP) and rural learning paths found in and around African institutions, universities, technical colleges, and rural communities(Amaonwu et al.). The objectives of ARIFA and how they fit into the greater African development agenda were discussed by Dr. Irene Annor-Frempong, Director of Research and Innovation at FARA. Dr. Annor-Frempong has been in charge of FARA's development and coordination of programmes spanning the entire continent, such as the SCARDA (Strengthening the Capacity of Agricultural Research and Development for Africa) and UniBRAIN (Universities, Business Research in Agricultural Innovation) programmers, as well as the AHCSTAFF (African Human Capital for Science, Technology and Agri-preneurship for Food Security) programme. The Science Agenda for Agriculture in Africa (S3A), the underlying continental framework for addressing the Comprehensive Africa Agriculture Programme's (CAADP) goal of increasing productivity, and the STI Strategy's (STISA) priority one on reducing hunger and food insecurity in African countries, are both being addressed by the director of research and innovation at the moment.

According to the most recent data, agricultural technology and software innovation have contributed to new digital employment being created in a variety of economic sectors, in addition to helping to increase GDP(Rehman, Jingdong, Chandio, & Hussain, 2017). In Nigeria, the agricultural sector of the economy employs about 35% of the workforce as of 2020 (Osabohien, Olurinola, & Matthew, 2020). As described by the FAO,(Adegbite & Machethe, 2020) , even though Nigeria has large deposits of natural resources like oil and solid minerals, agriculture still forms the backbone of the country's economy. Most rural Nigerians rely on it as their primary source of income. Crop Production, Livestock, Forestry, and Fishing make up the four subsectors that make up the agricultural sector(Adewale, Lawal, Aberu, & Toriola, 2022),(Crumpler et al., 2022). The sector experienced a reduction of 3.44% points from the third quarter of 2018 in the third quarter of 2019, although it still experienced nominal year-over-year growth of 14.88%. Crop Production, which made up 91.6% of the industry in the third quarter of 2019 and experienced a quarterly growth of 44.12%, is still the key driver of the sector. In the third quarter of 2019, the agricultural industry made up 29.25% of the total real GDP(Ahmed, Yusuf, & Ahmed, 2020)

Agro-Based Extension Services

The current subheading in line with agricultural utilities is focused on the idea and practice of extension services alongside digital agricultural management. However, before delving into the numerous varied facets of extension practice in the following section, it is necessary to consider what the term "extension" means in the context of rural agricultural practice. The rural agricultural extension is currently a widespread practice in the majority of the world's nations and a fundamental component of projects and programmes designed to bring about change in the rural agricultural settlements(Geza, Ngidi, Slotow, & Mabhaudhi, 2022). The administrative framework of rural regions frequently includes extension services, which are tasked with guiding change-related projects and programmes in collaboration with farmers. Agricultural extension service is a loosely structured educational practice aimed at the rural populace(Sumani, Kanukisya, & Mwaikokesya, 2022). This procedure provides guidance and knowledge to assist people in resolving their issues as a microcosm of the larger society within the agricultural channels of distribution. According to agricultural economists, focusing more on small farms causes employment and overall economic output to rise more quickly(Agyemang, Ratinger, & Bavorová, 2022). Additionally, agricultural extension service strives to boost the productivity of the family farm and generally raise the family's standard of living through additional earning when market distribution channel has been formed. The goal of extension is to alter farmers' perspectives on their challenges through government-private sector partnership(Jarial, 2022),(Yulo Loyzaga, Uy, Lo, & Porio, 2022). Extension focuses on the growth of rural communities as a whole, in addition to their physical and economic accomplishments. Therefore, extension agents engage in conversation with rural residents, assisting them in better understanding their issues and coming up with solutions.

Hassan et al(2022), observed that working with rural residents to enhance their quality of life is provided in the programme of extension services (Hassan, Hewidy, & El Fayoumi, 2022). This entails assisting farmers in raising the efficiency of their agricultural production as well as enhancing their capacity to shape their own future growth. Agricultural extension can provide farmers with additional knowledge and information that they do not already have, even when they already have a great deal of understanding about their environment and farming practices(Hörner, Bouguen, Frölich, & Wollni, 2022),(Smidt & Jokonya, 2022). For instance, the agent can help farmers by sharing knowledge about the reasons behind crop loss, basic pest control concepts, or the processes by which manure and compost decompose to release nutrients for plants. The application of this knowledge frequently requires the farmer to learn new skills of many different kinds, such as technical skills to operate unfamiliar agricultural equipment, organizational skills to manage a group project, the ability to evaluate the economic implications of technical advice, or farm management skills to keep track of usage of resources and equipment on the farm. The extension agent must take all necessary precautions to ensure success when imparting knowledge and skills to farmers and their families. He needs to identify the knowledge gaps or skills gaps that exist among the farmers in his region, and then he needs to set up learning opportunities that will help the farmers fill those gaps.

Through a dynamic learning process in the assimilation of new knowledge and skills, CIITTA seeks to equip technicians and extension workers to promote the finest agricultural production and processing techniques in their countries of origin. Every training program is designed to enhance knowledge through hands-on sessions delivered on CIITTA's own campuses. Workers in agricultural extension programs also give farmers guidance and information to help them make decisions and generally empower them to take action. For instance, it might include data on prices and marketplaces, or it might include details on the accessibility of financing and inputs. Technical guidance is likely to be more immediately applicable to the family farm's production operations and the actions required to increase or maintain this productivity. This technical guidance will be mostly based on the results of agricultural research. However, in many cases, farmers may also be trusted sources of guidance and knowledge for other farmers, thus agents should constantly make an effort to connect farmers. Farmers also require some kind of organization, both to represent their interests and to provide them with a way to take collective action, in addition to knowledge, information, and technical guidance.

Therefore, Extension should focus on assisting in the formation, organization, and growth of local farmer organizations. This should be a shared effort, and any organization of this kind should only be established after consulting the farmers. These groups will facilitate extension services' interactions with neighbourhood farmers in the future and act as a conduit for the communication of information and expertise. Isolation and the belief that there is nothing they can do to improve their circumstances are two major barriers to development that many farmers experience. Some farmers may have spent their entire lives toiling away, with little help or encouragement, in trying situations in order to sustain their families. In order to effectively engage farmers in extension activities, it is crucial for extension to work directly with them, support their initiative, and generally encourage them to do so. Convincing farmers that they are capable of taking care of themselves, being in charge of their own lives, and having the power to escape poverty is equally crucial(Charatsari, Lioutas, Papadaki-Klavdianou, Michailidis, & Partalidou, 2022). In the developing world, extension operations are common, and most governments have established formally structured extension agencies to carry out extension projects and programs(Ankrah & Freeman, 2022).

SMART IOT AGRICULTURAL FRAMEWORK FOR GREEN IMPERATIVE

The **Fig.1** presents a framework for the smart IoT agricultural framework that consists of five key elements: IoT Data Collection, IoT Platform for Communication, Data Processing, Data Visualization, and System Administration. The network that has been converged from several communications networks makes up the data acquisition component. The communication medium may be a wireless technology like LoRa, Zigbee, NB-IoT, or Bluetooth, or it may be a wired technology like a controller area network(Tao, Zhao, Wang, & Liang, 2021). In the meantime, IoT mobile communication technologies were adopted which is further broken down into wide area network (WAN) sub-components, having the cellular communication of 4G/5G technology, which will alter the way agriculture is monitored by enabling high-speed data transfer, network control, and energy efficiency. In addition to transmitting the agricultural-related data gathered by the data visualization component, the IoT data collection component also delivers control instructions to the system management. By integrating numerous models and algorithms for the agricultural production process, the IoT Platforms component is responsible for decision making, data storage, and statistical analysis on agricultural data. The component has been further subdivided into (i) Edge Computing, (ii) Cloud Computing, and (iii) Big Data sub-components. Using information gathered through information mining and other methods, big data technology does predictive analysis by identifying internal connections between the data.

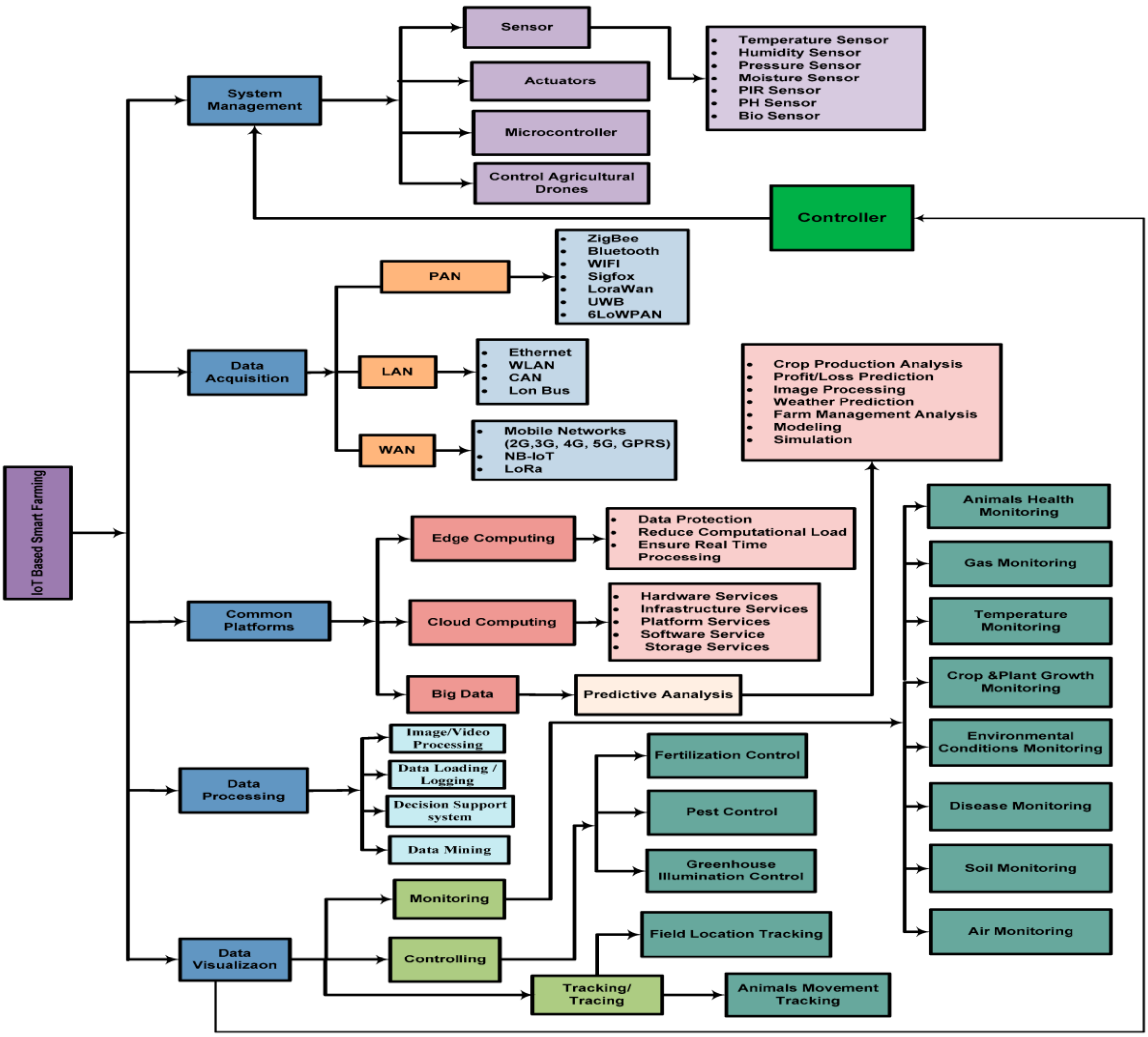

Fig 1: IoT Agriculture Framework(Farooq, Riaz, Abid, Umer, & Zikria, 2020).

Numerous IoT agricultural applications benefit from cloud computing's provision of platform, infrastructure, hardware, software, and service capabilities. Farmers can save their images, texts, videos, and other types of agricultural data on the cloud platform for a reasonable price, which helps agricultural businesses by cutting down on storage costs (Hua et al., 2023). Making decisions based on farmers' technical skills while using direct access to actual agricultural data is also challenging. On the other hand, agronomists are qualified to offer advice and form reliable conclusions based on data. Because of this, only cloud computing offers a wise and secure platform for monitoring crops. Farmers still experience technological losses associated to poor internet access and limited electricity, despite the fact that the cloud platform aids them through its advanced capabilities. One of the modern computing models called edge computing executes calculations at the network's edge. Additionally, this platform safeguards agricultural data because edge computing processing happens more often than in cloud computing, hence reducing computational burden and speeding up data transfer.

RESEARCH DESIGN & METHODOLOGY

Information for the current study were acquired from both primary and secondary sources. The government documents and digital archives from the ministry of agriculture are among the secondary sources, as memos from the TETFUND Abuja on the Memorandum of Understanding between TETFUND and some foreign higher education institutions as well as other institutions whose mission is focused on research and development were all studied. The study went on to evaluate supplementary information from StatCounter Globalstats' open repository about the market share of Android and iOS smartphones in Nigeria and Africa. The agricultural production value in Brazil from 2010 to 2020 were obtained from Statista corporation open repository and interpreted to provide justification as per why the Brazil-Nigeria Green Imperative expectation. The distribution of questionnaires to participants in rural agriculture who were chosen at random within the study area were required as part of primary data sources.

This study focused on the socioeconomic and demographic characteristics of farmers, the accessibility of agricultural mobile apps, levels of awareness and usage, and the extent, intensity, purpose, and limitations of farmers' app usage. It also looked at the availability of mobile phone apps in general. A sample size of 400 farmers from an extension block of the Agricultural Development Project in the Selected States of Katsina, Kano, and Jigawa were included in the study, which used a survey methodology. Four hundred (400) respondents who provided the primary statistical data for this study through the application of a series of pre-tested and structured questionnaires were chosen using a multi-stage, combined with purposive and random sampling approaches. Descriptive statistics tools were used to assess and show and analyzed the data relevant to the study. The secondary sources of data, on the other hand, included digital archives with academic works that investigated the topic of agricultural technology innovation from the global data bank archives.

POPULATION AND SAMPLING

The study comprised of 400 Rural Agricultural participants from agro extension services of Jigawa state, Katsina state and Kano state, all in the North Western Region of Nigeria, that had successfully implemented digital agro economy systems made up the population of this study in the ongoing green imperative agricultural automation. The researcher chose the agricultural innovation within the green imperative implementation plans for digital agriculture systems from the general farmers population to participate in the study. A purposeful sampling approach was used to choose the instances for this investigation. Purposeful sampling is a non-random research technique in which a researcher includes in the sample particular examples that might produce data that is relevant to the study. Sampling is a planned process for choosing specific cases from a population of a given distribution. Flexible sampling is a method used by qualitative researchers. The choice of sampling approach is influenced by factors including the nature of the case, the population, and the logistical challenges of reaching instances. For this investigation, other sample techniques like convenience sampling and snowball sampling were inadequate. With convenience sampling, a researcher chooses easily accessible study venues and subjects. Convenience sampling is less time and resource-intensive for a researcher, but lacks rigor, which could have an impact on the validity of the study and the quality of the data collected. With the snowball sampling approach, a researcher invites past study participants to suggest more potential study participants.

There is enough information available at data saturation to guarantee the study's repetition. Information from many data sources can be brought together through the process of triangulation. By exploring and analysing several viewpoints on the phenomenon, triangulation aids in the saturation of data. For a researcher to come to any conclusions regarding a case study, additional sources of evidence beyond interviews are required. The study's credibility is improved by gathering enough data to achieve saturation. In this study, data redundancy occurred when there was no more fresh material to be discovered after conducting participant interviews and reviewing corporate records as already stated in the research design and methodology. A multi-case study of the 30 rural farmers were conducted as part of the strategy to achieve data saturation, and case studies of additional agri-businesses were then conducted as a result of the failure to reach saturation. To find participants and cases that satisfied the following eligibility requirements, the researcher employed an intentional sampling technique. Participants must be owners or managers of agribusinesses with plans for deploying smart IoT digital systems within the study areas. Purposeful sampling is a non-random research technique in which a researcher includes in the sample particular examples that might produce data that is relevant to the study.

DATA COLLECTION INSTRUMENTS

Since the qualitative method was used for this study, the researcher became the main primary tool for data collection. Multiple data sources, including interviews, documents inspection, direct observation, participant observation, archival records, and physical artifacts, can be used by the case study researcher to assemble evidences. Face-to-face semi-structured interviews with study participants as well as document analysis were used to obtain the study's data. Interviews allow participants to directly respond to questions in their own words and can be structured, unstructured, or semi-structured. Information for case studies can be found from interviews, which are reliable sources. In a structured interview, participants are questioned in the same order and with the same questions; in an unstructured interview, participants are questioned first with a general inquiry and then with more specific questions based on their answers. Numerous case studies make use of semi-structured interviewing techniques. When conducting a semi-structured interview, a researcher employs a set of predefined questions but is free to add more if necessary for clarity. Through face-to-face, semi-structured interviews with open-ended questions, the researcher gathered primary data. Document analysis served as the primary source of secondary data for this investigation. In this study, document analysis involved going over pertinent corporate papers as already stated in the research design, including those found on corporate websites.

Finding pertinent documents, both printed and electronic, and combining the data they contain are steps in the methodical process known as document analysis. The purpose of papers as a tool is to support and confirm evidence from other sources. Document analysis may involve evaluating advertisements and reviewing manuals, books, brochures, company reports, event programs, charts, diaries, and other records that may be accessible in the public domain. The researcher improved the reliability and validity of the data collection instruments and process by (a) using an interview protocol to direct the process of interviewing participants, (b) using the technique of member checking to ensure correlative data, and (c) using a questionnaire to collect data from participants. The level of consistency in the outcomes obtained after repeating the same case study with similar data gathering techniques is known as reliability(Bolarinwa, 2015). The level of accuracy of data obtained from a measuring instrument is indicated by its validity(Rao, Su, & Chan, 2023).

DATA ANALYSIS

The most important component of any research is the data analysis, which involve summarizing all the meaningful details into an applicable information(Donaires, Cezarino, Liboni, Ribeiro, & Martins, 2023). It entails the analysis of acquired data using logical and analytical reasoning to identify patterns, correlations, or occurrences of events. As a result, descriptive statistical techniques were utilized to evaluate the digital agricultural practice that the end-user needed in the ongoing green imperative. The charts were transferred to Microsoft excel and mapped to the table. To exhibit the data and interpret the tabulated results, pie charts and bar graphs were produced. The study's findings, which were identified in the research, include the identification of the essential end-user requirements as well as the implications and difficulties that aided in the development of the digital agricultural service portfolio and roadmap for green imperative implementation for agricultural productivity.

ANALYSIS OF FINDING

Nigeria now has the largest economy in Africa and is one of the most populous country with over 200million citizens, and it is predicted that by 2025, there will be over 140 million smartphone users in the country(Farouk, David, & David, 2019). There are currently about 40 million smartphone users in Nigeria, according to estimates from various sources(Otu, Ukpeh, Okuzu, & Yaya, 2021). Taking into account the social and economic makeup of the modern society, it may be challenging to pinpoint the exact number of IoT smartphone users in Nigeria(Amaonwu et al.). The number of smartphone users in Nigeria is expected to triple in the next five to ten years, looking at the highly impressive growth predictions for the sector(Aker & Fafchamps, 2015). From 85.1% in 2018 to 86.6% in 2019, the market share of Android Operating System had increased. Furthermore, the Chinese government's efforts to bring 5G to fruition are expected to re-energize the global smartphone market and propel it to growth in 2020. Additionally, markets like the United Kingdom, Canada, Korea, and the United States are anticipated to be the key markets boost to help the 5G Mobile Phone remain essentially dominant within global market spaces to sustain competitions and enable reasonably priced 5G devices for the consumers in the upcoming year. In July 2018, Android dominated the OS market globally with 85.1% of the total smartphone market. That proportion had increased to 87.0% as of January 2022, four years later, refer to Table 1. On the other hand, global iOS adoption decreased by 1.9% over the same four years, from 14.9% to 13.0%. Analysis by StockApp shows that other smaller-scale OS developers received the remaining 1.9% of iOS's loss.

Table 1: Market Share of iOS and Android Smartphones

Year	Android Powered	iOS Powered	Others	Total
2017	85.1%	14.7%	0.2%	100%
2018	85.1%	14.9%	0.0%	100%
2019	86.6%	13.4%	0.0%	100%
2020	86.6%	13.4%	0.0%	100%
2021	86.9%	13.1%	0.0%	100%
2022	87.0%	13.0%	0.0%	100%
2023	87.15%	12.9%	0.0%	100%

Source: https://www.statista.com/statistics/272307

Android tablets continued to rule the market in August 2017 in South America (57.46%), Africa (70.07%), and Europe (34.44%), according to data on the Stat Counter website. The Android operating system and related hardware will rule the mobile industry in the coming year (Schinle et al., 2017). Android will be very important when choosing a mobile device, much like Apple's iOS devices are to the Apple family of mobile devices (Giachetti, 2018). Android OS and Android devices will be the most popular in Africa in the future year (Coe & Yang, 2022). Techno Android Mobile and Infinix Mobile will spread over the mobile phone market with various adjustments and modifications. With Nigeria functioning as the main market for Android in the foreseeable future, Techno Mobile and Infinix Mobile will prosper excellently in Africa(Qumer & Singh, 2019), refer to Fig 2 & Fig 3. Techno Android Mobile and Infinix Android Mobile will rule the continent of Africa as a result of the Nigerian origins of SLOT Technologies, one of the founding companies of Techno Mobile and Infinix. SLOT Systems Limited quickly gained notoriety as a top supplier of PCs, accessories, mobile Android phones, and various specialized gadgets that are both economical and reliable. With importance and dominance in Nigeria and the entire African market, it is widely recognized as crucial for cutting-edge digital technology on a worldwide scale (Vasudeva & Mogaji, 2020).

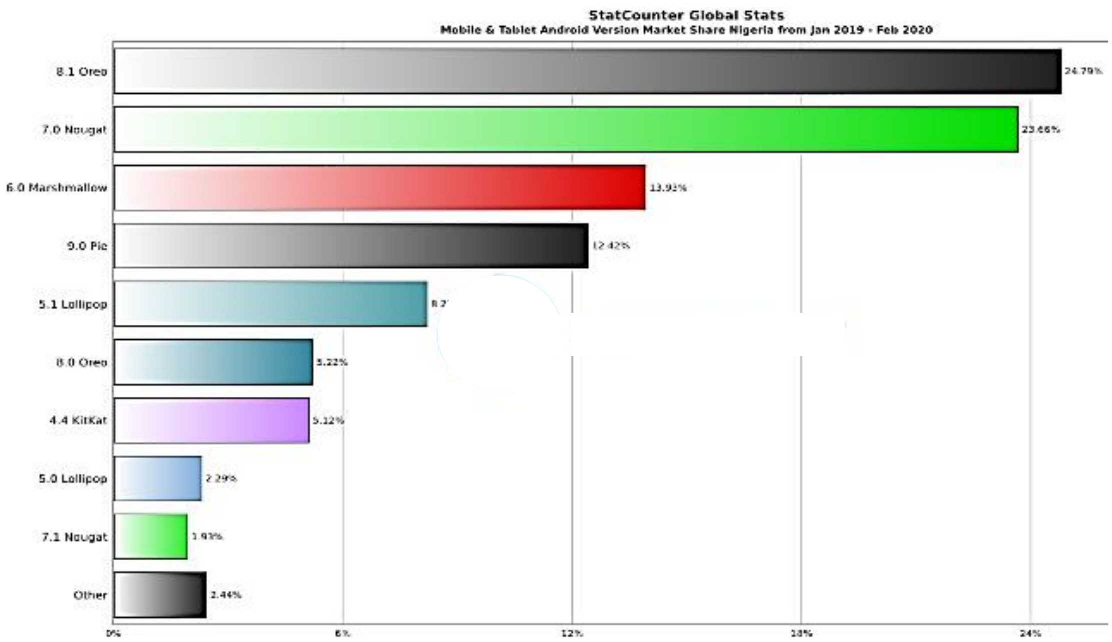

Fig 2: Mobile Phones & Tablet Android Version Market Share in Africa from Jan 2019 – Jan 2020

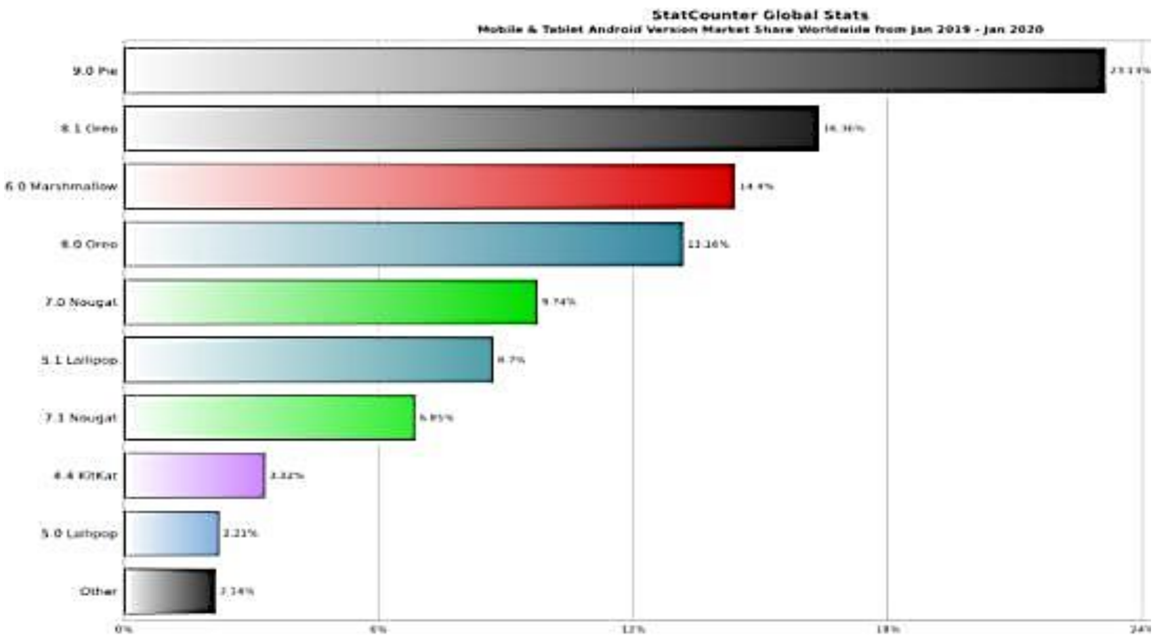

Fig 3: Mobile Phones & Tablet Android Version Market Share in Nigeria from Jan 2019 – Jan 2020

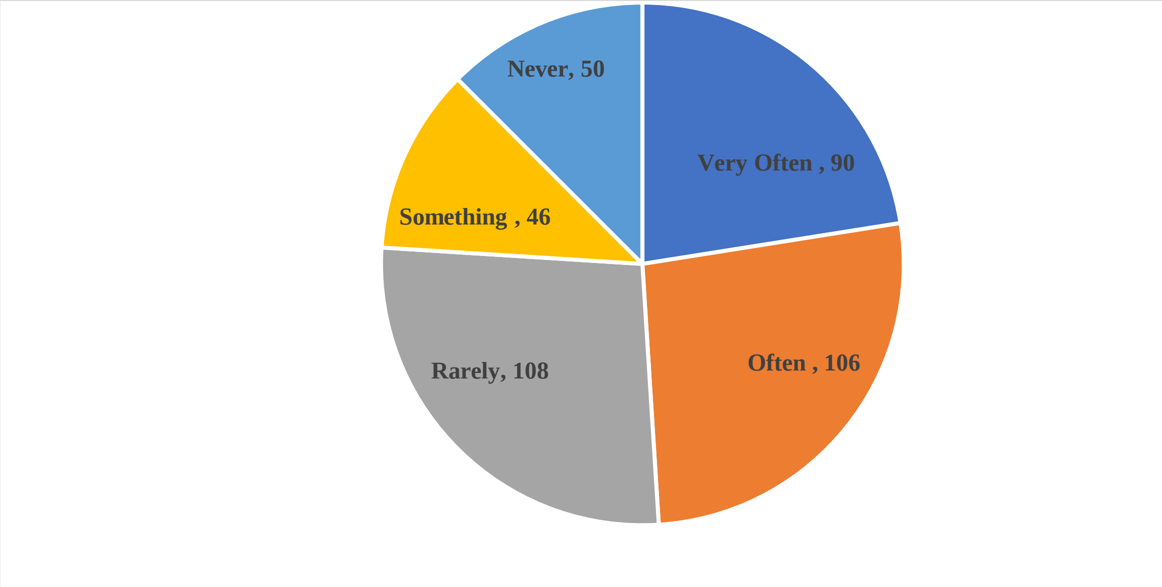

Fig 4: Rural Farmers Mobile Phones Accessibility under the Green Imperative Agro-Industrial Sector Reform.

Table 2: Information on Smartphones Availability to Rural Farmers

Responses	Frequency	Percentage
Very Often	90	22.5
Often	106	26.5
Rarely	108	27
Something	46	11.5
Never	50	12.5
Total	400	100

Research Survey 2021

Referring to Fig 4, Table 2, and Fig 5, descriptive statistics were used to analyse the important research issues identified in the current study. The study found that 23% (90 rural farmers) agreed that mobile digital devices are very often available, 27% (106 rural farmers) agreed that mobile devices are often available, 27% (108 rural farmers) agreed that mobile smart devices are rarely available, and 12% (46 rural farmers) agreed that mobile devices are occasionally available to the farmer to negotiate with the smart agricultural innovation in the selected study area, while 50 rural farmers representing 13% of the total distribution said they had never used mobile devices for farming.

Table 3: The use of digital gadgets by farmers in the agricultural supply chain.

Mobile Device Type	Frequency	Percentage
Non-Smart Phones	165	41.25
Smart Android Phones	205	51.25
PDA& Portables	5	1.25
Tablets	15	3.75
Laptops	10	2.5
Total	400	100

Research Survey 2021

Some of the barriers to mobile technology adoption for agricultural implementation in the study area were depicted in Fig 5. In fact, lack of digital literacy was highlighted by 120 rural farmers, or 30% of the distribution, as a barrier to smart agriculture adoption in their respective regions. The lack of government incentive is one of the problems impeding rural agricultural integration, according to 180 rural agricultural respondents, or 45% of the total distribution. While 50(13%) farmers identified financial difficulty as a barrier to the implementation of smart agriculture, 30 (8%) farmers claimed a lack of infrastructure, including roads, electricity, modern storage facilities, and telecommunication, water, irrigation, and drainage systems. At last, 20 (5%) of the farmers cited resistance to modern implementation as a reason hindering innovative farming in the study area.

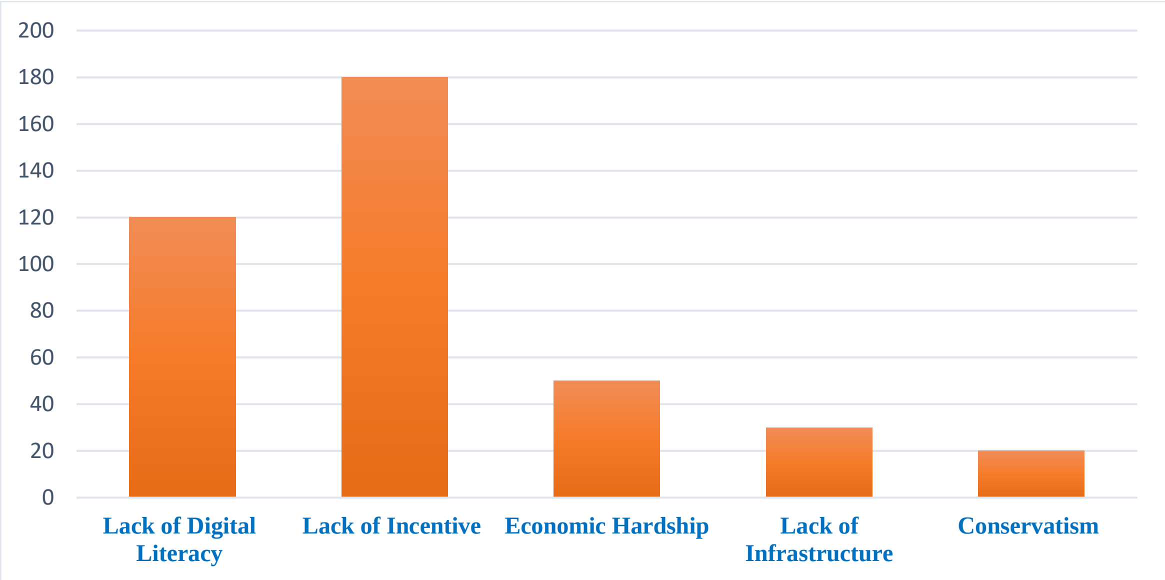

Fig 5: Factors preventing rural areas from adopting mobile technologies for agricultural implementation

DISCUSSION OF FINDINGS

On the account of Green Imperative programme and south-south collaboration, Brazil has the strongest economy in Latin America and the Caribbean and is a significant industrial and agricultural power(Koengkan et al., 2022). It is the world's fourth-largest producer of agricultural goods, ranking first in the production of citrus, coffee, and sugarcane, and second in the production of beef, soybeans, and chicken. Since the early 2000s, Brazil has made great strides toward reducing poverty. The population's overall poverty rate dropped from 35.8% to 27.6% between 1992 and 2015, while the population's incidence of extreme poverty fell from 7% to 4%. Brazil continues to be a nation of vast contrasts despite the fact that economic and social situations have greatly improved. The Northeast's semi-arid rural areas are where inequality is strongest. The second-worst economic recession to ever affect Brazil occurred in 2014. Although there are sluggish signs of recovery, the crisis is not predicted to end before 2021 and has put a pressure on attempts to eliminate poverty and inequality across the nation. Recent data indicates that between 2016 and 2017, the percentage of the population living in poverty rose from 25.7% to 26.5%, which indicates that about 2 million individuals have fallen into poverty. Brazil is a country with stark regional differences, and the northeast region is marked by a high concentration of poverty, with 44.8% of its 57 million residents living below the poverty line and 14.7% in extreme poverty.

Brazil, however, expanded its agricultural exports to feed the globe and preserve an equitable distribution of economic prosperity among its people(de Castro, de Lima, & Romano, 2022). The Brazil agricultural exports reached a historical highpoint of US$ 120.6 billion in 2021, surpassing Ecuador's GDP and rising by 19.7% from the previous year which altogether exceeded Nigeria annual budget from 2015-2025. As a result, the Brazil trade balance for agricultural businesses is in surplus by $105.1 billion. China accounted for 20.9% of Brazil's total exports in November 2021, followed by the European Union (16.3%) and the United States (9.8%). Other nations with noteworthy involvement included Egypt (4.4%), Vietnam (3%), South Korea (2.7%), Japan (2.5%), Chile (2.3%), Iran (2%), and Turkey (2%). As opposed to December 2020, certain destination countries performed significantly better in November 2021. Highlights on this list include Egypt (+102.5%) and Turkey (+98.7%). When looking at the entire year, exports to Iran (+70.3%) had the largest positive change in comparison to 2020, followed by Chile (+58.1%) and the US (+30.2%).

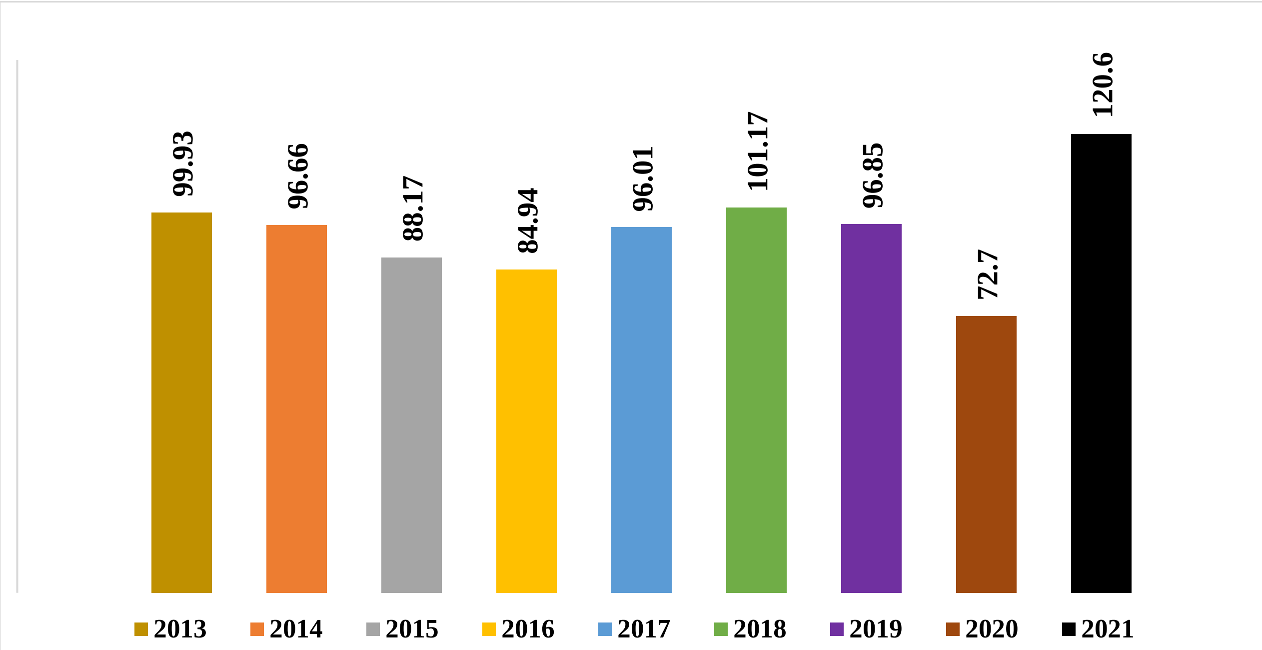

Fig 6: Exports of the Agribusiness in Brazil from 2013 to 2021(in billion U.S. Dollars)

Source: statista.com/statistics/1076723/export-value-agribusiness-brazil/

With reference to Fig 6, nearly 97 billion dollars in exported from the agribusiness in Brazil were recorded in 2019, which represents a decline of about 4.3 percent from 2018. The export further declined in 2020 from the previous year 2019 by 24.9%. Brazil exports more fresh chicken meat than any other country in the world, accounting for 30% of global exports and 14% of global production(Chatellier, 2021). Brazilian exports increased by 8.2% from 2020 to 2021, totalling over 4.4 million tons. It is notable that this is the highest volume during the time period under consideration (2013-2021). With a projected 3.4 million tons of exports in 2021, the United States will rank as the second-largest exporter in the globe(Chatellier, 2021). Brazilian exports recorded their best performance in terms of value in 2021, totalling US$ 7.2 billion, or 25.5% more than in 2020, refer to Fig 6. More than 40% of Brazilian exports in 2021 will be required by nations in East Asia (China and Japan) and the Middle East (Saudi Arabia and the United Arab Emirates)(Chatellier, 2021). The statistics on Gross Production Value (GPV) data demonstrate the consistent increase in agricultural exports from Brazil. According to the Brazilian Confederation of Agriculture and Livestock (CAN), the GPV reached R$ 1.21 trillion (about US$ 224.1 billion) in 2021.

Taking into account the production of crops and livestock as well as the typical price paid to farmers across the nation, the GPV indicates the gross income in rural companies. Based on reports and data from December 2021, this prediction was made. Additionally, a 7.3% growth over 2020 is predicted by the prediction. The two goods that contributed most to the successful outcomes continue to be soy and corn. The GPV estimate for cattle farming for 2021 is R$ 402.8 billion, which is 0.7% more than the figure from 2020.

FUTURE RESEARCH FOCUS

The Green Imperative agricultural development program was a planned collaboration between Nigeria and Brazil to scale up the nation's agriculture in order to increase food production, enhance food security, create more jobs, and ultimately raise household income. Nigeria's agricultural industry, from processing to commerce to transportation, is primed for market-driven expansion. The industry has tremendous potential and already contributes significantly to food security in both West and Central Africa as a result of rising demand and population multiplicity. In addition to fostering economic growth, Green Imperative initiatives also provide employment possibilities, empower women and young people, encourage innovation, advance trade, and help people escape extreme poverty. Nigerians, especially women and young people, can find work and economic opportunities on the account of the country's booming agricultural sector under the ongoing reform. Women and young people are becoming more prevalent in agricultural markets, agricultural technologies and food systems due to government-supported activities in agricultural economy. On this note, every other future research should focus on the following agenda:

1. Encouraging collaboration in scientific and technological research between Nigeria and other foreign institutions on the technology transfer, in addition to the currently available developments.
2. Bridging gaps that fortifies ties between the Nigerian scientific evolution and other institutions of other nations.
3. Improving agricultural productivity by providing access to resources for smallholder farmers community through an intense capacity rural agro-extension program.
4. Strengthening inclusive policy frameworks in the areas of agriculture, nutrition, and resilience for people living in rural areas including women and youths.

RECOMMENDATION

The agricultural extension service, public sector commitment, private sector initiative, and rural farmers' consultation for grassroots mobilization for food security projection are essential to enhancing the capacity of the rural farmers towards improving agricultural productivity. A new and expanded understanding of the public sector's function in terms of food security, rural development, and agricultural extension is long overdue. The authors' five primary suggestions to governments and all significant stakeholders down the chain of command are as follows:

1. Development of a new policy agenda for agricultural extension services and the establishment of communication channels for rural development with a focus on agricultural production using digital technology methods.

2. Implementing a diverse and pluralistic national policy that encourages agricultural extension and communication channels for rural agricultural development, focusing on rural farmers' participation in the agricultural supply chain.
3. Establishment of a platform for interaction and collaboration with the relevant organizations that comprise the range of multi-sectoral agricultural extension services.
4. Implementing security measures that would stop the current threat to rural communities' sources of livelihood and way of life.
5. Formation of agro banks for microcredit facilities and other social amenities is a key social engineering tool that has the power to propel all other economic sectors along the agricultural supply chains.

CONCLUSION

This study has provided critical information on the discussion of IoT-based rural agricultural practice, with a focus on the transfer of agro-technology between Nigeria and Brazil under the green imperative. The examination of various IoT agriculture applications and IoT mobile communication-related rural agricultural supply chain considerations are then given. The fact that numerous governments are supporting this field of study and that many of them have IoT agriculture policies is the most encouraging factor. Aside from this, the framework has been contextualized for all the key elements of IoT-based agriculture. For further investigation by researchers working in the field of IoT-based agriculture, the promising future directions have been highlighted. The current study identified five questions which was focussed in directing the discussions to achieve the desired ends. On the part of the ongoing Brazil-Nigeria Green Imperative and South-South triangular Corporation on agro-innovation for food and nutrient security through technology transfer, the research discovered that the services of agro-extension workers should be made sufficient for rural agricultural technology transfer using Android IoT Smart Mobile devices through establishment of well-structured communication and feedback loop towards addressing issues of agricultural importance. On the rural farmers in Nigeria acceptance of the technology transfer and possession of digital skills necessary to use it effectively for agricultural management that would lead to food security, the paper discovered an essential digital characterization showing receptiveness of the rural farmers to implement the agenda of the green imperative. On the Nigeria Incentive-Based Risk-Sharing System for Agricultural Lending (NIRSAL) which supposed to strengthen the bond between finance and agriculture, the paper discovered the federal government of Nigeria commitment towards agricultural development through establishment of microcredit facilities to support the rural agro reform agenda.

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Influence of Enhanced Efficiency Fertilization on Fall Armyworm (*Spodoptera frugiperda J. E. Smith*) Infestations and Agronomic Performance of Maize (*Zea mays L.*)

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Abstract:
Fall armyworm (FAW), still remains an important pest of many agricultural crops including maize. There is the need to use environmentally friendly approaches to address this current menace. Field experiment was laid in randomized complete block design with three replications, using eight different fertilization regimes to evaluate eight different fertilization regimes on the larval abundance and damage incidence of FAW, its impact on maize yield in the Savanna ecology of Ghana. The economic viability of the treatments on maize production was also assessed. Fertilization significantly influenced FAW larval abundance and damage incidence. Unfertilized plot recorded significantly lower larval numbers and damage incidence compared to fertilizer treatments. Among the fertilization regimes, UNIK 15 (NPK 15:15:15)-Amidas (AMI) and Actyva (ACT)-sulfan (SUL) recorded significantly higher larval abundance and damage incidence whilst the least were recorded from CLB-CLB (CropLift Bio) and UNIK 15-Sulphate of ammonia (SOA) + insecticide spray (IS). Among the fertilization regimes, CLB-CLB recorded significantly lower grain yield, with UNIK 15-URE (Urea) and ACT-AMI yielding the highest. All the fertilization regimes yielded more profit compared to the unfertilized plots, among the fertilization regimes, CLB-CLB yielded lowest profit and cost-benefit ratio, whilst the highest profit and cost-benefit ratio was obtained from UNIK 15-URE. Application of UNIK 15-URE or ACT-AMI is recommended for better management of FAW, maximized yield, as well as higher profit.

INTRODUCTION

The fall armyworm (FAW) (*Spodoptera frugiperda* J. E. Smith) is a major pest that has wide host range, with a strong preference for maize (FAO, 2017). Across Africa, the economic impacts of FAW on agricultural productivity are essential. Without proper control methods, yield losses to maize caused by the FAW is estimated to have ranged from 8.3 to 20.6 metric tonnes annually from 12 sampled maize producing regions across the African continent. Between US$2.48 billion and US$6.19 billion was estimated as the value of these losses (CAB International, 2017; Day *et al*., 2017). FAW has become a serious threat to maize production in Africa, due to the availability of a diverse range of host plants throughout the year and favourable climatic conditions for its growth and development (Nboyine *et al*., 2021). The management of FAW appears challenging due to its short life cycle, wide host range, rapid multiplication and ability to spread across large geographical areas (Day et al. 2017; Prasanna et al. 2018).

Currently, there is a little knowledge of proper tactics to prevent and avoid FAW, and attempts to limit the pest population mostly depended on the synthetic pesticides use, sometimes in an improper way with ability to bring about danger to human, animals and the environment (Prasana *et al*., 2018). Aside the cost involved in the control of this pest using insecticides, the penetration of this pesticides in to the whorl of the maize is another problem, as the pest (larvae) hide inside the whorl of the maize plant and need regular application (Yu *et al*. 2003). It has been reported of FAW building resistance to a number of individual classes of insecticides including carbamates, benzoylureas and pyrethroids (Diez-Rodrigues and Omoto, 2001; Yu *et al*., 2003). The negative impact of synthetic insecticides on non-target organisms within the agroecosystem calls for the need to explore environmentally friendly approaches to manage the pest.

Mineral nutrients are important for plant growth and development. Discoloring of the leaf surfaces by nutritional deficiencies increases susceptibility to pests. These nutrients usually served as food for plants essentially for better growth and yield yet, mineral nutrition also impacts growth and yield by influencing resistance and susceptibility of plants to insects and pathogens (Schumann *et al*., 2010). Plant development depends on nutrients availability (Gogi *et al*., 2012). According to Schumann *et al*. (2010), supply of a balanced nutrients ensures optimal plant growth. As well, plants with an optimum nutritional status have a maximum resistance (tolerance) to pests and diseases to nutrient deficient plants. Mineral nutrition can impact two primary mechanisms of resistance: The mechanical barriers formation (in essence through the development of thicker cell walls) and the combination of natural defense compounds, (for instance phytoalexins, flavonoids, and antioxidants) which issue defense against pathogens. According to Altieri and Nicholls (2003), the vital plant physiological features for hold out against pests and diseases is healthy plants and vigorous plant growth. As there is a likelihood of FAW staying, medium and longstanding responses are essential, along with actions to address the instantaneous crises that farmers are facing (CABI, 2017).

In Ghana, YARA is the largest importer of bulk fertilizer (estimated to account for around 70,000-80,000 tones in 2008) (Arthur, 2014). Also, YARA Vita (Croplift Bio) being a newly formulated foliar fertilizer with both the macro (NPK+B small quantity) and micro nutrients (Cu, Mn, Mo and Zn) can improve nourishment to the plants to boost it immunity to be able to withstand (tolerance/resistance) insect-pests infestation especially FAW. However, there is a little research finding available on the influence of fertilization on FAW infestation and yield of maize in Ghana. Hence, there is the need to use YARA formulated fertilizers with the Croplift Bio to improve the health and vigorous growth of plants to be able to withstand the FAW infestation. This study sought to evaluate eight different fertilizer protocols from YARA Ghana Limited on the larval abundance and damage incidence of FAW, and its impact on maize yield in the Guinea savanna ecology of Ghana. The economic viability of the treatments for maize production was assessed.

MATERIALS AND METHODS

Study Area

The study was conducted at the University for Development Studies Research Field, Nyankpala. The area has a unimodal rainfall pattern which has a mean annual rainfall ranging from 800 mm to 1200 mm (Kombiok *et al*., 2012). The area has a warm climate of mean minimum temperature of 25 ^{o}C and a maximum temperature of 35 ^{o}C (SARI, 2001). The soil is sandy loam to loamy sandy (Yidana *et al*., 2011). According to Yidana *et al*. (2011), the area is a low-lying grassland with few spread perennial woody species.

Experimental Design, Planting and Treatment Application

The experiment was a single factor experiment with ten treatments, arranged in a randomized complete block design with three replications. The variety of maize used was Obatanpa. Plot size of 4 m × 4 m (16 m²) were used. Buffer zones of 2.0 m were created between blocks and 1.0 m within plots on the same block. The experiment covers a land area of 16 m × 49 m (784 m²). Eight treatments were based on YARA Ghana limited protocol provided, one treatment was non-YARA fertilizer and a control. Application of the treatments was done using deep placement method. A dibbler was used to puncture a hole about 2 cm from the plant, after which the fertilizer was then put in to the hole and covered with soil to prevent it from carrying away by rain water. Table I shows the treatments and their descriptions.

Table 1: Fertilizer treatment protocols used for the trial

Treatments	Description	
	2 weeks after planting	**4 weeks after planting**
ACT-AMI	YARA Mila Actyva (NPK 23-10-5+2MgO+3S+0.3ZN) @ 250kg/ha	YARA Vera Amidas (40N-5.6S) @ 125kg/ha
ACT-SUL	YARA Mila Actyva (NPK 23-10-5+2MgO+3S+0.3ZN) @ 250kg/ha	YARA Bela Sulfan (24N-6S) @ 125kg/ha
ACT-URE	YARA Mila Actyva (NPK 23-10-5+2MgO+3S+0.3ZN) @ 250kg/ha	YARA Urea (46%N) @ 125kg/ha
UNIK-AMI	YARA Mila UNIK 15 (NPK 15-15-15) @ 250kg/ha	YARA Vera Amidas (40N-5.6S) @ 125kg/ha
UNIK-SUL	YARA Mila UNIK 15 (NPK 15-15-15) @ 250kg/ha	YARA Bela Sulfan (24N-6S) @ 125kg/ha
UNIK-URE	YARA Mila UNIK 15 (NPK 15-15-15) @ 250kg/ha	YARA Urea (46%N) @ 125kg/ha
NPK-SOA+IS	(non-YARA) NPK (15-15-15) @ 250kg/ha with insecticide spray	Sulphate of Ammonia (SA 21%) 125kg/ha with insecticide spray
CLB-CLB	YARA Vita CropLift Bio (NPK 8.5-33.4-6+B+Cu+Mo+Zn) @2.5 l/ha	YARA Vita CropLift Bio (NPK 8.5-33.4-6+B+Cu+Mo+Zn) @2.5 l/ha
CONTROL	No fertilization	No fertilization

During the third week of May, the field was disc-ploughed and leveled with a hand weeding hoe. The Obatanpa (late maturity maize variety) obtained from Ganorma agrochemicals in Tamale, Ghana, was used for planting. The field was planted on the fourth week of June 2021. They were a sowing spacing of 40 cm between plants and 75 cm between rows. There was a construction of bunds around each plot before application of the treatments to prevent drift of the fertilizer into adjacent plots. The control of the weeds was undertaking at three weeks and six weeks after planting. K-optima (insecticide) was used to control pest in NPK + SOA +IS plots and that of No fertilization plots to control pests. The insecticide was applied two weeks, four weeks and six weeks after emergency and after the application of the treatments.

Assessment of FAW Abundance and Damage Incidence

FAW larval abundance was assessed using 2×3 m (6 m²) at the middle of each plot. This was done to avoid the border effect. In the course of each data collection, the maize plants that fall within the 6 m² were rigorously hunted for the existence of the larvae and the number existed were then counted and recorded. Leaf and whorl defoliation was assessed using the Davis rating scale from 0 to 9 to score FAW damage incidence on plants (Davis and Williams, 1992). Assessment of pest population and damage were done at 4 WAP (week after planting), 6 WAP and 8 WAP.

Estimation of Maize Yield

The harvesting was done in plot bases manually while each harvested plot was put into the various experimental sacks. Six meters square (6 m²) in the middle of each plot was harvested, de-husked and de-grained. The grains were allowed to further dry to 12% moisture content before aerial winnowing to take out the chaffs from the grains. The resulting grains were then weighed on a Camry digital weighing scale and extrapolated to kilogram per hectare for each treatment. Hundred (100) seeds were also counted and weighed.

Resistance/Tolerance Level of *S. frugiperda*

Foliar damage caused by FAW infestation was evaluated by scoring each infested crops on 1-9 scale (Davis and Williams, 1992) modified by Prasanna *et al*. (2018). This scale assessment was based on degree of foliar damage, where highly resistant plants were graded with 1 (no visible damage) whilst 9 rated as highly susceptibility crops (completely damaged).

Statistical Analysis and Partial Budget Analysis

The data collected were transformed using √y+0.5 where y is the response variable, before subjected to repeated measures analysis of variance (ANOVA) in GenStat Statistical Programme (12^{th} edition). Treatments means were separated at the probability level of 5% using least significant difference (LSD) test.

Partial budget analysis was employed to evaluate the net benefit as a result of fertilization and net returns to FAW control. This were to assess the economic view of investment in FAW management compared to no fertilization. Both chemicals, maize and the fertilizer market prices were employed in landing at the value of production and cost of production respectively. The assumption was that, all other cost were constant whilst the cost that differ were therefore applied to calculate the input cost. The value of yields increment due to fertilization were calculated using mean grain yield of maize with the following formula:

$$Value\ of\ increased\ yield\ due\ to\ fertilizer = Price\ \times\ Increased\ yield\ over\ control$$
$$V_{yield} = P_{makt}\ \times (Q_{treatment} - Q_{control})$$

Where $P_{market}$the market is price of maize (GHS) and $Q_{treatment}$ is the output of treated plot (kg/ha) and $Q_{control}$ is the output of control plot (kg/ha).

The total variable cost of fertilizer application was calculated as:

$$TVC_{faw} = \left(P_{mf} \times Vol_f\right)$$

Where $TVC_{faw}$is the total variable cost (GHS), P_{mf} is the market price of fertilizer used, Vol_f is the volume of fertilizer used (lha^{-1}).

The net benefit is calculated using the following:

$$Net\ benefit\ due\ to\ fertilization = V_{yield} - TVC_{faw}$$

Where V_{yield} is the value of increased yield due to fertilization and TVC_{faw} is total variable cost of fertilizer.

The returns to fertilization were then calculated using the following:

$$Returns\ to\ fertilizer\ use = \frac{Value\ of\ increased\ yield\ over\ control(GHS/ha)}{Total\ variable\ of\ fertilizer\ application(GHS/ha)}$$

RESULTS

FAW Larval Abundance and Population Dynamics

FAW larval abundance was significantly affected ($P < 0.05$) by the fertilization regimes as shown in figure 1. Control recorded significantly lower larval abundance than ACT-SUL, UNIK 15-AMI, UNIK 15-URE and ACT-URE. Comparing the fertilization regimes, ACT-SUL and UNIK 15-AMI recorded significantly higher larval abundance. Also, UNIK 15-URE and ACT-URE recorded significantly higher larval abundance than NPK-SOA+IS and CLB-CLB when compared.

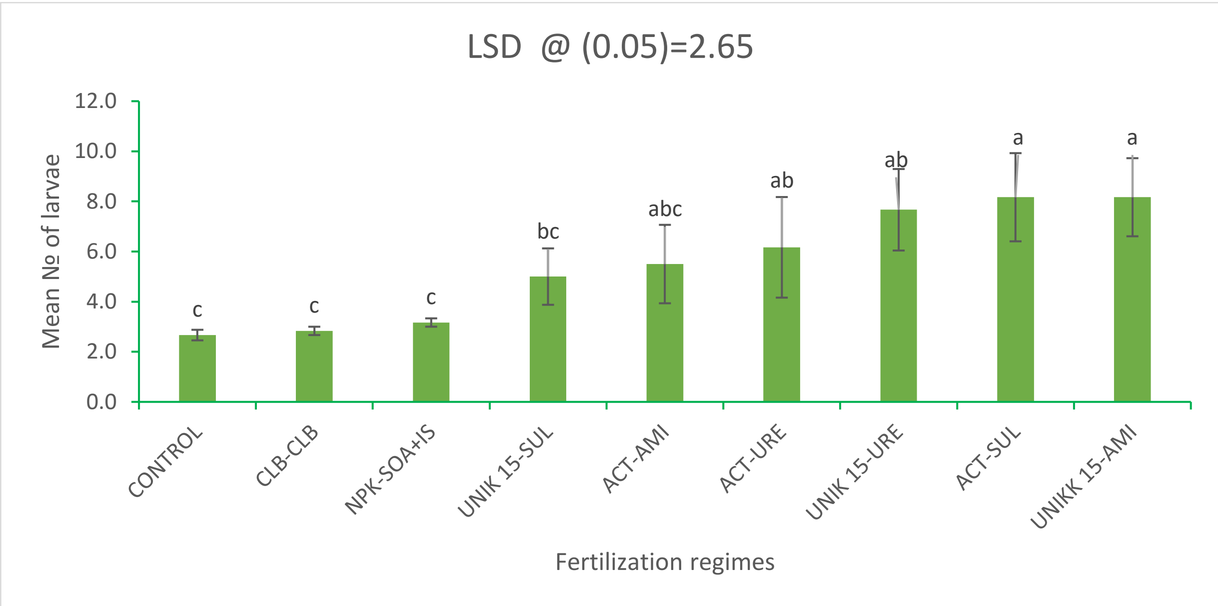

Figure 1: Effect of fertilization regimes on FAW larval abundance

The population dynamics of *S. frugiperda* was affected significantly by the fertilization regimes as presented in figure 2. At 4 WAP, UNIK 15-AMI recorded the highest larval mean number while ACT-SUL recorded the second highest followed by UNIK 15-URE. However, CLB-CLB, control and NPK-SOA+IS recorded the least larval mean number.

At 6 WAP, ACT-SUL and UNIK 15-URE recorded the first and second highest mean number of larval populations followed by UNIK 15-AMI, while the least number recorded from CLB-CLB and control.

There was a similar trend of 8 WAP to that of 4WAP where UNIK 15-AMI recorded the highest, followed by ACT-SUL and UNIK 15-URE. However, control recorded the lowest mean larval number followed by CLB-CLB and NPK-SOA+IS.

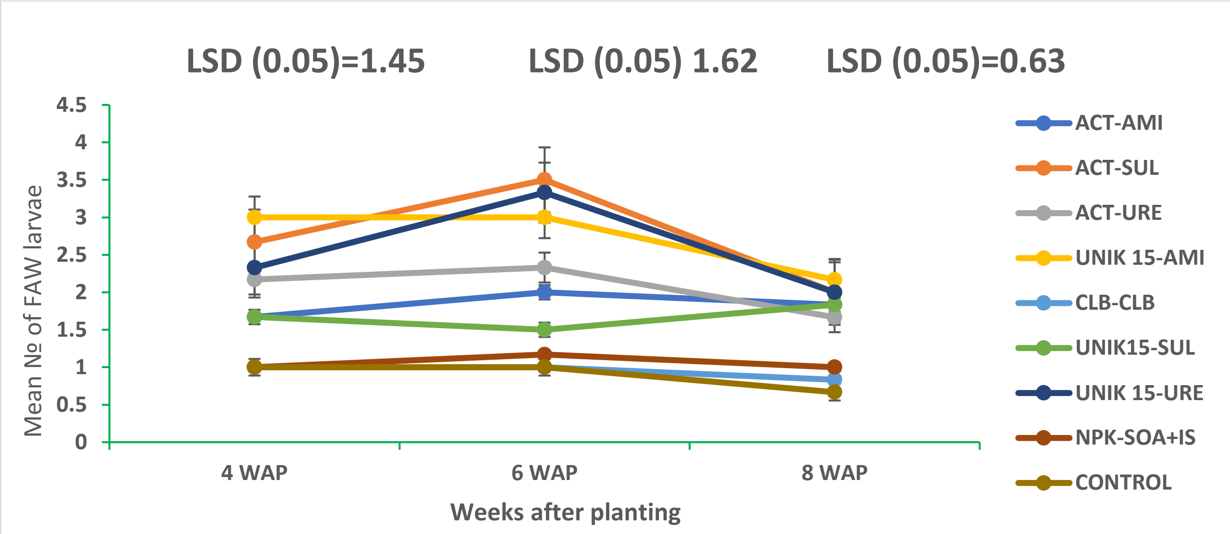

Figure 2: Effect of fertilization regimes on FAW population dynamics

FAW Damage and Trend of Damage Incidences on Maize

There was a significant variation ($P < 0.05$) in FAW damage incidence among the fertilization regime (Figure 3). Apart from NPK-SOA+IS and CLB-CLB, control recorded significantly lower damage incidence than the rest of the fertilization regimes. Among the fertilization regimes, UNIK 15-AMI and ACT-SUL recorded significantly higher damage incidence than ACT-AMI, CLB-CLB and NPK-SOA+IS. Significantly, CLB-CLB and NPK-SOA+IS recorded the lowest damage incidence.

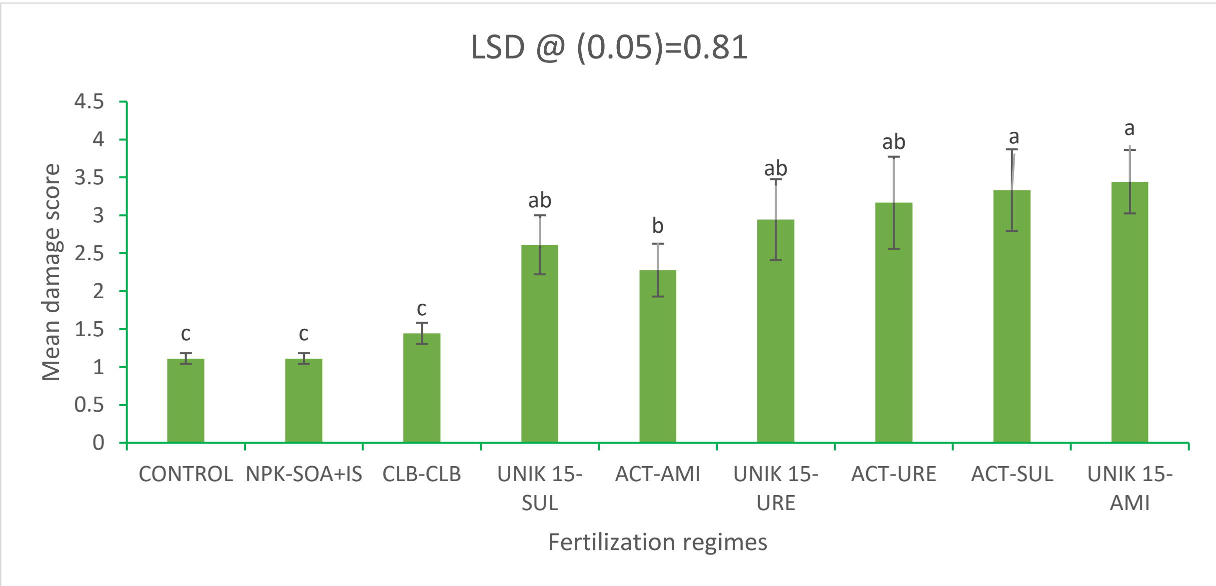

Figure 3: Effect of fertilization regimes on damage incidence of FAW to maize

The trend of damage was affected significantly by the influence of fertilization regimes (figure 4). At 4 WAP, with the exception of NPK-SOA+IS, control recorded the least trend of damage than the rest of the fertilization regimes. The highest damage incidence recorded in UNIK 15-AMI followed by ACT-SUL while NPK-SOA+IS recorded the least damage incidence among the fertilization regimes.

At 6 WAP, control recorded the lowest damage incidence compared to the fertilization regimes. Among the fertilization regimes ACT-URE (3.67) placed at the highest damage incidence level whilst ACT-SUL, UNIK 15-AMI and UNIK 15-URE recorded (3.5 each) the second highest. However, the least damage incidence was recorded from NPK-SOA+IS (1.33).

At 8 WAP, with the exception of CLB-CLB and NPK-SOA+IS, control recorded the least damage incidence compared to the fertilization regimes. Among the fertilization regimes, NPK-SOA+IS recorded the lowest damage incidence while ACT-SUL (2.83) recorded the highest damage score.

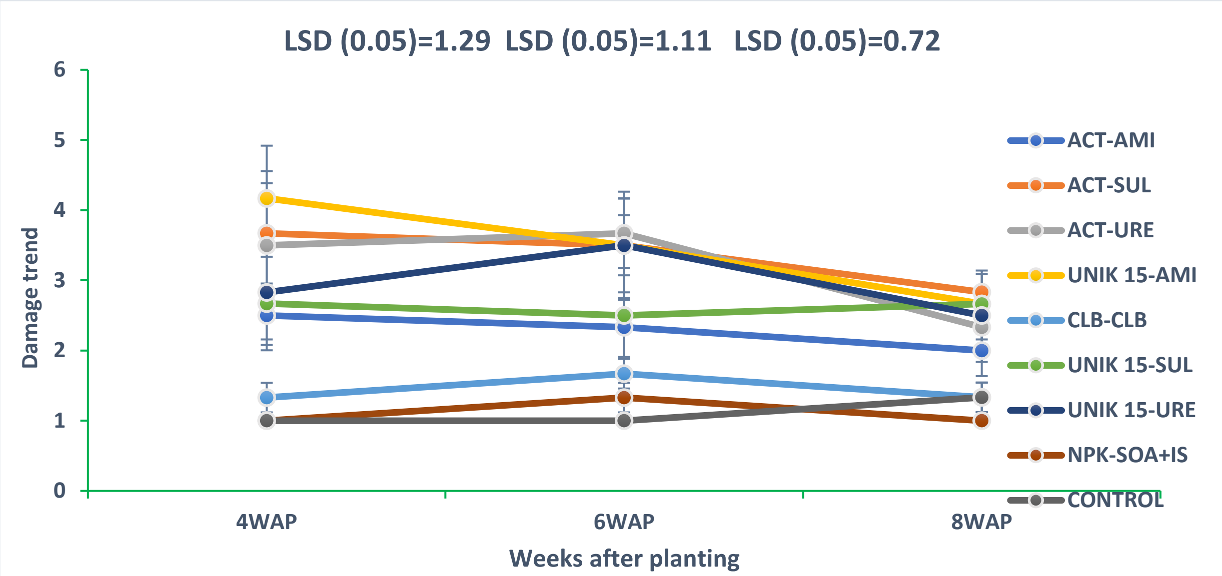

Figure 4: Trend of FAW damage incidence on maize as affected by the fertilization regimes across the sampling weeks

Resistant/Tolerance Level of Maize to FAW Infestation

There was an influence of the resistant levels of maize by the fertilization regimes as presented in Table 2. The fertilization regimes were able to tolerate/resist the FAW infestation by obtaining a varying damage score below four (4) and confirming by obtaining the expected output.

Table 2: Resistance status of maize to FAW infestation as influenced by YARA fertilizer formulations

Fertilization regimes	Damage score	Description	Resistance status
CLB-CLB	1.44	No visible leaf feeding damage	Highly resistant
ACT-AMI	2.29	Few pin holes on older leaves.	Resistant
ACT-URE	3.17	Several shot-holes injury on a few leaves	Resistant
UNIK 15-AMI	3.44	Several shot-holes injury on a few leaves	Resistant
ACT-SUL	3.33	Several shot-holes injury on a few leaves	Resistant
UNIK 15-SUL	2.61	Several shot-holes injury on a few leaves	Resistant
UNIK 15-URE	2.94	Several shot-holes injury on a few leaves	Resistant

Grain Yield and 100 Seed Weight

The grain yield of maize was significantly affected ($P < 0.05$) by the fertilization regimes (figure 5). Maize grain yield ranged from 582 kg/ha in the control to 3,773 kg/ha in UNIK 15-URE respectively. All the maize plots treated with fertilizer, recorded significantly higher grain yield compared to control except CLB-CLB. Among the fertilization regimes, grain yield was in the order, UNIK 15-

URE, ACT-AMI, UNIK 15-AMI, UNIK 15-SUL, ACT-URE, ACT-SUL, NPK-SOA+IS and CLB-CLB. However, apart from CLB-CLB which recorded significantly lower maize grain yield, there was no significant variation among the rest of the plots treated with fertilizer.

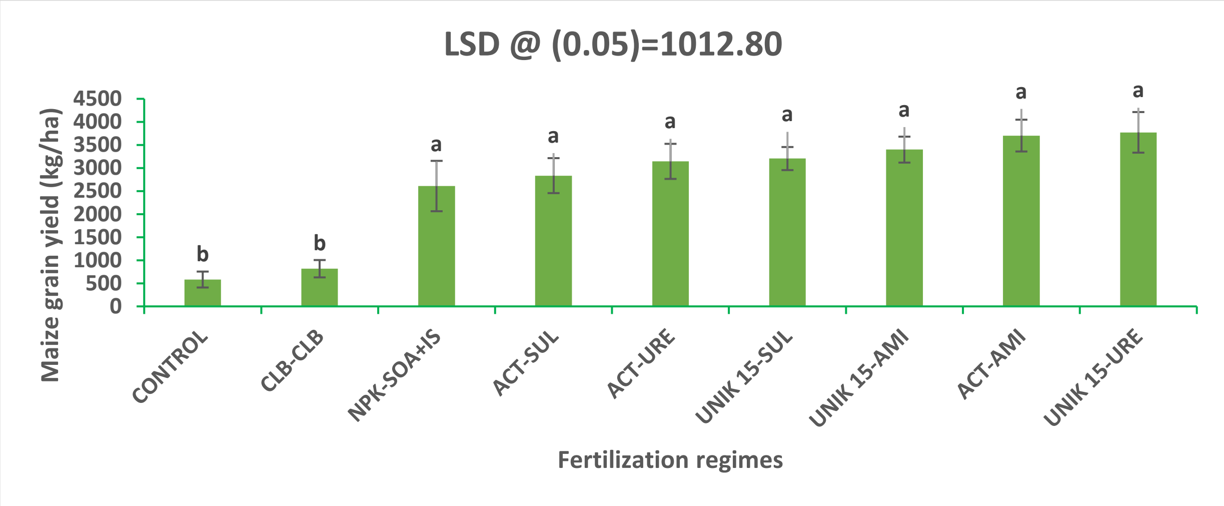

Figure 5: Effect of the fertilization regimes on grain yield (kg/ha) of maize

Hundred (100) seed weight of maize was found to be significantly affected ($P < 0.05$) by the fertilization regimes (Figure 6). Mean seed weight obtained from all the fertilizer treated plots was found to be significantly higher than control except CLB-CLB. Among the plots treated with fertilizer, UNIK 15-URE (26.8) and ACT -AMI (26.3) obtained significantly higher maize grain weight than CLB-CLB (23.0).

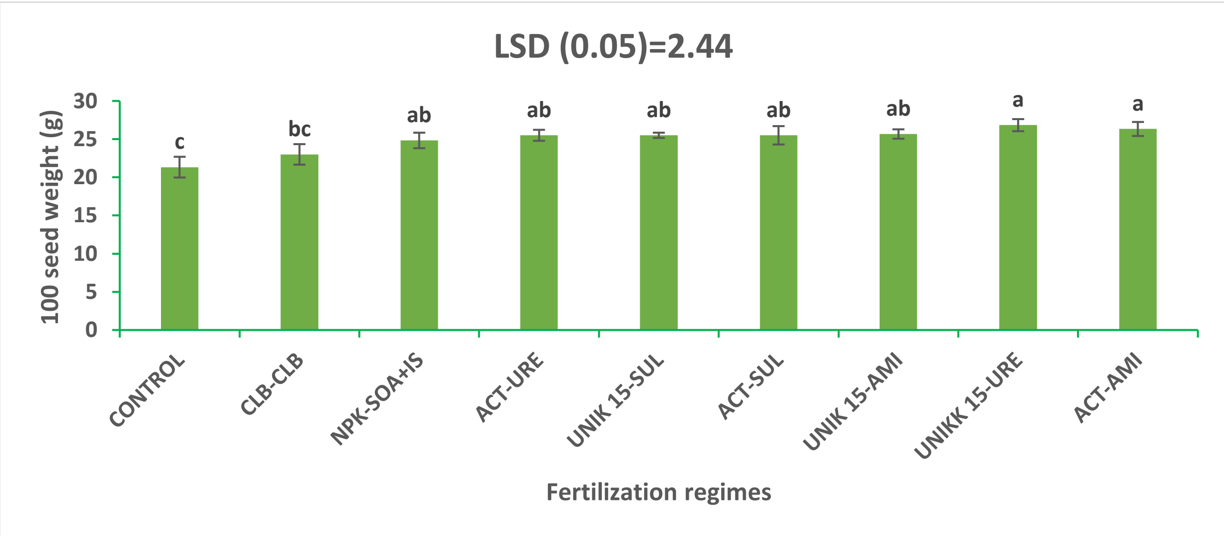

Figure 6: Effect of fertilization regimes on 100 seed weight of maize

Partial Budget Analysis from Maize Grain Yield

The results of partial budget analysis showed a positive value of grain yield increment for all the fertilization regimes compared to no fertilization plot (control). The net benefit of using YARA formulated fertilizers for FAW management were positive and these net returns on investing in YARA formulated fertilizers were higher than unity. Among the fertilizer treatments used, UNIK

15-URE had the highest net benefit and net returns compared to other treatments as presented in Table 3.

Among the fertilization regimes, UNIK 15-URE recorded the highest profit (GH¢ 10,986/ha) closely followed by ACT-AMI with a profit of (GH¢10,488/ha). UNIK 15-AMI (GH¢ 9,614/ha), UNIK 15-SUL (GH¢ 9,143/ha) and ACT-URE (GH¢ 8,873) yielded third, fourth and fifth highest profit. However, with the exception of CLB-CLB (GH¢ 640/ha), NPK-SOA+IS (GH¢ 6758/ha) gave the lowest profit compared to YARA formulated fertilizers.

The cost-benefit analysis shows that UNIK 15-URE provided the highest cost-benefit ratio (GH¢ 10.1) while UNIK 15-SUL provided the second highest (GH¢ 7.9). The third highest was obtained from ACT-AMI with cost-benefit ratio of GH¢ 7.8, which was closely followed by UNIK 15-AMI (GH¢ 7.5). ACT-URE was lower with cost-benefit ratio (GH¢ 7.2) than UNIK 15-AMI (GH¢ 7.5) but higher than ACT-SUL (GH¢ 6.1). NPK + SOA + IS obtained GH¢ 5.0, while CLB-CLB (2.1) recorded the least.

Table 3: The profit and cost-benefit ratio accrued from the maize grain yield obtained from the fertilization regimes in FAW management.

Fertilization regimes	Outputs			Inputs		
	Yield kg/ha	Increased yield due to fertilization over control kg/ha	Value of increased GH¢/ha	Cost of fertilizer GH¢/ha	Net benefit due to fertilization GH¢/ha	Net returns due to fertilization
CONTROL	582	–	–	–	–	–
ACT-AMI	3,703	3,121	12,484	1,423	11061.5	7.8
ACT-SUL	2,835	2,253	9,012	1,273	7739.5	6.1
ACT-URE	3,144	2,562	10,248	1,249	8999.5	7.2
UNIK 15-AMI	3,399	2,817	11,268	1,324	9944.5	7.5
CLB-CLB	817	235	940	300	640.0	2.1
UNIK 15-SUL	3,205	2,623	10,492	1,174	9318.5	7.9
UNIK 15-URE	3,773	3,191	12,764	1,149	11615.5	10.1
NPK-SOA+IS	2,609	2,027	8,108	1,350	6758.0	5.0

K-Optima (250ml) = GH¢50, Unik 15 (50kg) = GH¢175, Actyva (50kg) = GH¢195, Amidas (50kg) = GH¢155, Urea (50kg) = GH¢85, Sulfan (50kg) = GH¢95, NPK 15-15-15 (50kg) = GH¢190, SOA (50kg) = GH¢160, Croplift Bio (1L) = GH¢30, maize (1kg) = GH¢3.20. These prices were for 2022 cropping season.

DISCUSSION

Effect of the fertilization on FAW infestation

This research revealed that the abundance of *S. frugiperda* was significantly affected by various fertilization regimes (Figure 1). However, the abundance of *S. frugiperda* on UNIK 15-AMI, ACT-SUL and UNIK 15-URE could be due to the balance of nitrate and ammonium nitrogen in ACTYVA, in combination with SULFAN that has nitrate and ammonium of which the N is immediately available to the plants compared to SA, the unique combination of UNIK 15 that give a well and true proportion of NPK 15-15-15 in combination with high efficiency of the sulfur that improves N efficiency by reducing N volatilization losses in AMIDAS, in combination with the high quality urea that promote green leafy growth and make the plant look lush. This is in line with Shah (2017) who reported that, nutrients application to the soil help crops to produce more succulent, broad and fresh leaves which serves a surface suitable for egg-laying by the varying pests.

The low abundance of *S. frugiperda* on control, CLB-CLB and NPK-SOA+IS could be attributed to plants starved by nutrients and also, the insecticide treated in the control plots. According to Gogi *et al*., (2012), plants development depends on nutrients availability while that of insect-pests depends on the availability of quality food from its host plants. The low abundance of *S. frugiperda* on CLB-CLB (8.5N, 3.4P, 6K+B+Cu+Mn+Mo+Zn) treatment could be the effect of the foliar fertilizer that scared off the FAW larval feeding. Leuck *et al*. (1974) proved that foliage of 'Coastal' Bermuda grass, (*Cynodon dactylon* (L.) person), corn, or sorghum, (S*orghum bicolor* (L.) Moench), sprayed with 14 chemical fertilizers could scare off FAW larval feeding. Nonetheless, the low abundance of FAW in the NPK-SOA+IS plots is due to the pesticides (K-optima) sprayed on those plots that scared off the FAW larvae. Research proofed that, the larval of FAW inflict excessive leaf feeding damage in unsprayed maize than those treated with pesticides (Babendreier *et al*., 2020; Nboyine *et al*., 2021).

Generally, the results from population dynamics of FAW shown that, population increases from the 4 WAP to 6 WAP and finally dropped at the 8 WAP (Figure 2). Normally FAW moths lay their eggs at the early stages of maize growth, therefore damage is limited. The succulent growth stage is the time that the infestation becomes great and the damage duplicated, while during and after tasselling leaf become unpalatable for feeding, that is when the leaf became old. This is in corroboration with Igyuye *et al*. (2018) that, larval feeding behavior was studied by Pannuti *et al*. (2015), and described that despite the fact that vegetative stage (young leaf tissue) is favourable for growth and survival, the leaf tissue is unpalatable on more older plants. Consequently, the leaves of maize are unsuitable for the development of early instars after the VT and reproductive growth stages (Nboyine *et al*., 2021).

The analysis of variance indicated that there was a significant variation on the damage incidence among the fertilization regimes (Figure 3). The high damage incidence on UNIK 15-AMI and ACT-SUL may be due to their combinations (UNIK 15 with Amidas or Actyva with Sulfan) that turned to give the high concentrated nutrients especially N that invites the pests (FAW). As reported by Martin *et al*. (1980) that, Coastal Bermuda grass in particular was susceptible to FAW when pastures are heavily fertilized. More so, as reported by Wiseman *et al*. (1973), that maize plants applied with N fertilizer was the most susceptible to this pest. Further, adding more N to any NPK combination increases the susceptibility of 'Antigua' corn (*Zea mays* L.) foliage to FAW larval feeding greatly. Further reported by Chang *et al*. (1985), that both the larval number and the leaf damage related with FC (fertilized every two weeks) was significantly greater than the larval number and leaf damage of NC (non-fertilized) during all the three observational periods of centipedegrass**.** However, the low damage incidence recorded from NPK-SOA+IS treatments was due to the insecticide's treatment. This is in conformity with Babendreier *et al*. (2020) who stated that, leaf feeding damage incident caused by FAW larvae was higher in corn that was not protected compared to those with insecticides protection.

The weekly trend of FAW damage incidence generally moves from high to low, though some treatments move from low to high and back to low (Figure 4). This incidence could be attributed to the fact that, at the early stages the plants are succulent and palatable for their consumption but at the latter stages leaf becomes tough and unpalatable for consumption. This corroborates with Pannuti *et al*. (2015) that, maize leaf age impacts quality parameters like availability of water, nitrogen and toughness; these may give on to high mortality of the neonate even if the same leaves are consumable for older instars.

Resistance/Tolerance Level of Maize to FAW Damage

The fertilization regimes without insecticides were able to withstand FAW infestation (Table 2). The resistance level of the fertilization regimes might be influenced by the high-quality nutrients that gives a smooth and continuous flow at the righteous proportion and at the righteous hour to the plants when required, the ability to resist the pest damage through thicker cell wall development and or natural defense compounds. This corroborates with Singh *et al*. (2011) who stated that, mineral nutrition safeguards the crops from varying hurdles and greatly execute a unique aspect during the plant's whole life cycle. Also reported by Schumann *et al*. (2010) that, plants with an optimum nutritional status have a maximum resistance (tolerance) to pests and diseases to nutrient deficient plants. And added that, Mineral nutrition can impact two primary mechanisms of resistance: The mechanical barriers formation, (in essence through the development of thicker cell walls) and the combination of natural protection compounds, (for instance phytoalexins, flavonoids, and antioxidants) which issue defense against pathogens. Moreover, fertilization regimes in combination with the CLB-CLB that made up of 8 chemical fertilizers can also influence plant ability to tolerate the damage incidence of FAW. As reported by Leuck *et al*., (1974) that foliage of 'Coastal' Bermuda grass, (*Cynodon dactylon* (L.) person), corn, or sorghum, (*Sorghum bicolor* (L.) Moench), sprayed with 14 chemical fertilizers could scared off FAW larval feeding. Further, some of the nutrients such as S, Mn, Cu and Zn can aid in plants ability to defend itself from the FAW infestation. This corroborates with Fernando *et al*. (2009) that, manganese contributes in the manufacturing of phenolic compounds and some crop protection mechanisms.

Impact of the Fertilization on Maize Grain Yield

This result indicated that, fertilization has a significant effect on maize grain yield (Figure 5). The low maize grain yield received from control could be accredited to inadequate nutrition to the plants as there was no fertilizer applied to the control plots. This correspond with Arthur (2014) that, grain yield among plants in the fertilizer treated plots were significantly higher than those in the no fertilizer treated plots. Among the fertilization regimes, CLB-CLB treated plots obtained significantly low grain yield. This might be caused by insufficient macro-nutrients applied to the crops as the NKP concentration in CLB-CLB is not adequate for the plant to give good yield. This corroboration with Adu *et al*. (2014), who reported that, nutrients requirements of corn is high particularly NPK. Further, observation by Memon *et al*. (2012) reported that, the yields of grain were affected by a variety of fertilizer treatments.

Among the fertilization regimes, there was no significant variation though, the highest grain yield recorded from UNIK 15-URE (3,773 kg/ha) followed by ACT-AMI (3,703 kg/ha) and UNIK 15-AMI (3,399 kg/ha) demonstrated that, the maize grain yield increased in the company of increasing of N concentration. The increment of the grain yield might be influenced by the concentration of N content in the fertilizer formulations applied as a top-dressing after applying NPK as basal. Urea (46% N content) applied as top-dressing recorded highest grain yield followed by YaraVera (Amidas) (40% N content with 5.6% S). This correspond with Adu *et al*. (2014) that, among the primary nutrients that most often limits yield is N, the quantity of leaves the plant produces and the seed quantity per cobs is determined by the N and thereby determines the potential of the yield. Further, reported by Harrison *et al*., (2019), that inorganic fertilizer can lead in increased yield in spite of higher pressure of the pest, as a result of better plant growth.

Partial Budget Analysis from Maize Grain Yield

As shown from the partial budget analysis, it will be most profitable managing FAW in maize field for grains using YARA formulated fertilizers compared to unfertilized field (Table 3). All the YARA formulated fertilizers yielded more profit than the non-YARA formulated fertilizer with insecticide spray (NPK-SOA+IS) except CLB-CLB. The highest profit and cost-benefit ratio obtained from UNIK 15-URE (GH¢11615.5) among the fertilizer treatments may be due to its high yielding and low input cost associated with the production. Though ACT-AMI (GH¢11,061.5) and UNIK 15-AMI (GH¢9,944.5) yielded second and third highest profit per hectare, the cost-benefit ratio (7.8 and 7.5 respectively) obtained from its use was lower than that of UNIK 15-SUL (GH¢ 9,318.5) cost benefit ratio (7.9). This high cost-benefit ratio of UNIK 15-SUL could be associated with the low cost of sulfan to that of amidas. However, CLB-CLB (GH¢641.0) lowest profit and cost-benefit ratio (2.1) obtained could be attributed to the inadequate nutrients supply. This correspond to Teetes, (1980) and Listinger, (1993), who stated that plants that get adequate nutrients are healthier, stronger and generally capable to pay back for the pest damage better compared to those under nutritional deficiency.

CONCLUSION

Generally, there was significant variation in FAW larval abundance in various fertilization regimes. Apart from CLB-CLB, control recorded significantly lower larval abundance compared to fertilization regimes. Among the fertilization regimes, UNIK 15-AMI and ACT-SUL obtained statistically higher larval abundance whilst CLB-CLB recorded the least. There was some level of tolerance offered to maize plants against FAW infestations by the fertilization regimes. Control obtained significantly lower damage incidence compared to fertilization regimes except NPK-SOA+IS and CLB-CLB. Among the fertilization regimes, UNIK 15-AMI and ACT-SUL obtained statistically higher damage incidence when compared. All the fertilizer plots yielded significantly higher grain yield compared to control. Among the fertilization regimes, CLB-CLB recorded significantly lower grain yield, though there were no significant variations among the rest of the treatments, UNIK 15-URE, ACT-AMI and UNIK 15-AMI was in the order of high to low. The partial budget analysis demonstrated a positive value of profit increment for all the fertilization regimes compared to control. Among the fertilization regimes, CLB-CLB yielded less profit and cost-benefit ratio, whilst the highest profit and cost-benefit ratio was obtained from UNIK 15-URE. The second and third profit was recorded from ACT-AMI and UNIK 15-AMI respectively. Though UNIK 15-SUL recorded fourth in terms of profit yet, it cost-benefit ratio was higher compared to ACT-AMI and UNIK 15-AMI respectively. It is recommended that, farmers apply UNIK 15 at basal and urea or amidas as topdressing for management of FAW, better yield as well as high profitability per hectare.

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Pollen Analysis and Physicochemical Characterization of Honey Samples from Owo Local Government Area, Ondo State, Nigeria

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Abstract:
Bees (Apis mellifera var. adansonii) produce honey, a naturally occurring sweet viscid liquid, from blossom nectar and it has both medicinal and antibacterial properties. Pollen, physical and chemical analyses are used to ascertain floral sources, the purity of honey, its botanical, ecological, and geographic provenance, the main honey-producing season, and the processing facilities that honeybees most frequently visit while gathering pollen and nectar. Four samples of honey were acquired from the Owo Local Government Area in Ondo State, Nigeria, and treated to the aforementioned evaluation. Out of 36 pollen types that originated from 25 plant families, one (1) was identified to family level, twenty-six (26) to generic level, eight (8) to species level, and one (1) was unidentified. The described species come from numerous genera of trees, shrubs, grass, and herbs. Ilale, Isuada, Ipeme, and Alaguntan each had pollen grain counts of 61, 169, 172, and 236, respectively. Alaguntan provided the richest sample, with two hundred and thirty-six pollen counts. Ipeme, Isuada, and Ilale samples were next, with one hundred and seventy-two, one hundred and sixty-nine, and sixty-one pollen counts, respectively. In varying amounts, the predominant pollen types include those of Elaeis guineensis followed by Poaceae, Ageratum conyzoides, Hymenocardia acida, Phyllanthus sp., Tridax procumbens, Coffea sp., Talinum triangulare, Morellia senegalensis, Solanum melongena, and Mimosa pudica. The honey samples were all multi-floral. To confirm the safety of the analysed samples of honey, the investigation used pollen densities and quantities. Tests for protein, electrical conductivity, moisture content, ash content, pH level, and specific gravity were all part of the characterization studies. Due to the impact on texture and stability, which are crucial during honey extraction and storage, all of the results for the samples were found to meet the specifications for honey laid out by international regulatory agencies.

Keywords: Honey, Pollen analysis Physico-chemical examination, multi-floral.

INTRODUCTION

Since ancient times, people have used honey, a complex liquid made by honeybees (*Apis mellifera* var. *adansonii*), as a source of energy, a natural sweetener, and a curative that inhibits the growth of disease-causing organisms (National Honey Board, 2002; Aled *et al*., 2012; Maddocks *et al*., 2012; Nwankwo *et al*., 2014; Ng and Lim, 2015; Adeonipekun *et al*., 2016; Ng *et al*., 2017).

In addition to other chemicals required for typical human growth and development, honey contains macro- and micronutrients such as water, carbohydrates, minerals, amino acids, organic acids, proteins, volatile substances, enzymes, and phenolic compounds. The nectar sources have a significant impact on the content of honey (Fernandez-Torres *et al*., 2005). High-quality honey has been proven to restore damaged intestinal mucosa and facilitates the emergence tissues (Kek *et al*., 2014; Nolan *et al*., 2019).

The Greeks also utilized honey as gout, fever, pain, and wound healing treatment. A rising incidence of diseases in recent years has led to an increase in the use of natural honey in place of processed sugar and related products. For instance, Nigerian supermarkets and outdoor markets sell a variety of honey products. The chemical, physical, sensory, and microbiological properties of honey affect its quality (Khalil *et al*., 2012). Assessing the pollen content of the honey is among the strongest factors to check the provenance and type of flora that produced the honey (Jasicka-Misiak *et al*., 2012). Several scientists in Nigeria have researched on various elements of honey pollen analysis. Sowunmi (1976), who examined the phytogeographical background of the honey, made the first indigenous attempt. Agwu *et al.* (1989), Agwu and Abaeze (1991), Sowunmi (2001), Ige and Modupe (2010), Agwu *et al*., (2013), Oyeyemi (2017) and Essien *et al*. (2022) are a few other noteworthy contributions. In various regions of the world, research into the use of palynological and physicochemical techniques to determine whether a sample of honey is authentic or contaminated is still ongoing (Saxena *et al*., 2010; Anklam, 2010; Ramirez-Arriaga *et al*., 2011; Rateb and Hussein, 2012).

According to Lawal *et al*. (2009)'s report, it was discovered that honey samples produced in various parts of Turkey, where floral diversity was relatively significant, did not share the same quality. This can be explained by the various geographical areas from where honey samples were gathered and, consequently, the variety of plant species that go into honey production. Regulations that govern honey packaging in the European Community advocate using labels to specify the product's floral and geographic backgrounds as well as its customer satisfaction (CODEX, 2001). The authentication of the honey's botanical source responds to consumer needs and ensures product quality, prohibiting frauds. As a consequence, it becomes imperative to characterize honey samples in precise details. Numerous honeys produced in massive quantities in Spain, including Eucalyptus, Heather, Lavender, Thyme, Citrus, Rosemary, and honeydew, have been well evaluated (Ferna´ndez-Torres *et al*., 2005). Through the use of pollen and physicochemical analysis, the current study sought to identify the qualities of honey samples and assess the veracity of honey from the study area.

MATERIALS AND METHODS

Study Area

The study area is located on the northern edge of the Yoruba Hills, between latitude 701146"N and longitude 503512"E. Nigeria's Ondo State is situated in the southwest. Two seasons, the dry season and the wet season-define the region's climatic conditions. The wet season begins in March and lasts until roughly November. The dry season, which lasts throughout February, officially begins in December. In Owo, the month of August seems to have the lowest temperature of the year. Honey flows in these regions between September and April. Despite a high level of anthropogenic activity, pollen assemblages provided evidence that the vegetation of the study region was of the tropical rainforest vegetation type (Essien and Ige, 2019).

Collection of Honey Samples

Four samples of honey were used in this investigation, and they were from Ilale, Isuada, Ipele, and Alaguntan communities in Owo Local Government Area of Ondo State, Nigeria. In sealed, labeled plastic bottles, the honey samples were shipped to the Palynology Research Laboratory at Adekunle Ajasin University, Akungba-Akoko.

Sample Preparation, Mounting and Microscopic Examination

We carefully weighed 10 g of filtered honey from each sample using a weighing balance, and the colour was noted. Each sample of honey was vigorously shaken to fully mix and distribute the chemical and botanical components. The vigorously shaken sample was then diluted with 35 ml of warm (40–50^{0}C) dilute sulphuric acid solutions (3 ml in 100 ml of water) in accordance with the procedure of Agwu *et al*. (2013). The honey-acid solution was thoroughly shaken before being centrifuged for 5 minutes at a speed of 2000 rpm. The supernatant was then decanted. For each sample of honey, the density of the retrieved polleniferous granules was determined. The recovered particles were treated with ten milliliters of ethyl acetate to eliminate water prior to acetolysis. Fresh acetolysis mixture was made by mixing concentrated sulphuric acid and acetic anhydride in a 9:1 ratio. The strategies of Erdtman (1969) and Agwu *et al*. (2013) were used to do the acetolysis. In boiling water set at boiling point (100^{0}C), the solution was mixed with the sediment and suspended for five minutes before being removed to cool for ten to twelve minutes. After 5 minutes of centrifuging and stirring, the supernatant was collected. The recovered granules then were spun twice, washed two times using distilled water, and decanted. The recovered residues were kept in a glycerin and ethanol solution in storage plastic vials (2:1).

Each vial's contents were vigorously shaken before two drops of each suspension were put on a microscope slide and covered with an 18x18 mm^2 cover slip. To keep the mount from drying out, it was sealed off with colourless nail polish. The 18 mm^2 surface was covered equally with the sample, and no samples leaked from the sides. The prepared slide was subsequently examined under an x40 Olympus microscope for counting and identification. Reference descriptions and photomicrographs from books and journals, including Sowunmi (1978; 1995), Agwu and Akanbi, (1985), Agwu *et al*. (2013), Shubharani *et al*. (2013), Essien (2014) and Essien and Ige (2019), were used for identification, counting, and categorization. Pollen grain frequencies are denoted by the Louveaux *et al*. (1970) classification of highly frequent (above 45 percent), frequent (16-45 percent), rare (3-15 percent), and sporadic (less than 3 percent).

Physicochemical Analysis

In order to quantitatively assess the moisture content, protein, ash content, specific gravity, pH, and electrical conductivity of four samples of honey, physicochemical analysis was performed on the samples. The associations of official analytical chemists' established procedures were used to evaluate these parameters (A.O.A.C, 1990).

Determination of pH

The pH of a sample of honey was measured using a pH meter (HANNA Instrument model HI 2211) from a solution of 20g of honey in 75ml of distilled water in a 250ml beaker. It was stirred using a stirrer. The pH electric meter was immersed in the solution, read, and recorded.

Determination of Moisture Content

Gravimetric measurement was the method used. The weight of a previously moistened can was measured using a weight sample (5.0g). The sample in the can was dried in a 105°C oven for three hours. After chilling in a desiccator, it was weighed. The sample was returned to the oven to complete drying. After several hours of drying, cooling, and weighing the sample again, there were no longer any weight losses (i.e., constant weight was obtained). The weight of the moisture lost was calculated and reported as a percentage of the weight of the sample analyzed. It was expressed in the manner of:

$$\% \text{ Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1}$$

Where;
W_1 = Weigh of empty moisture can
W_2 = Weight of empty can + sample before drying
W^3 = Weight of can + sample dried to constant weight.

Determination of Protein

James' Kjeldah technique was used to accomplish this. The total nitrogen was determined and multiplied by 6.25 for the protein reactions. Precisely 0.5g of the substance was added to 10 ml of concentrated H_2SO_4 in a digestion flask. A selenium catalyst tablet was added, and it was heated under a fume cupboard until a clear solution was created (i.e., the digest). Before being used for the analysis, the digest was boiled in a volumetric flask and diluted to 100 cc. 10 ml of the digest were mixed with an equivalent volume of a 45 percent NaOH solution in a Kjeldahl distillation apparatus. 50cc of the distillate in total were collected and titrated from green to a deep crimson end point against 0.02 N EDTA. In 10 ml of 4 percent boric acid with 3 drops of mixed indicator (broocressol green/methyl red), the liquid was distilled. A blank reagent was also broken down, distilled, and titrated. The nitrogen content, and consequently the protein content were calculated using the formula below:

$$1 \text{ Mole of IN } H_2SO_4 = 14 \text{ mg } N_2$$

$$\% \text{ Protein} = \% N_2 \times 6.25$$

$$\% \text{ N} = \frac{100 \times N \times 14 \times V}{W \times 1000 \times Va} - T - B$$

W = Weight of sample (0.5g)
N = Normality of titan (0.02N H_2SO_4)
Vt = Total digest volume (100 ml)
Va = Volume of digest analyzed (10 ml)
T = Sample titer value
B = Blank titer value

Determination of Ash content

This was accomplished using the furnace's gravimetric incineration. A ceramic crucible that had already weighed exactly 50 g was filled with the sample. The sample was heated to 550°C for three hours in a muffle furnace, reduced to ashes, cooled in a desiccator, and weighed again.

The weight of the ash recovered was calculated by difference and expressed as a percentage of the weight of the sample under study, as shown in the formula below:

$$\% \text{Ash} = \frac{W2 - W1}{W1 \text{ of sample}} \times \frac{100}{1}$$

Where;
W_1 = Weight of empty crucible
W_2 = Weight of crucible + ash

Determination of Electrical Conductivity

The pH meter was used to test the electrical conductivity in millivolts after 20g of honey was dissolved in 100 ml of distilled water and properly mixed to produce a solution.

Determination of Specific Gravity

The ratio of the sample weight to the weight of an equivalent volume of water was used to calculate the specific gravity.

$$SG = \frac{W_{Sb} - W_b}{W_{Wb} - W_b}$$

Where;

W_b = Weight of pycnometer.

W_{sb} = Weight of the sample + pycnometer

W_{wb} = Weight of the water + pycnometer

RESULTS AND DISCUSSION

Pollen Analysis

The relative abundance (quantity) of pollen in each sample has served as a metric for the purity and reliability of the honey samples. A total of thirty-six (36) pollen types belonging to twenty-five (25) plant families were encountered in the study; one (1) was identified to family level, twenty-six (26) to generic level, eight (8) to species level, and one (1) was unidentified (Table 1). The encountered species are among the diversity of flora (grasses, trees, shrubs, and herbs) present in the local vegetation of the study area. Pollen grain counts varied from 61 to 236 for Ilale, Isuada, Ipeme, and Alaguntan, respectively. There were 26 different pollen types found in Alaguntan, 20 in Ipeme, 19 in Isuada, and only 12 in Ilale; the pollen type with the fewest numbers.

Table 1: The pollen spectrum of honey samples from the study area

S/N	POLLEN TYPES	LOCALITIES				
		ILALE	ISUADA	IPEME	ALAGUNTAN	TOTAL
1.	ANACARDIACEAE					
	Lannea spp.	1	0	0	0	1
	Mangifera indica	0	0	4	2	6
2.	ANNONACEAE					
	Annona senegalensis	0	0	3	7	10
3.	ARECACEAE					
	Elaeis guineensis	20	62	55	109	246
4.	ASTERACEAE					
	Ageratum conyzoides	0	2	8	3	13
	Tridax procumbens	0	3	4	2	9
5.	BOMBACACEAE					
	Ceiba pentandra	0	0	4	0	4
6.	COMBRETACEAE					
	Combretum spp.	7	0	9	0	16
7.	COMMELINACEAE					
	Aneilema spp.	0	0	3	0	3
8.	CONVOLVULACEAE					
	Merremia spp.	2	1	0	0	3

9.	EUPHORBIACEAE					
	Euphorbia hirta	0	0	0	4	4
	Manihot spp.	0	3	1	0	4
10	FABACEAE: SUB-FAMILY					
	1. CEASALPINIOIDEAE					
	Cassia fistula	0	1	0	4	5
	Caesalpinia pulcherrima	0	0	0	3	3
	Delonix regia	6	0	0	10	16
	Mimosa pudica	0	1	7	2	10
	Zygia latifolia	1	0	0	0	1
	2. MIMOSOIDEAE					
	Albizia zygia	0	3	0	5	7
	Gliricidia sepium	0	2	1	5	9
11	IRVINGIACEAE					
	Irvingia gabonensis	1	0	0	3	4
12	MALVACEAE					
	Sida acuta	0	0	0	1	1
13	MELIACEAE					
	Trichillia preuriana	0	3	1	7	11
14	MORINGACEAE					
	Moringa oleifera	0	0	3	0	3
15	MYRTACEAE					
	Syzygium guineense	0	0	0	3	3
16	PHYLLANTHACEAE					
	Hymenocardia acida	0	9	5	6	20
	Phyllanthus spp.	0	11	5	3	19
17	POACEAE	15	45	32	25	117
18	PORTULACACEAE					
	Talinum triangulare	2	2	12	5	21
19	PROTEACEAE					
	Protea elliottii	0	0	0	1	1
20	RUBIACEAE					
	Coffea spp.	0	10	5	7	22
	Morellia senegalensis	1	2	6	7	16
21	RUTACEAE					
	Citrus sp.	3	0	0	2	5
22	SAPINDACEAE					
	Paullina pinnata	0	0	0	3	3
23	SOLANACEAE					
	Solanum melongena	0	6	4	7	17
24	VERBENACEAE					
	Vitex grandifolia	0	1	0	0	1
25	Indeterminata	2	2	0	0	4
	Total Pollen counts	61	169	172	236	638

The four samples of honey were all pure. Based on pollen weights larger than 0.4 g, this was determined (Agwu and Akanbi, 1985). The predominant pollen types in the four honey samples include those of *Elaeis guineensis*, Poaceae, *Ageratum conyzoides*, *Hymenocardia acida*, *Phyllanthus* species, *Tridax procumbens*, *Combretum* species, *Coffea* species, *Talinum triangulare*, *Morellia senegalensis*, *Solanum melongena*, *Mimosa pudica*, and *Manihot* species (Table 2). Bees prefer the plant that grows a lot; the essential pollen types spanned from "frequent to sporadic."

The relative abundance of the pollen types present in the honey samples are shown in Figure 1 and the predominant pollen types, percentage occurrences and classification of the honey are presented in Table 2.

Table 2: Predominant pollen types, percentage occurrences and classification of the honey

Localities	Class of honey	Pollen type	Percentage composition	Frequency class
Alaguntan	Multi-floral	*Elaeis guineensis*	17.08	Frequent
		Poaceae	3.92	Rare
		Delonix regia	1.56	Rare
		Coffea spp.	1.09	Rare
		Morellia senegalensis	1.09	Rare
		Annona senegalensis	1.09	Rare
		Solanum melongena	1.09	Rare
		Trichillia preuriana	1.09	Rare
		Hymenocardia acida	0.94	Sporadic
		Albizia zygia	0.78	Sporadic
		Talinum triangulare	0.78	Sporadic
		Irvingia gabonensis	0.47	Sporadic
		Syzygium guineense	0.47	Sporadic
Ipeme	Multi-floral	*Elaeis guineensis*	8.62	Rare
		Poaceae	4.68	Rare
		Talinum triangulare	1.88	Rare
		Combretum spp.	1.41	Rare
		Agerattum conyzoides	1.25	Rare
		Mimosa pudica	1.09	Rare
		Morellia senegalensis	0.94	Sporadic
		Hymenocardia acida	0.78	Sporadic
		Ceiba pentandra	0.62	Sporadic
		Mangifera indica	0.62	Sporadic
		Solanum melongena	0.62	Sporadic
Isuada	Multi-floral	*Elaeis guineensis*	9.71	Rare
		Poaceae	7.03	Rare
		Phyllanthus spp.	1.72	Rare
		Coffea spp.	1.56	Rare
		Hymenocardia acida	1.41	Rare
		Solanum melongena	0.94	Sporadic
		Manihot spp.	0.47	Sporadic
		Tridax procumbens	0.47	Sporadic
		Gliricidia sepium	0.47	Sporadic
		Trichillia preuriana	0.47	Sporadic
Ilale	Multi-floral	*Elaeis guineensis*	3.13	Rare
		Poaceae	2.35	Rare
		Combretum spp.	1.09	Rare
		Delonix regia	0.94	Sporadic
		Citrus spp.	0.47	Sporadic
		Merremia spp.	0.31	Sporadic
		Talinum triangulare	0.31	Sporadic

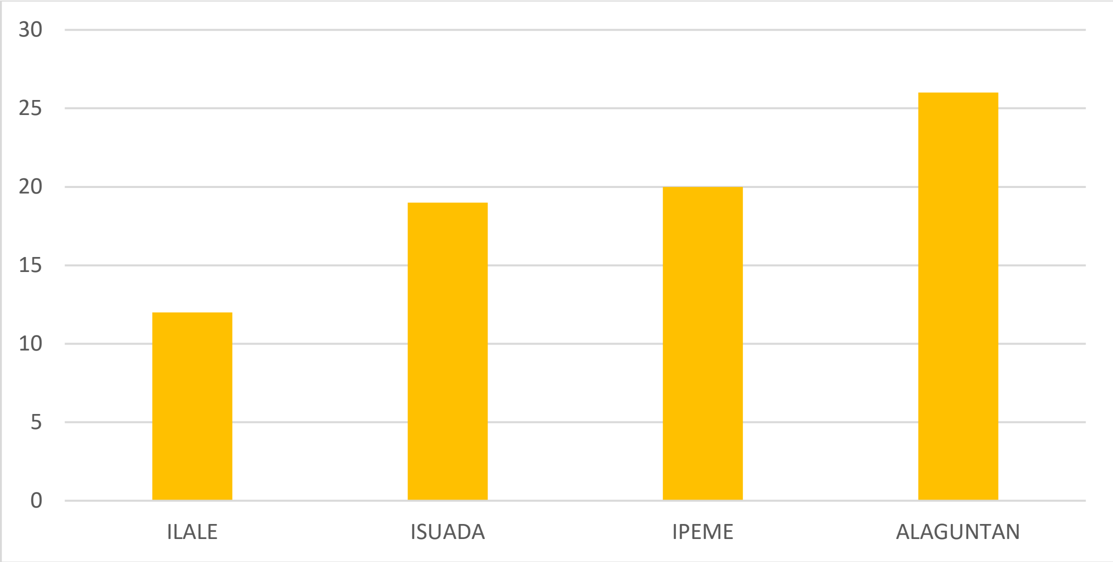

Figure 1: Histogram showing the abundance of pollen types in the study locations

Pollen grains of diverse forms, sizes and morphological features were found in the honey samples, indicating that they were all multi-floral honeys made from a range of nectar sources. The four samples of honey used for this investigation were all multi-floral and distinguished by a variety of pollen types. Indicator species that honeybees commonly visit for pollen and nectar sources have been identified in this study. In designed to motivate competitive honey production in the study locality and Nigeria in general, such plants could be properly conserved and managed for long-term exploitation.

It has been reported by Richard (1999) that lighter-coloured honeys are supplied directly for consumption whereas darker-coloured honeys are frequently used in industrial applications. In this study, the four samples of honey that were analysed varied from light brown to yellowish brown to dark brown in colour. Each sample gives a visual representation of pollen in honey, the colour of diluted honey, and the amount of honey (Table 3).

Table 3: Colour of diluted honey and weight of pollen in the honey sample

Localities	Color of diluted honey	Weight of honey (gram)	Weight of pollen (gram)
Ilale	Light brown	10	0.20
Isuada	Dark-brown	10	0.23
Ipeme	Yellowish brown	10	0.35
Alaguntan	Dark brown	10	0.32

Physicochemical Analysis

The physicochemical parameters tested for were: pH value, Moisture content, Ash content, Electrical conductivity, Proteins and Specific gravity. The results are presented in (Table 4).

The pH Values

The pH range for blossom honeys should be between 3.2 and 4.5, according to CODEX (2001) international standards, and all of the honey samples met this requirement.

According to CODEX (2001) international regulations and all of the honey samples surpassed this specification. The four samples were all certified acidic, with pH values ranging from 3.36 to 4.04

(Table 4). The results conformed to Saxena *et al*. (2010)'s assertion that honey is usually acidic regardless of its source. Similar results were reported by Lawal *et al*. (2009) who opined that samples exhibiting acidic pH values were pure and had the ability for longer shelf life.

Table 4: Physicochemical parameters of the studied honey sample

LOCATIONS	Moisture content (%)	Specific gravity	pH value	Electrical conductivity (Mv)	Protein (%)	Ash content (%)
ILALE	14.29%	1.47	4.03	27.3%	0.95	0.02
ISUADA	17.04%	1.52	3.70	83.5%	1.11	0.05
IPEME	13.39%	1.49	3.36	98.7%	0.91	0.03
ALAGUNTAN	19.35%	1.50	3.59	88.6%	1.75	0.02

Conductivity

Electrical conductivity is frequently used in honey quality control and purity techniques since it is considered to be a reliable criterion. Every one of the samples' electrical conductivity data (Table 4) indicated that they were all within permissible limits. The electrical conductivity of the Ipeme honey sample was the highest (98.7 mV), whereas the Ilale honey sample had the lowest electrical conductivity (27.3 mV) but the highest pH level. High conductivity was reportedly correlated with high pH by Ouchemoukh *et al*. (2010).

Protein Content

The samples of honey had a protein content that varied from 0.91 to 1.75 percent. As per the CODEX (2001) standard, this was accomplished. The findings reinforce Njokuocha and Osayi's (2005) report, which highlighted that floral origin, nectar sources, and quality, as well as pollen type in the honey sample; all have an influence on the protein composition of honey, which varies extensively in comparison to the plant sources.

Moisture Content

Maturity level is inversely correlated with water content. The obtained water contents ranged from 13.3 to 19.35 %. Among the amalysed samples, the honey samples from Ipeme and Alaguntan had the lowest and highest water content. Getachew *et al*. (2014) suggest that depending on the source of the honey, the season, and other parameters, the moisture content of honey can naturally range between 13 and 23 %. High moisture load in some varieties of honey may cause the honey's water activity to ferment and hasten crystallization (Gomes *et al*., 2010). Honey with a value around 16 and 18 % is considered to be the best honey for conservation and storage, according to Azzedine *et al*. (2007). Premature extraction may provide honey samples with high moisture content. Honey with a longer shelf life presumably has lower moisture content, according to Fredes and Montenegro (2006).

Ash Content

The other honey samples exhibited total ash values of 0.03 percent (Ipeme), 0.02 percent (Alaguntan), and 0.02 percent (Ilale), all of which were within the regulatory agency's restrictions. Isuada had a total ash content of 0.05 percent. The Isuada honey sample had the highest ash content (0.05%), which was within the threshold of 0.50 % that was considered to be suitable. These findings are in agreement with those of White (1975), who evaluated various varieties of honey and discovered that their ash contents ranged from 0.020 to 1.028 percent. The variation may originate from variables including plant physiology, weather factors, and soil properties.

Specific Gravity
Isuada and Ilale already had a specific gravity of 1.52, and Ilale reached 1.47. These honey sample specific gravity estimates are relatively close to the range of 1.47-1.52 (Table 4). This breaches the 1.38–1.45 range of the established Codex standard (Adams *et al*., 2010)

Botanical Origin of Honey
Due to the obvious considerable species diversity prevalent in anthropogenically disturbed mosaics of lowland rainforest and secondary grassland, pollen grains from various plants families and pollen types are detected in honey samples. The honeys from the transition zones exhibited a plethora of pollen types. Irrespective of source locations and attendant localized ecological characteristics, some species were common to some localities while others were encountered in all samples analysed. For example, *Elaeis guineensis*, Poaceae, *Delonix regia*, *Morellia senegalensis*, *Solanum melongena*, *Phyllanthus* sp., and *Talinum triangulare* are a few of the pollen types that occur in this category. The presence of a diversity of major pollen types in the four samples proved that the honey samples were of botanical origin and provided a clear indication of their geographical origin (Ige and Modupe, 2010). Similar findings were reported by Essien and Ige (2020) and Aina and Owonibi (2011).

Geographical Origin of Honey
The majority of honey samples in Nigeria are sourced in the Mosaic of lowland rainforest and secondary grassland. Lowland rainforest and derived savanna vegetation are characterized by *Elaeis guineensis*, Poaceae, *Morellia senegalensis*, *Tridax procumbens*, and *Phyllanthus* sp. Farmlands and suburban complexes are distinguishable by the sight of these indicator floras as reflected by their pollen. Published investigations undertaken across the globe had already established that the pollen content of a sample of honey can be used to pinpoint the geographical origin of honey. Similar findings were reported by Maurizio (1951), Sowunmi (1976), and Agwu *et al*. (2013). All of the aforementioned pollen types were detected in varying amounts, indicating confirmations that their geographical backgrounds being disturbed tropical lowland rainforest and secondary grasslands.

Season of Honey Production
The periods within which honey is produced can be linked to the flowering phases of the floras which their pollen reflects. The majority of Nigerian honey is produced during the season with no or little rainfall (that is September to April) according to ethno-linguistic evidence and market study report. Tropical plants, specifically trees, flower instantly once the sunshine is high intensely and the atmosphere becomes less humid, and the climatic conditions are naturally more suitable for the insect's motion including honeybees.

For instance, *Elaeis guineensis* flowers bloom all year but peaks in October to April, Poaceae flowering from October to June, *Annona senegalensis* flowers in April, Asteraceae taxa blooms from April to December, *Hymenocardia acida* blooms from January to March, *Syzygium guineensis* blooms from November to May, *Phyllanthus* sp. blooms from January to October, and *Lannea* (January to April). The presence of pollen grain from *Phyllanthus* and Asteraceae plants in the honey samples suggests that honeybees foraged from December to June. Those from the Asteraceae family and *Elaeis guineensis* suggest that the honeybees gather their food between October to April. The findings reinforce with the report of Essien (2020) and Sowunmi (1976). As a consequence of the predominant nectar plants' flowering cycles, the honey samples from the study localities were primarily produced between the months of October and April. Pollen analysis revealed that the honey samples acquired from sourced localities demonstrated that honeybees foraged for both native and exotic flora from the various and different floral sources used in the honey production.

CONCLUSION

Numerous indicator species were identified by pollen examination of honey specimens from four localities in Owo Local Government Area of Ondo State, Nigeria. The honey's pollen spectrum substantially matched the floristic makeup of the vegetative environment where it was produced. This study revealed that the weight and the proportion of pollen can be leveraged to discern between adulterated and pure honeys. The finding of this research also demonstrated that the marker taxa that honeybees (*Apis mellifera* var. *adansonii*) routinely visit in supplies of nectar and pollen were the principal pollen types that were observed in these catchment areas. The outcomes should be efficient in guiding the conservation and ethical exploitation of these indicator species, which will boost the region's capacity to produce large quantities of honey.

The honey samples' physicochemical investigation suggests that, when compared to the Codex honey standard, these were of relatively high quality and equivalent to those reported in earlier investigations for honey quality assurance. The honey specimens' acidified pH levels confirmed overall integrity and indicated that they might have a long shelf life. For the identification, multiplication, cultivation, conservation, and even the sustainable usage of these taxa, the creation of a pollen flora and/or atlas for the honeybee foraged plants of a study area is highly imperative. Attributable to the underlying facts that a vegetation source (or sources) seems to have a substantial impact on the physical and chemical characteristics of honey, is considered to be integral towards its establishment. It is essential to attach importance towards how contrasting honey as well as the procedures suppliers use for its extraction, processing, storage, and preservation.

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Promotion of Onion Seed Production Technologies for Improving Productivity in Upper and Middle Awash Irrigated Areas

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Abstract:
The onion (Allium cepa L.) is a member of the family Alliaceae and the most widely grown biennial vegetable crop that needs quality planting material for its successful production. For the supply of seeds, the informal sector is playing a significant role in reaching many farmers. Most of the demand for onion seeds is either met by local supplies through an unorganized market system or by imported seeds through an informal trend. Therefore, this experiment was conducted at two kebeles in each of the Fentale and Amibara districts on small-scale irrigation in 2021 to demonstrate Nafis and Nafid onion seed production technologies through a participatory approach. The experiment was done on a systematically selected agro-pastoralist. The field experiment was laid out in a single plot having an area of 10 by 10 m2. Two released onion varieties, Nafis and Nafid, were used in this experiment. Planting date, seed yield per plot and hectare, number of stakes per plant, stake diameter, length of primary stake, and numbers of umbels per plant were all collected. Using SAS software, version 9.0, collected data were analyzed for an independent two-sample t-test. The yield performance of demonstrated onion varieties was computed using an independent-sample t-test to compare the performance of average yield differences between the two varieties. Accordingly, a significant difference was observed in the average seed yield for varieties Nafis (10.72 q ha-1) and Nafid (9.17 q ha-1). It is concluded that the Nafis variety really does have an advantage of 1.55 q ha-1 seed yield over the Nafid variety. Therefore, it suggests that the Nafis variety will increase their seed yields when aggro-pastoralists need to produce onion seed.

Keywords: Onion, Agro pastorals, Seed yield, KOPIA, Demonstration

INTRODUCTION

The bulb onion (*Allium cepa* L., *Alliaceae* family) originated in the region comprising Afghanistan, Iran, and the southern portion of the former Soviet Union. The supposed onion ancestor, onion from Central Asia, most likely migrated to the Near East, and areas around the Mediterranean Sea are secondary centers of development (Malik M.N., 2000). The majority of germplasm introduced and developed in Ethiopia has its origins in India, Brazil, Sudan, and Italy. The genus Allium is highly diverse and contains more than 600 species, among them the edible species A. fistulosum (bunching onion, Japanese onion, Welsh onion), A. sativum (garlic), A. ampeloprasum (leek), A. schoenoprasum (chives), and A. tuberosum (Chinese chives). Allium cepa is the most widely cultivated of these species. Bulb onion has been cultivated for more than 5000 years and is not known to exist in the wild, though the closest wild relatives are A. galanthum and A. vavilovii (Hanelt, 1990), both of which can be found in its areas of origin.

Onions are a very important vegetable crop as a source of food for human beings. It is valued for its distinct pungency and forms an essential ingredient for flavoring varieties of dishes, sauces, soups, sandwiches, snacks as onion rings, etc., and is a cash crop both for local and export earnings and serves as an area of employment for many people due to its intensive culture. Dry onions are indispensable kitchen vegetables in every home and are typically used as an ingredient in many dishes and salads. Numerous scientific studies suggest that onions and their relatives can be used to treat, reduce, or prevent a variety of health problems, including cardiovascular disease, diabetes, cancer, asthma, antibiosis, and prebiotic effects (Desjardins, 2008). Allicin and alliin in the onion whet the appetite, facilitate digestion and serve as a regulatory impact on the intestines. Onions have vitamins (A, B1, B2, C, nicotinic acid, pantothenic acid) and important substances such as protein, calcium, phosphorus, potassium, and traces of Fe, Al, Cu, Zn, Mn, and I. Furthermore, it has anti-fungal and anti-bacterial properties and contains an acrid volatile oil with a pungent smell. Its oil is rich in sulfur (Augusti, 1990).

Ethiopia has favorable and diverse agro-ecological conditions for growing a wide range of fruit and vegetable crops. Vegetables (onion, tomato, pepper, kale, etc.) are the most popular crops with varied food and culinary uses, providing vitamins and minerals vital for a balanced and healthy diet that helps to prevent deficiencies caused by nutritional imbalance. Vegetables, including onions, can also protect our bodies from serious diseases. Besides, the production of vegetables can create job opportunities, particularly for women, youth, and poor households because of its labor-intensive nature. Furthermore, they can give a high yield per unit area compared to cereals and hence generate a high income for farmers due to their high market value and profitability.

In Ethiopia, onions rank third in terms of area coverage, trailing only red pepper and kale, and kale is second in production (CSA, 2018). The same report indicated that 880,638 smallholder farmers produced about 293,888 tons of onions from 31,673.21 hectares of land in a year. Moreover, annually, Ethiopia earns more than 2.6 million USD from the export of fresh and chilled onion and shallot products. Hence, by considering the economic, nutritional, and social significance of the crop for Ethiopians, the Ethiopian Institute of Agricultural Research has identified onion as one of the priority crops in research to improve yield and quality in order to satisfy the demands of local consumption and export markets. Through years of research, improved varieties (seven open pollinated that include Adama Red, Bombay Red, Melkam, Nasik Red, Nafis, Robaf, and Nafid varieties) and corresponding production technologies have been recommended, which have contributed to the improvement of production and productivity of the crop in the country. The area covered and productions of the crop have been increasing for the last six years (CSA,2018). The area under onion was only 21,865 ha in 2013; whereas, it has now increased to 31,673.21 ha in 2018, which is about a 45% increment. Similarly, the production was 219,189 and 293,888 tons in 2013 and 2018 respectively, which accounted for a 34% increment.

However, still, the national average yield is low when compared to the yield potential of released varieties, onion-producing countries, and the world average. Besides, despite the increase in cultivated areas and production, Ethiopia is importing a significant amount of fresh onion bulbs from Sudan since the demand for the crop and its local production are not balanced. The low productivity could be attributed to the limited availability of quality seeds and associated production technologies used, among others.

In Ethiopia, the productivity of onion seeds is much lower than in other African countries (Nikus, O. and Fikre, M., 2010). The yield of onion seed ranges from 1000–1300 kg ha^{-1} (Lemma et al., 2006) and 75.15–115.75 kg ha^{-1} (Teshome et al., 2014; Tamrat, 2006) in Ethiopia, while in other countries it ranges from 828–1446 kg ha-1 (Aminpour, R. and Mortzavi, B. A., 2004). The area coverage and production across the country are increasing from time to time, and most of the recently released varieties account for the largest area coverage (Ahmed, I. H. and Abdella, A. A., 2006). Despite an increase in the area of coverage, the productivity of onion varieties in Ethiopia is much lower than the expected production level. The low productivity could be attributed to the limited availability of quality seeds and associated production technologies used, among others. Onion cultivars vary in their susceptibility to flower stalk development depending on climatic conditions and their genetic background (Shimeles, A., 2000).

For the supply of seeds, the informal sector is playing a significant role in outreaching a large number of farmers. Most of the demand for onion seeds is either met by local supplies through an unorganized market system or imported seeds through an informal trend. The formal sector, Ethiopian Seed Enterprise (ESE), is not generally supplying onion seed. Most amounts are catered for small-scale irrigation users by public sector organizations such as the Ethiopian Institute of Agricultural Research (EIAR)-Werer Agricultural Research Center as pre-scaling out activities (Nigussie A. *et al.* 2015). Therefore, this research seeks to demonstrate seed production technologies of onion in small-scale irrigation are of upper and middle awash.

MATERIAL AND METHODS

Description of the Study Area

The experiment was conducted at Beadamo and Bonta (Amibara district) and Sareweba and Gare-dima (Fentale district) of Afar and Oromia region, respectively in 2021 cropping season. Bedehamo and Bonta are located in the Afar National Regional State, Zone-3, Amibara district, which is 280 km in the north east of Addis Ababa. It is located at 9^{o} 60' N latitude and 40^{o} 9' E longitude with an altitude of 740 meter above sea level (m.a.s.l.). The mean annual temperature is 34 ^{O}C, while the mean annual rainfall and evapotranspiration are 560 and 2600 mm, respectively. The weather is very long hot and dry and rainfall is very erratic. Sareweba and Gare-dima are located in the Oromia National Regional State, East Shewa Zone, Fentale district, located at about 198 km East of Addis Ababa in the Great Rift Valley lies between 8 0 54' north latitude and 360 23' to 390 54' east longitude. The average annual rainfall is 486 mm. It has a yearly maximum temperature range from 32 to 42 degree centigrade while the minimum temperature ranges from 10 to 22 degree centigrade.

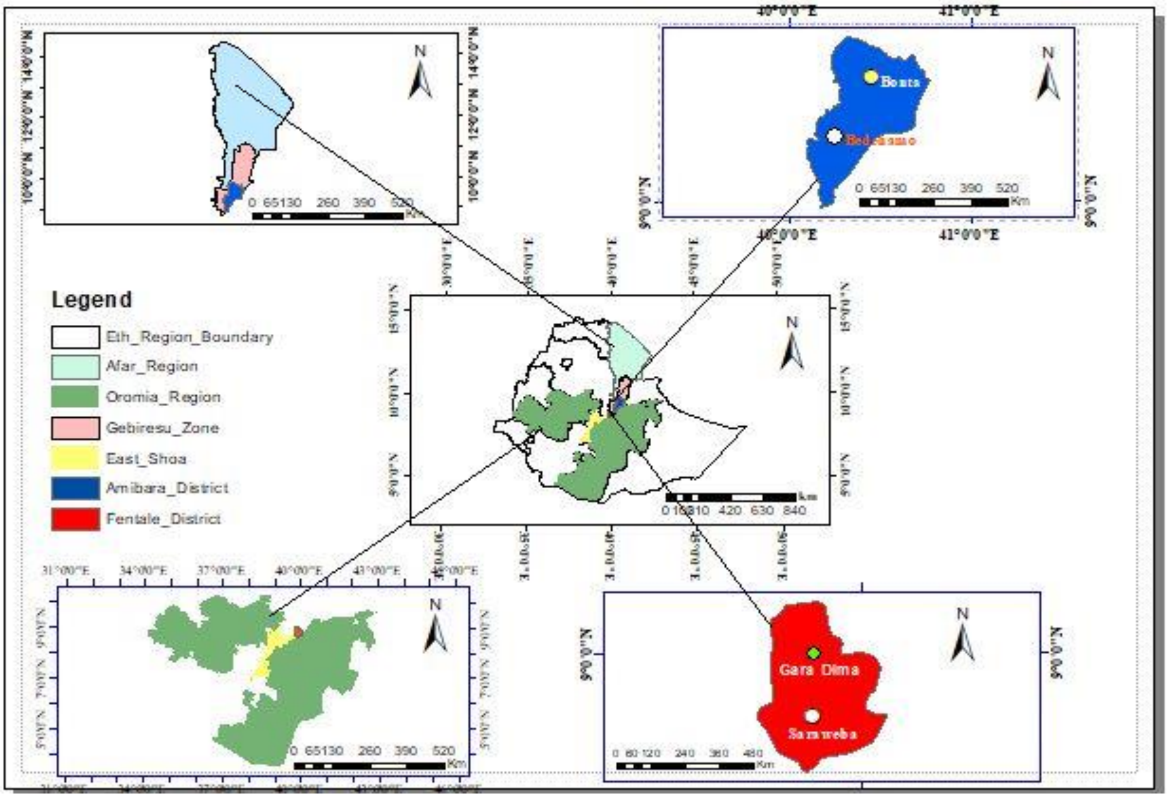

Figure 1: Location map of the study area

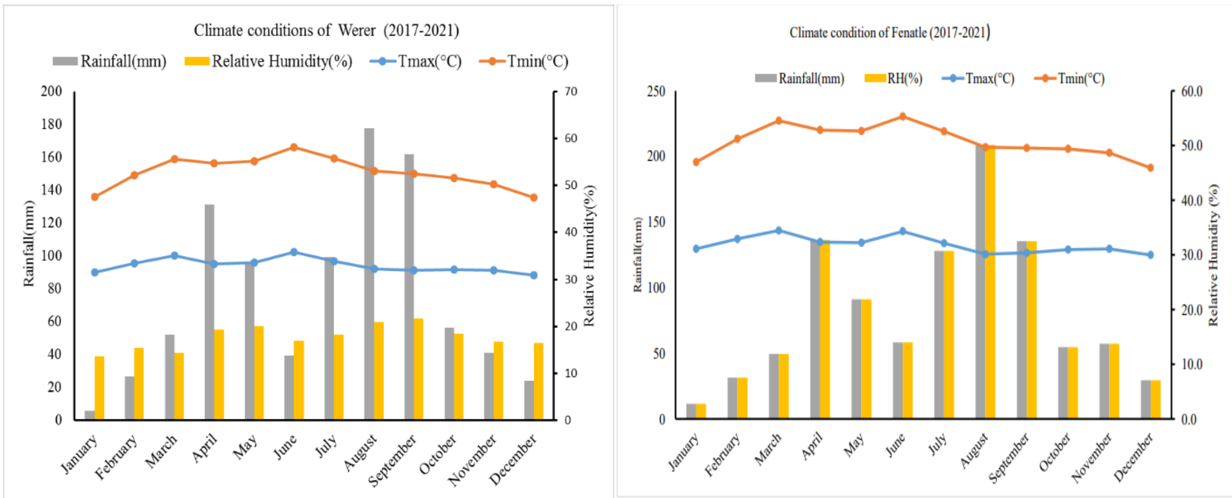

Figure 2: Climate condition of the study area

Participatory Research Group (PRG) Setup

The experiment was done on systematically selected agro-pastoralist. Participatory Research Group (PRG) was formed through the help of development agents and agricultural experts of the kebeles following the appropriate procedures involving innovative agro pastorals. The PRGs was had member of about ten agro-pastorals that include both men and women. Training was given to the PRG members, developments agents and agricultural experts of the districts about onion seed production techniques. All management practices were performed as per the research recommendation as per training. Finally, all PRG actors including agro pastoralists, researchers and development agents was let to collect seed and made their own evaluation and conclusion.

Field Experiment

The field experiment was laid out in single plot having the area of 10 by 10 m^2. Two released onion varieties: Nafis and Nafid were used in this experiment. The seed of each variety were sown on nursery bed for seed bulb production. The onion seedlings of the targeted varieties was transplanted to the field at 45-55 days after sowing in double rows of 40 x 20 x 5 cm, spacing which includes water furrows, rows on the bed and between plants, respectively.

The bulbs were harvested and replanted for breeder seed production in October at Werer Agricultural Research Centers after being stored for one month. Bulbs which were healthy, free from any mechanical and physiological defects, true-to-type and uniform bulbs of about 5cm diameter were selected for seed production and demonstration. Seed bulbs were planted in double rows of 50 x 30 x 20 cm spacing which includes water furrows, rows on the bed and between plants, respectively during the off-season by irrigation. The area will be divided into block/s of a 10m width and 10m length and the space between blocks were 1.5m.

NPS were applied at the rate of 242 kg ha^{-1} before transplanting and urea at the rate of 100 kg ha^{-1} were applied at side dressed in split application: 50% after 21 days of transplanting and the remain 50% at one and half month after transplanting. Irrigation was applied at the interval of every 5 days for the first 4 weeks and every 7 days then after (Lemma and Shimeles, 2003). Every standard cultural practice was followed regularly as recommended. Diseases and insect management practices were made according to the recommendations given for onion seed production in the country.

Harvesting was done when the umbel/head exposes some black seeds but before shattering by hand. After harvest, the heads were dried on canvas under ventilated shed or sun according to onion seed harvesting procedures.

Data Collection procedures

Data on yield and yield related traits were collected: planting date, Seed yield $plot^{-1}$ and hectare, number of stake $plant^{-1}$, stakes diameter (cm), length of main stake (cm), number of umbels $plant^{-1}$.

Statistical Analysis

Collected data were used to carry out Analysis of independent two sample t-test using SAS software, version 9.0 (SAS Institute Inc., 2002). Mean comparison were computed by comparing of the mean of one sample with the mean of another sample to see if there was a statistically significant difference between the two varieties at 95% of confidence interval.

RESULT AND DISCUSSION

Yield and Yield-Related Parameters

Seed Yield Performance:

The yield performance of demonstrated onion varieties were illustrated in figure 3 and 4 for Amibara and Fentale districts, respectively. An independent-samples t-test was conducted to compare the performance of average yield differences between the two varieties (Table 1). There was a significant difference in the average seed yield for Nafis variety (M=10.72 q ha^{-1}, SD=0.78) and Nafid variety (M=9.17 q ha^{-1}, SD=0.59); t (18) = -5, p = <0.0001. This result suggests that Nafis variety really does have an advantage of 1.55 q ha^{-1} seed yield over Nafid variety. Specifically, it suggests that when agro-pastoralists produce onion seed, Nafis variety increase their yields. The difference in seed yield might have been due to the genetic differences. The current result was in line with the result of S. Ahmed *et al*., (2020) in which significant variation in respect of seed yield per hectare (kg) of two varieties of onion were identified. That was the variety Kalash Nagari, which gave a significantly higher seed yield per hectare (630 kg ha-[1]) in comparison to the variety Taherpuri (270 kg ha-[1]).

Similarly, an independent-samples t-test was conducted to compare the yield differences of the two varieties across the two locations (Table 1). Accordingly, there was non-significant difference in the yield of both Nafid and Nafis varieties at Amibara districts (M=9.79 q ha^{-1}, SD=0.99) and Fentale districts (M=10.11 q ha^{-1}, SD=1.12); t (18) = -0.67, p = 0.51. This result suggests that there is no statically difference between the two locations and the only difference between the two varieties were independent of locations that perhaps either due to the similarity of agro ecology of the two locations or the adaptability of varieties to a wide range of environmental conditions (Tesfaye et al. 218 and Khokhar et al, 1990).

Table 1: T-test of yield difference among the varieties and locations

t-test of variety difference							
Statistics							
Variety			**N**	**Mean** (q ha^{-1})	**SD**	**SE**	
Nafid			10	9.17	0.59	0.19	
Nafis			10	10.72	0.78	0.25	
Equality of Variance							
F value				**Sig**			
1.76				0.41			
t-test for equality of Means							
Method	**t**	**Df**	**Sig (2 tailed)**	**Mean Diff** (q ha^{-1})	**SE Diff**	**95% CI of Diff**	
						Lower	**Upper**
Pooled	-5	18	< 0.0001	-1.55	0.3	-2.2	-0.9
Satterthwaite	-5	16.7	0.0001				

t-test of location difference						
Statistics						
Districts		**N**	**Mean** (q ha^{-1})	**SD**	**SE**	
Amibara		10	9.79	0.99	0.32	
Fentale		10	10.11	1.12	0.35	
Equality of Variance						
F value			**Sig**			
1.26			0.74			
t-test for equality of Means						
t	**Df**	**Sig (2 tailed)**	**Mean Diff** (q ha^{-1})	**SE Diff**	**95% CI of Diff**	
					Lower	**Upper**
-0.67	18	0.51	-0.32	0.47	-1.31	0.68
-0.67	17.8	0.51				

Yield Related Parameters

The most important components for onion seed production were presented in Table 2. These are number of stalks per plant, length of main stalk, number of umbels per plant, number of flowers per umbel, umbel diameter, number of seed per ample, seed yield per umbel, seed yield per plant, and stalk diameter.

Number of Stalk Per Plant:
The analysis of independent sample t-test indicates that the number of stalks per plant significantly differs. It ranges from 3 to 6 with an average of 4.2 for variety Nafid and 4 to 6 with an average of 5.1 for variety Nafis. The overall means for number of stalks per plant was 4.6. This study in line with the study Asaduzzaman *et al,* 2012 that revealed that the number of flowering stalks per plant was significantly high (3.63) in the large sized bulb (15±2g) whereas the minimum (2.45) in small sized bulb 5±2g

Length of Main Stalk (cm):
The analysis of independent sample t-test showed significantly higher length of main stalks 45cm over variety Nafid and 64cm over variety Nafis. The overall mean for length of main stalk was 59.65 cm. This result in line with the result of Pushpendra S. *et al.,* 2017 in which plant height varied from 41.7 to 53.4 cm with an overall mean 47.67.

Number of Umbels Per Plant:
The mean number of umbels per plant was lowest (3) and while it was highest (13) for Nafid variety. Similarly, the highest and lowest of number of umbels per plant were 5 and 11 for Nafis variety with overall mean of (7.2). The current finding is in line with the work of Geetharani and Ponnuswamy (2007) and Ashrafuzzaman *et al*. (2009) on onion plants in which large bulbs may contain higher food reserves and be responsible for the higher number of flowering stalks per plant.

Number of Flowers Per Umbel:
Both varieties were significantly different from each other by mean numbers of flowers per umbel. Nafis variety was produced the highest (395.80) mean numbers of flowers per umbel while the lowest mean numbers of flowers per umbel (285.80) were observed by variety Nafid with an overall mean of 340.80.

Stalk Diameter:
The lowest mean flower stalk diameter (1.16 cm) was achieved for variety Nafid which was statistically similar to the highest mean flower stalk diameter (1.19 cm) of Nafis.. The finding is similar to the results of Pandey *et al.* (1994) who obtained larger flower stalk diameter from wider intra-row spacing.

Umbel Diameter:
The mean umbel diameter was significantly differing and it ranged from 1.9 cm to 3.6 cm for variety Nafid and 2.5 cm to 4.2 cm for variety Nafis with an overall mean of 2.78 cm. The highest umbel diameter (3.04 cm) was recorded from Nafis variety and was significantly different from Nafid variety which was lowest (2.52 cm). this result was in line with the result of Mollah *et al.* (2015) recorded umbel diameter with a range of 6.9 cm to 3.0 cm. Teshome *et al.* (2014) also reported umbel diameter with a range of 6.0 cm to 4.8 cm.

Number of Seed Per Umbel:

The two varieties were showed significantly difference in number of seeds per umbel. The mean number of seeds per umbel ranged from 182 to 280 over variety Nafis. On the other hand, minimum mean number of seeds per umbel 100 to 222 was recorded from variety Nafid with an average of 199.55. Similar with current finding Teshome *et al*. (2014) reported 515.3 to 256.6 seeds per umbel. Likewise, Mollah *et al*. (2015) reported 299.9 to 93.0 seeds per umbel in Bangladesh. The low mean number of seed per umbel may due to high temperature during flowering resulted in flower abortions and hence lower seed yield. So, selection of appropriate months in a given locality is crucial in onion seed production. Teshome *et al*. (2014) reported that, variation in number of seeds per umbel might be due to flower abortion caused by high temperature, lack of efficient pollinators of all the flowers in the umbel, shortage of nutrition which caused high competition and death of the weak florets in the umbel.

Seed Yield Per Umbel:

Seed yield per umbel was highly significantly differ ($p \leq 0.05$) on the two varieties. The maximum and minimum mean seed weights per umbel were recorded 3.38 g and 0.67 g, respectively from Nafid variety whereas the highest and lowest weights of seed per umbel were recorded 2.99 g and 1.25 g, respectively from variety Nafis.

Seed Yield Per Plant:

The average seed yield per plant ranged from 5.08 g to 15.18 g over variety Nafid while the maximum and minimum average number of seeds per plant of 7.80 g and 11.62 g over variety Nafis with an average of 9.08 g. Asaduzzaman et al. (2012) also described those larger-sized bulbs (20±1 g) and broader arrangement (25 × 20 cm) brings about in higher seed yield per plant (3.78 g). Bulb size and plant spacing are serious factors in generating quality onion seeds (Mirshekari and Mobasher, 2006).

Table 2: Mean performance of yield and yield related traits of two varieties over the study area

Variety	Location	NSP	SD	LMS	NUP	NFU	UD	NSU	SYU	SYP
Nafid	Amibara	4.20	1.12	55.20	6.60	280.40	2.58	180.80	1.49	8.45
	Fentale	4.00	1.20	57.60	6.80	291.20	2.46	178.20	1.66	8.04
	Mean	4.10	1.16	56.40	6.70	285.80	2.52	179.50	1.58	8.25
	SD	0.99	0.22	6.26	3.27	98.53	0.57	37.40	0.78	2.88
	SE	0.31	0.07	1.98	1.03	31.16	0.18	11.83	0.25	0.91
	Min	3.00	0.90	45.00	3.00	120.00	1.90	100.00	0.67	5.08
	Max	6.00	1.50	64.00	13.00	490.00	3.60	222.00	3.38	15.18
Nafis	Amibara	5.00	1.14	63.40	7.80	389.40	3.14	220.00	2.22	9.86
	Fentale	5.20	1.24	62.40	7.60	402.20	2.94	219.20	2.35	9.98
	Mean	5.10	1.19	62.90	7.70	395.80	3.04	219.60	2.29	9.92
	SD	0.88	0.19	5.86	2.11	53.97	0.51	34.82	0.70	1.11
	SE	0.28	0.06	1.85	0.67	17.07	0.16	11.01	0.22	0.35
	Min	4.00	1.00	56.00	5.00	296.00	2.50	182.00	1.25	7.80
	Max	6.00	1.60	71.00	11.00	475.00	4.20	280.00	2.99	11.62
Overall Mean		**4.60**	**1.18**	**59.65**	**7.20**	**340.80**	**2.78**	**199.55**	**1.93**	**9.08**
Diff (1-2) Mean		-1.00	-0.03	-6.50	-1.00	-110.00	-0.52	-40.10	-0.71	-1.68

N	10	10	10	10	10	10	10	10	10
DF	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	11.60
t-value	-2.39	-0.32	-2.40	-0.81	-3.10	-2.16	-2.48	-2.15	-1.72
Sig. (2 tail)	0.03	0.75	0.03	0.43	0.01	0.04	0.02	0.05	0.11
F-value	1.29	1.35	1.14	2.40	3.33	1.27	1.15	1.24	6.73
Sig.	0.71	0.66	0.85	0.21	0.09	0.73	0.84	0.76	0.01

SC=Stand Count at harvest, SNP= Number of Stalk plant-1, LMS= Length of main stalk (cm), NUP=Number of umbels plant^{-1}, NFU= Number of flowers umble^{-1}, UD= Umbel diameter (cm), NSU=Number of seed umple^{-1}, SYU= Seed yield umble^{-1}(gm), SYP= Seed yield plant^{-1}(gm), and SD= Stalk diameter (cm)

Training of Farmers and Das on Improved Production Packages

Training participants consisted of agro pastorals and developmental agents from two kebeles of each Amibara and Fentale districts. A total of 40 agro pastorals composed of booth females and males 4 developmental agents were participated in the training conducted on improved onion seed production packages (Figure 5 and 6).

The training was conducted at different time: prior to planting theoretical training were given on onion seed production and through all production periods (at planting, field management, harvesting and seed grading.

The report revealed that the training actually had an immense, positive impact on small scale agro-pastoralists the results indicated that of the agro-pastoralists at Fentale district that already had pragmatic knowledge of onion seed production showing their performance more than double that of Amibara district, this is reflecting an achievement of the training goal. The agro-pastoralists of both districts finally reflect on the following topics:

Time of Planting:

Timely planting is very much essential for onion seed production. Timely planted crop can achieve good vegetative growth and will get sufficient period for seed set before onset of high temperature, so the crop must be planted during September 1st.

Varieties:

Nafid and Nafis varieties are suitable for both districts in addition to Adama red and Bombe red varieties which are currently under production.

Weed Management:

In onion seed production hand weeding is better than any others. The agro-pastoralists were understood that weeding during bolting is not recommended so that destroys the bolting one.

Harvesting, Grading and Seed Treatment:

Farmers were exercised seed harvesting and grading techniques for the first time. It was done when the umbel/head exposes some black seeds but before shattering by hand. After harvest, the heads were dried on piece of clothes under open ventilated shed.

Carefully clip the stalks a few inches (8 cm.) below the head and place them in a sacs bag. Set the sac in a cool, dry place for a week to dry. When the heads were completely dry, it was shaken vigorously within the sac to release the seeds. The fine sieve was used to retain the seeds from the dust to sort the seeds. Then the seeds were poured in cold water and stirred. The fertilized seeds were showed heavier than unfertilized seed, so they will sink. All empty ones and the debris that float was removed. Then immediately dry the good seeds on a plate.

In general, the attitude of agro pastoralists who engaged in onion seed production thinks it was difficult and complex work. Finally, there was a strong sense of appreciation articulated by the participants about being participated for the onion seed production training. Participants were very engaged and excited about what they learn about best all onion seed production practices, they highlighted that onion production is their lifeline as cash crop, they urged that future training be done often and should include more practical classes. Participants responded very positively throughout the training, and expressed a strong desire to enhance their skills in best onion seed production practices.

Fig.5: Pastorals and DA training at Amibara districts

Fig.6 Pastorals and DA training at Fentale districts

Field Performance of Onion Seed Production at Amibara and Fentale Districts

Productivity of any crop is a good indicator of the land conditions, since it directly reflects the difference in the quality and limitations of the land. The main objective of field management for farming is to generate favorable conditions for good crop growth, emergence, root growth, plant development, seed formation and harvesting period. Accordingly, the performance of the community-based onion seed productions was indicated in figure 5 and 6.

Land Preparation:

Land preparation is the first operation in ensuring that crops can achieve the best yields. Unfortunately, at the time of field preparation in the Fentale district the farmers were under the pressure of society leaders as they are ordered to produce only irrigated wheat. In addition, these practices are a burden for small-scale farmers that have to prepare seed beds manually with backward tools.

Crop Management:

Several crop managements determine a crop's field performance, including planting, irrigation and weeding. Adequate planting spacing is crucial for the development of the plant but in both locations the population of the onion decreased time to time due to bulb rotting and damage due to weeding managements.

Fig.3: Community based onion seed production at Amibara districts

Fig.4: Community based onion seed production at Fentale districts

CONCLUSION AND RECOMMENDATION

Conclusion

The finding showed significant differences between the two varieties in terms of yield and yield components: yield ha^{-1}, number of stalks per plant, length of main stalk, number of umbels per plant, number of flowers per umbel, umbel diameter, number of seeds per ample, seed yield per umbel, seed yield per plant, and stalk diameter. The result also indicates that there was a significant difference in the average seed yield of varieties Nafis (10.72 q ha^{-1}) and Nafid (9.17 q ha^{-1}) and that the Nafis variety really does have an advantage of 1.55 q ha^{-1} seed yield over the Nafid variety. Therefore, it can be concluded that the use of the improved onion variety for agro-pastoralists need to produce onion seed, the Nafis variety was recommended to increase their yields. Finally, the district administration; The head of the district agriculture office, experts and agro-pastoralist said that the experiences they have seen are viable and good, so they will work hard to spread it in other kebeles of both districts.

Recommendation

Community-based seed multiplication, as a modality important for technology delivery, provides all management practices for seed production and crop diversification; the introduction of newly improved and high-yielding varieties; opportunities for market integration; and experience sharing. Therefore, this type of community-based seed multiplication should be continued as it is important to agro-pastoralists and farmers on transfer knowledge on onion seed production system.

The government of Ethiopia has been working to enhance wheat import substitution by intensifying domestic wheat production in various parts of the country. As the government teaches the summer wheat production, other crop production was neglected. Therefore, the district experts have to be accepted and informed the farmers about the small-scale onion and other crop production.

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Data Collection Procedures for Selected Horticultural Crops Prepared for Junior Researchers

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Abstract:
The document you are going to cover during this reading time is known as data collection procedures for selected horticultural crops that implemented under horticultural crop research division of Werer research center. It is the document which teach you how to prepare data collection procedures, data sheet and basic knowledge you have obtained during field observation, and come up with scientific conclusion that bring some benefits to your society. Many junior researchers do not fully understand the way in which data collection procedures are plan and conducted data collection to generate very simple information that can be understood by ordinary peoples. The paper contains data collection procedures with its important descriptions. Therefore, these materials are intended to help junior researchers assigned to horticultural research division. I hope it will prove a valuable contribution in data collection procedures and skill of junior researchers and I encourage the reader to provide constructive feedback in order to move this integration forward.

INTRODUCTION

Statistics concerns itself mainly with conclusions and predictions resulting from chance outcomes that occur in carefully planned experiments or investigations. The objective of statistical inference is to draw conclusions about a population using a sample from that population. Most of the methods that are used in statistics and in experiments assume that random samples are used (Montgomery, 1991). The values of the statistics will vary from sample to sample. Values we estimate from samples are called statistics while corresponding values of the population are known as population parameters. The population mean, is a fixed value, while its estimates from a sample of size n, the sample means vary from sample to sample. The same is true for the population variance, standard deviation, and range. Statistics obtained from samples vary from sample to sample. If the population contains N elements and a sample of n of them is to be selected, then if each of the N! /[(N-n)! n!] Possible samples have an equal probability of being chosen, the procedure employed is called random sampling (Montgomery, 1991).

A population is the whole set of measurements or counts about which we want to draw conclusion. Populations are described by characteristics called parameters and parameters are fixed values. If only one variable is of interest, the population can be called as a univariate. For example, the heights of all male students in universities form a univariate population. Notice that a population is a set of measurements, not the individuals or objects on which the measurements or counts are made. A sample is a sub set of a population, a set of some of the measurements or counts that comprises the population. Samples are described by sample statistics. We calculate sample statistics to estimate population parameters. The essential nature of a sample is that it should be representative. This means that a sample should be a small-scale replica of the population that might affect the conclusion of the study. Accuracy and precision are used synonymously in everyday speech, but in statistics they are defined more rigorously. Precision is the closeness of repeated measurements and accuracy is the closeness of a measured or computed value to its true value. Therefore, developing data collection procedures for horticultural crops including vegetables, fruits and root and tuber crops are a pre-requisite for the newly employed junior researchers. I hope that this paper data collection procedures for horticultural crops. is used for researchers in adopting uniform definitions of data procedures and, thereby, enable them to generate a standardized, authentic and uniform data so that a sound database networking may be developed for exchange and utilization of information.

ONION DATA COLLECTION PROCEDURES

Background

Onion (*Allium cepa* L.) is a vegetable crop of major commercial importance though out the world. Onion is a recent introduction in the country but rapidly becoming a popular vegetable crop among consumers (FAO & WARC, 2006). In Ethiopia there are different agro-ecologies suitable for growing of onion. However, the production is concentrated to the central rift valley of the country (WARC, 2006).

1. **Bulb Dry Weight (BDW):** the average dry matter weight of the mature bulb expressed in grams.
2. **Days to Maturity (DTM):** the actual number of days from seedling emergence to a day at which more than 90% of the plants attained physiological maturity.
3. **Total Soluble Solids (TSS):** the amount of total soluble solids present in the bulb will be estimated using refractometer Bellingham and Stanley limited, UK (model 60/70) and expressed as percentage.
4. **Days to bolting:** Number of days when 50% of flower shoots appeared in cultivars
5. **Days to flowering:** Number of days when 50% the inflorescence showed open flowers.
6. **Days to harvest:** Number of days from planting to last date of seed harvest
7. **Fresh Weight above Ground (FWAG):** the total fresh weight of above ground biomass of physiologically mature plant recorded in grams.
8. **Dry Weight above Ground (DWAG):** the total dry weight of aboveground biomass of physiologically mature plant recorded in grams.
9. **Germination percentage**: The number of germinated seeds from 100 seeds raised on a petridish.
10. **Neck diameter (ND):** average thickness measured at the narrowed point and expressed in cm.
11. **Bulb length (BL):** the height of the mature bulb measured in cm.
12. **Bulb diameter (BD):** the average size measured at the widest point in the middle portion of the bulb and expressed in cm.
13. **Number of cloves per bulb (CB):** the total number of cloves per plant counted after harvest.
14. **Weight of cloves (WC):** the average weight of cloves measured in grams.
15. **Number of seeds per umbel**: This will be calculated as followes =seed yield/plant X 1000seeds/1000seed weight and divided by number of flower stalks per plant
16. **Plant height (PH):** the height measured in cm from the ground level to the top of the mature leaf.
17. **Number of leaves per plant (NLPP):** the total number of healthy leaves taken at physiological maturity.
18. **Leaf diameter (LD):** the diameter of the longest leaf measured by caliper at maturity and expressed in cm.

19. **Leaf length (LL):** the average length of the longest leaf expressed in cm at physiological maturity.
20. **Plant Height (PH):** the distance measured in cm from the soil surface to the tip of the mature leaf in the plant.
21. **Leaves per Plant (LP):** total number of leaves per plant recorded at physiological maturity.
22. **Leaf Length (LL)**: the average length of the longest leaf expressed in cm at physiological maturity.
23. **Leaf Diameter (LD**): the diameter of the longest leaf at the time of maturity expressed in cm.
24. **Neck Thickness (NT):** average wall thickness measured at the narrowest point expressed in cm.
25. **Bulb Length (BL):** the height of the mature bulb measured in cm.
26. **Bulb Diameter (BD):** the average size measured at the widest point in the middle portion of the mature bulb expressed in cm.
27. **Yield Per Plant (YPP):** the average weight of mature bulb expressed in gram.
28. **Biological Yield Per Plant (BYPP):** the total yield at the time of maturity expressed in grams
29. **Harvest Index Per Plant (HIPP):** the ratio of mature bulb yield per plant to the biological yield expressed in grams.
30. **Seed yield/plant:** The weight taken in grams from 5 plants
31. **Thousand seed weight:** Estimate will be based on average weight of 250 seeds drawn randomly from the bulked seeds of five plants in each replication.
32. **Total number of flower stalks per plot and per plant**: All number of flower stalks with seed heads and aborted flowers in each plot and the average number of flower stalks/ plant counted at first harvest
33. **No. of flowers /umbel:** The mean number of flowers on an umbel counted at full flowering from 5 plants /plot
34. **Flower stalk height**: Height measured in centimeter from the bulb to the umbel.
35. **Total seed yield/plot:** The sum of seed yield of all harvest.
36. **Umbel diameter in (cm):** Diameter of the inflorescence at full flowering measured in centimeter using vernier caliper.
37. **Weight and number of cloves by size category (WCC):** weight of cloves categorized as heavy, medium and lightweight, expressed in grams.
38. **Yield per plant (YPP):** the average weight of mature bulb expressed in grams.
39. **Biological yield per plant (BYPP):** the total yield at the time of maturity expressed in grams.
40. **Harvest index per plant (HIPP):** the ratio of total bulb yield per plant to the biological yield expressed in percentage.
41. **Dry weight above ground (DWAG):** the total dry weight of above ground biomass of physiologically mature plant recorded in grams.
42. **Bulb dry weight (BDW):** the average dry matter weight of the mature bulb after being oven dried at 80 oC for 48 hours and expressed in grams.
43. **Days to maturity (DTM):** the actual number of days from planting to a day at which more than 90% of the plants attained physiological maturity.

SHALOT DATA COLLECTION PROCEDURES

Background

Shallot (Alliums cepa var. aggregatum Don; Syn: Allium cepa varascalonicum, Backer) belongs to the genus Allium and family Alliaceae. The genus Allium is distributed from the tropics to subarctic belt, but a region of high species diversity stretches from the Mediterranean basin to Central Asia and Pakistan (Fritsch and Friesen, 2002). As shallot and its relative species are generally open pollinated crops and have cultivated for long time, a number of land races and natural hybrids either intraspecific or interspecific probably are to be on the increase (Arifin and Okubo, 1996). The majority of shallot genotypes are clonally propagated, even where seed production is possible, to maintain the unique quality traits and population homogeneity of highly heterogeneous plant (Currah and Proctor, 1990).

1. **Plant height (PH):** the distance measured in cm from the ground level to the top of matured leaf.
2. **Number of leaves per plant (NLPP):** total number of leaves taken at physiological maturity.
3. **Leaf diameter (LD):** the diameter of the longest leaf taken at maturity. It will be measured using caliper and expressed in cm.
4. **Number of lateral branches per plant (NLBP):** the total number of lateral growths per plant and taken at physiological maturity.
5. **Number of bulb splits per plant (NSPP):** the total number of bulblets per plant counted after harvest.
6. **Days to maturity (DTM):** taken as the actual number of days from emergence to 90 percent of the plants attained physiological maturity.
7. **Bulb diameter (BD):** the average size of bulbs measured at the widest point (middle portion) of matured bulb; it will be measured using caliper and expressed in cm.
8. **Total yield per plant (TYPP):** the average weight of matured bulb expressed in grams.
9. **Marketable yield per plant (MYPP):** recorded as the average weight of matured bulbs greater than 20 mm in diameter.
10. **Biological yield per plant (BYPP):** recorded as the total bulb yield, above ground parts and roots at the time of maturity expressed in gram.
11. **Harvest index per plant (HIPP):** expressed as the ratio of total bulb yield per plant to the biological yield in percentage.
12. **Bulb dry weight (BDW):** the average dry weight of the mature bulbs after oven dries for 12 hours at 110 degrees Centigrade and expressed in gram.
13. **Total soluble solid (TSS):** the amount of total soluble solids presents in the bulb, recorded from the juice of sample bulbs estimated using hand refractometer and values expressed in percent.
14. **Pungency (PCY):** bulbs will be evaluated for pungency by measuring enzymatically produced pyruvic acid and values will be expressed in μ mole pyruvic acid g-1 fresh weight.
15. Fresh **bulb weight (kg):** Fresh weight of bulbs will be taken immediately after harvesting and cutting the tops for bulbs that did not receive curing treatment and after curing for those that received curing treatment.
16. **Skin thickness (mm):** In order to determine skin thickness 30 bulbs (10 bulbs each representing small, medium, and large bulbs) will be taken from each plot. Change in the skin thickness will be measured using a digital calliper (FOWLER Sylvac 107884) in a biweekly interval and the difference between the initial and successive measures will be used as a loss in skin thickness parameter.

17. **Dry matter (%):** A homogenate will be prepared from bulbs of each plot. For determination of percent dry matter 25g of the homogenate will be taken and oven dried (Wagtechn Gp/ 120/ SS/ 100/ DIG oven) at a temperature of 700C for 48 hrs. Then the weight will be measured using digital balance (METTLER TOLEDO) and percent dry matter will be calculated using a formula
DW= [(FW CW) - CW] [(DW CW) - CW] x 100 Where: DW= dry weight, CW=container weight, FW= fresh weight
18. **Total soluble solids (%):** The TSS will be determined using the procedures described by Will bekar et al. (1999). Aliquot juice will be extracted using a juice extractor and 50 ml of the slurry centrifuged for 15 minutes. The TSS will be determined by hand refractometer (ATAGO TC-1E) with a range of 0 to 320 Brix and resolutions of 0.20 Brix by placing 1 to 2 drops of clear juice on the prism, will behed with distilled water and dried with tissue paper before use. The refractometer will be standardized against distilled water (0% TSS)
19. **Weight loss of bulbs (%):** Determined using the methods described by Will bekar et al. (1999). The measurement will be based on the difference in weight of bulbs at the beginning and mid of each month of 30 bulbs (10 small, 10 medium, and 10 large sized) taken from each treatment randomly. The difference between the initial weight and successive weights gave the weight loss percentages. WL (%) = W x100 Wi i Wf Where, Wi = initial weight, Wf = final weight
20. **Number of bulbs sprouted (%):** Percentage of bulbs sprouted will be cumulative, which will be based on the number of bulbs sprouted in biweekly storage period. The incidence of sprouting will be ascertained by counting the number of bulbs sprouted at the beginning and mid of each month. The sprouted bulbs will be discarded after each biweekly count to avoid double counting. Bulbs that sprouted and rotted at the same time will be classified as sprouting.
21. **Number of rotten bulbs (%):** The measurement of percentage bulbs rotted will be cumulative and will be based on the number of bulbs rotted in biweekly storage period. The incidence of rotting will be determined by counting the number of bulbs rotted at the beginning and mid of each month. The rotted bulbs will be discarded after each biweekly count to avoid double counting. Type of organism that caused storage rot will be identified by culturing the rotten bulbs following the procedure described by Solomon (1985).

TOMATO DATA COLLECTION PROCEDURES

Background

Tomato (Lycopersicon esculentum) is an important short duration vegetable crop worldwide which belongs to family Solanaceae. It was originated from the wild plants which were first present in Andean states of Peru and Chile. Tomato is very healthy and nutritional crop because tomato is rich in vitamin A, B and C, amino acid, iron, minerals and phosphorus. Tomato plays very important role in bone growth, cell division, upholding surface linings of eyes, regulation of respiratory system and immune system. It is also useful in maintaining bones, capillaries and teeth. Tomato fruit is use as salads, cooked in sauces, soup and meat or fish dishes etc. [PAR, 2016].

Tomato Growth parameters measured included:

1. **Plant height (cm)** from the ground to the tip of the plant;
2. **Stem diameter (mm**) will be measured 10 cm from the ground and
3. **Internode lengths (cm),** measured between the trusses.

4. **Relative water content (RWC)** is the appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit.
5. **Leaf number (LN)**: The total numbers of leaves counted at weekly intervals starting from crop emergence till 50% of the plants got bloomed
6. **Plant height (PH)**: The heights (cm) of plants that received the respective treatments will be measured from the ground level to the highest point at blooming stage.
7. **Number of branches per plant (NBP)**: the number of primary and secondary branches of each plant of each treatment at blooming stage will be recorded.
8. **Height of branches per plant (HBP)**: mean height (cm) of primary lateral shoots of each plant of each treatment at blooming stage will be recorded.
9. **Leaf length (LL)**: the average length of three leaves (cm) from the upper, middle and lower part of the plant will be measured at blooming stage.
10. **Leaf width (LW)**: the average size of three leaves (cm) at the widest point from the upper, middle and lower part of the plant will be measured at blooming stage.
11. **Days to 50% flowering (DF)**: This will be recorded when approximately 50% of the flower clusters on the plant had some flowers that will be in bloom.
12. **Days to maturity (DM)**: This will be recorded when approximately 70% of the plants had attained physiological maturity.
13. **Number of clusters per plant (CP)**: the number of clusters per plant counted at physiological maturity.
14. **Number of fruits per cluster (FC)**: the total numbers of fruits per cluster counted at physiological maturity.
15. **Total number/weight of fruits**: this is the sum total number/weight of fruits of successive harvests (eight harvests).
16. **Marketable and unmarketable fruit number and weight**: at each harvest, fruits will be categorized as marketable and unmarketable fruits of each treatment. Fruits, which will be cracked, damaged by insect, diseases, birds and sunburn, etc. will be considered as unmarketable fruits while fruits, which will be free of damage, will be considered as marketable.
17. **Fruit size:** diagonal section of the fruit measured by caliper
18. **Fruit volume**: ten randomly selected fruits from ten plants in a plot will be taken and floated in a water jar and their displacement will be recorded. Average fruit volume will be taken by subtracting the initial water level in the jar from the final and by the number of fruits immersed.
19. **Fruit juice content** the juice content of tomato will be extracted using a juice extractor (Kenwood). The intact tomato weight will be recorded prior to juice extraction. After extraction, extracted juice will be measured using a graduated glass cylinder and expressed in milliliter of juice per kilogram of fruit weight (ml/kg).
20. **Weight Loss (WL)** Weight loss (WL) will be determined using the methods described by Pirouani et al. (1997) and will bekar et al. (1999). The percentage weight loss will be calculated for each sampling interval using the formula given below and the cumulative WL will be expressed as percentage for the respective treatments.

$$WL\ (\%) = \frac{W_i - W_f}{W_i}\ x\ 100$$

Where, W_i = initial weight W_f = Final weight

Tomato Chemical Analysis

21. **Total Soluble Solids (TSS**): The TSS will be determined following the procedures described by Will bekar et al. (1999). An aliquot of juice will be extracted using a juice extractor (Type 6001x, USA). An Atago N, hand refractometer with a range of 0 to 32°Brix and resolutions of 0.2°Brix will be used to determine TSS by placing 1 to 2 drops of clear juice on the prism. Between samples the prism of the refractor meter will be beheld with distilled water and dried with tissue paper before use. The refractometer will be standardized against distilled water (0 percent TSS).
22. **Ascorbic Acid Analysis (AA)** The ascorbic acid content of the fruits will be determined by the 2, 6-dichlorophenol indophenols method (AOAC, 1970). The aliquot of 10 ml tomato juice will be diluted to 50 ml with 3 percent metaphosphoric acid in a 50 ml volumetric flask. The aliquot will be titrated with the standard dye to a pink end point (persisting for 15 second). The ascorbic acid content will be calculated from the titration value, dye factor and volume of the sample.

$$Ascorbic\ acid\ (mg\ ascorbic\ acid\ /100g) = \frac{Titre\ x\ dye\ \ factor\ \ x\ volume\ made\ up}{Volume\ of\ \ sample}\ x\ 100\%$$

23. **pH and Titratable Acidity (TA)** Tomato juice will be extracted from the sample with a juice extractor (Type 6001x, USA) and clear juice will be used for the analysis. An aliquot of juice will be extracted according to Nunes and Enond (1999). The pH value of the tomato juice will be measured with a pH meter. The TA of tomato will be measured according to the methods described by Maul et al. (2000). The titratable acidity expressed as percent citric acid, will be obtained by titrating 10 ml of tomato juice to pH 8.2 with 0.1N NaOH. The TA will be calculated from the following formula

$$TA\ (\%) = \frac{Titre\ \ x\ \ 0.1N\ \ NaOH\ \ x\ \ 0.67}{1000}\ x\ 100$$

24. **Sugar Analysis** Reducing and total sugars will be estimated by using the techniques of Somogyi et al. (1945) as cited by Tilahun (2002). Clear juice (10 ml) will be added to 15 ml of 80 percent ethanol, mixed and heated in a boiling water bath until the ethanol odor goes off. After extraction, 1ml of saturated Pb $(CH_3COO)_2.3H_2O$ and 1.5 ml of $NaHPO_4$ will be added and the contents will be mixed by gentle shaking. After filtration, the extract will be made up to 50 ml with distilled water. An aliquot of 1ml extract will be diluted to 25 ml with 1ml copper reagent in a test tube and heated for 20 minutes in a boiling water bath. After heating, the contents will be cooled under running tap water without shaking. Arsenomolybdate color reagent (1 ml) will be added, mixed, made up to 10 ml with distilled water and left for about 10 minutes to allow color development, after which the absorbance will be determined by a spectrophotometer at 540 nm in a Jenway model 6100 spectrophotometer. For total sugar determination, sugar will be first hydrolyzed with 1N HCl by heating at 70°C for 30 minutes. After hydrolysis, total sugar will be determined following the same procedure employed for the reducing sugar. A blank will be prepared using distilled water.

$$\text{Re}ducing\ or\ \ total\ \ sugars = \frac{1}{Slope}\ x\ \frac{Sample\ ABS\ \ O.D}{Weight\ of\ \ sample}\ x\ \frac{Volume\ made\ up}{aliquant\ taken}\ x\ \frac{1}{1000}$$

Where,
Slope = 0.00148
ABS = absorbance of sample
Subjective quality analysis

The marketable quality of tomato fruits will be subjectively assessed according to Mohammed et al. (1999). The descriptive quality attributes will be determined by observing the level of visible mould growth, decay, shriveling or dehydration and the surface appearance characteristics such as smoothness and shine of the fruits. The percentage of marketable fruits during storage will be calculated as follows

$$Marketable\ tomato\ fruits\ (\%) = \frac{Number\ of\ marketable\ tomato\ fruits}{Total\ number\ of\ tomato\ fruits}\ x\ 100$$

Identification of Dominant Decay Microorganisms
Microbiological identification and determination of infection level will be carried out on every sampling date. Dominant microorganisms causing post-harvest decay of tomato fruits will be determined. Fungi will be isolated in a general-purpose medium potato dextrose agar (PDA) and will be identified based on colony and microscopic characters. Isolation of bacteria will be carried out on yeast extract dextrose calcium carbonate (YDC) medium. The population of microorganisms will be determined on a 1-4 rating scale, where 1 refers to low microbial population and 4 refers to very high population.

PEPPER DATA COLLECTION PROCEDURES

Background
Pepper (Capsicum spp) is a new world crop that belongs to the Solanaceae family. The genus Capsicum is the second most important vegetable crop of the family after tomato (Rubatzky and Yamaguchi, 1997). Pepper is a dicotyledonous woody perennial small shrub in suitable climatic conditions, living for a decade or more in the tropics. It is with erect sometimes prostrate growth habit that may vary in certain characteristics depending on type of species (Bosland and Votava, 1999).

Growth Characters

1. **Plant height (cm):** Plant height measurement will be made from the soil surface to the top most growth points of above ground plant part. The measurement will be taken as the length from nine plants of central rows of each plot at the last harvesting time.
2. **Days to 50% flowering:** Is the number of days where 50% of the selected plants started blooming beginning from the days of transplanting.
3. **Number of flowers per plant**: The number of flowers of the nine sample plants at 100% flowering stage from each plot will be counted.
4. **Days to first harvest:** The number of days from transplanting to the date of first harvest will be recorded from nine sample plants selected from central rows.
5. **Canopy diameter (cm):** The mean values will be taken at fruit maturity at both locations by measuring diameter of the plant (North to South and East to West dimension of the above ground part of sample plants).
6. **Number of branches per stem**: Numbers of primary, secondary and tertiary branches per stem of randomly selected nine middle row plants at final harvest will be counted.

7. **Dry weight content per plant (g):** Mean values of the dry weight content (shoots and roots). The samples will be dried in an oven at 1050C until constant weight will be reached.

Yield And Yield Related Parameters

8. **Number of fruits per plant**: Mean number of red ripe fruits of individual plants from central rows for each plot at each harvest will be recorded.
9. **Average number of seed per pods:** Seeds of randomly picked ten marketable pods from sample plants will be counted and recorded.
10. **Seed weight (g):** Seed extracted from ten marketable pods will be weighed using sensitive balance and mean values will be calculated.
11. **Marketable yield (t/ha):** The marketable yield of nine sample plants will be determined at each harvesting by sorting dried fruits according to color, shape, shininess, firmness and size of the fruits. After drying, the dried marketable fruits will be separated, the weight of the respective categories will be recorded and converted to t/ha.
12. **Unmarketable yield (t/ha):** Is the yield which will be obtained by sorting the diseased, discolored, shrunken shape and small sized, totally unwanted pods by consumers from marketable dried pods will be recorded at each harvest and converted to t/ha.
13. **Total dry fruit yield (t/ha):** Weight of total (marketable and unmarketable) fruits harvested at each successive harvesting from the sample plants will be recorded and summed up to estimate yield per hectare.

Quality Parameters

14. **Fruit pericarp thickness (mm):** Pericarp of ten marketable fruits from each plot will be measured using venire caliper and mean values will be recorded.
15. **Fruit dry weight content (g):** of five plants from each plot will be taken. The samples will be dried in an oven at 1050C until constant weight will be reached.
16. **Fruit length (cm):** Length of ten marketable fruits from each plot for each variety will be measured at red and dried stage using venire caliper and mean values will be taken.
17. **Fruit diameter (cm):** Fruit wall will be measured from ten marketable fruits of sample plants from each plot at red ripe and dried stage using venire caliper and mean values will be recorded.

Disease Reaction

18. **Pest and Disease Incidence (%):** The number of infected plants will be considered and percentage of plants infected with bacterial wilt incidence estimated as suggested by Agrios (2005): Disease Incidence (%) = Number of infected plants per plot*100/ Total number of plants per variety

JUTEMALLOW DATA COLLECTION PROCEDURES

Background

Jute mallow *(Corchorus olitorius L)* consists of 50-60 species, of which about 30 are found in Africa (Schippers, 2002 and Kemei et.al, 1997) and used as a vegetable popularly in the world. It is the most frequently cultivated and most common species found in Africa. Africa is the primary centre of diversity of this genus, which occurs throughout the continent (Kemei et.al, 1997).

1. **Length of Plants (cm):** will be measured from the ground level to the tip of the stem.
2. **Length of roots (cm):** Will be measured from the ground level to the tip of root.
3. **Weight of fresh plants per plot (g):** will be measured without petioles in plot based.
4. **Fresh weight of leaves (g):** will be measured without petioles.

5. **Fresh weight of roots (g):** will be measured soon after harvest without any external particles.
6. **Dry weight of leaves (g):** dried in an oven at 105°c for 48 hours and then weighed.
7. **Dry weight of roots (g):** dried in an oven at 105°c for 48 hours and then weighed.
8. **Number of leaves per plant:** counting the whole leaves at consuming stage.
9. **Pigmentation on the stem:** will be estimated by looking to stem color
10. **Number of branches per plant:** will be counted at the end of the harvesting date.
11. **Pod yield (g):** the weight of all pods per plant.
12. **Number of pods per plant**: sum of the number of pods from all picking for a particular plant.
13. **Average pod weight (g):** obtained by dividing the pod yield per plant by the number of pods of that plant.
14. **Pod length (cm):** measured from the base of the pod (without including the calyx) to its apex.
15. **Pod diameter (cm):** measured by a Vernier at the base of the fruit.
16. **Number of seeds per pod:** samples of 10 mature pods will be taken from each plot. The pods will be longitudinally opened and the number of seeds in each pod will be counted.
17. **1000 – Seed weight (g):** samples from each plot of 1000 dry ripe seeds from each plot will be counted and weighed.
18. **Seed yield / unit area (kg / plot):** Total seed yield per plot
19. **Fresh leaves yield / unit area (kg / plot):** total leaf yield per plot

WATER MELON DATA COLLECTION PROCEDURES

Background

Watermelon belongs to the family Cucurbitaceae and the genus Citrullus and it's the only cultivated species of this genus (Bisognin, 2002). It is believed to have originated in Africa (Simmonds, 1979) but is now widely spread throughout the tropics and the Mediterranean (Tindall, 1983). Wild watermelon (Citrullus colocynthis) is a native of arid soils in Africa. Watermelon is thought to have been domesticated in Africa at least 4000 years ago and now grown worldwide, particularly in regions with long, hot summers (Robertson, 2004). Watermelon is one of the most widely cultivated crops in the world (*Huh et al.*, 2008). Its global consumption is greater than that of any other cucurbit. It accounts for 6.8% of the world area devoted to vegetable production (Guner and Wehner, 2004; Goreta *et al.*, 2005).

Reproductive Growth and Yield

1. **100 seed weighs:** weight of 100 seeds
2. **Fruit length**: average length of fruit longitudinal
3. **Fruit weight:** average weight of fruit
4. **Fruit girth:** average diameters using calipers
5. **Fruit number (Marketable and unmarketable):** total fruit number per plant
6. **Length of primary/ Main vine:** length from ground to the tip of main vine
7. **Number of flowers:** total number of flowers per plant
8. **Number of fruits per plant (Marketable and unmarketable):** total number of fruits per plant
9. **Fruit yield per plant (Marketable and unmarketable):** weight of fruit per plant
10. **Number of leaves:** total number of leaves per plant
11. **Number of secondary vine/ Number of branches on the main vine:** number of secondary vines arise from main vine.

12. **Number of seeds per fruit:** Self-pollinated fruits from putative tetraploid plants will be harvested at mature stage. The number of seeds present in each fruit will be counted and expressed as average number of seeds per fruit for tetraploids in each variety.
13. **pulp weight:** weight of soft tissue per fruit
14. **Seed length (mm):** Length of ten randomly selected seeds per tetraploid line will be recorded using digital Vernier caliper and expressed as average seed length.
15. **Seed width (mm):** Width of ten randomly selected seeds per tetraploid line will be recorded using digital Vernier caliper and expressed as average seed width.
16. **Total number of female flowers per plant**: number of male flowers per plant
17. **Total Soluble Solids (TSS**) The TSS will be determined following the procedures described by Will bekar et al. (1999). An aliquot of juice will be extracted using a juice extractor (Type 6001x, USA). An Atago N, hand refractometer with a range of 0 to 32°Brix and resolutions of 0.2°Brix will be used to determine TSS by placing 1 to 2 drops of clear juice on the prism. Between samples the prism of the refractor meter will be will behed with distilled water and dried with tissue paper before use. The referactrometer will be standardized against distilled water (0 percent TSS).

OKRA DATA COLLECTION PROCEDURES

Background

Okra (Abelmoschus esculentus) is one of the important vegetables with tremendous nutritional values. The edible portion (fresh fruits) contains 86.1% moisture, 9.7% carbohydrates, 2.25% protein, 1.0% fibre, 0.2% fat and 9% ash in addition to vitamins A, B, C and iodine (Kochhar, 1981). The fruits are consumed as vegetables, raw, cooked or fried in stews, gumbos and cecole dishes together with other vegetable. The dried and powdered or dehydrated okra is used in thickening soups, as emulsifier for salad dressing and as flavouring in preparing food products (Nonneck, 1989).

Crop Phenology and Growth Traits

1. **Days to 50%emergence:** Number of days from sowing to 50% seedling emergence.
2. **Days to first flowering:** The number of days taken from the date of sowing to onset of first flower appears on the plant in each plot.
3. **Days to 50% flowering:** The number of days taken from the date of sowing to the day on which 50 % of the plants in each plot produce flower.
4. **Days to maturity:** The average number of days from sowing to the date of first harvest of 10 sample plants of the plot will be recorded.
5. **Plant height (cm):** The height of 10 plants measured from the ground level to the tip at the time of final harvest and the average will be considered for statistical analysis.
6. **Stem diameter (mm):** Stem diameter at the basal region of plants will be measured using vernier calipers at the time of final harvest.
7. **Number of primary branches per stem:** The total number of primary branches per plant will be counted at final picking and average of 10 plants will be calculated.
8. **Number of internodes:** The total number of internodes per plant will be counted at final picking and average of 10 plants will be calculated.
9. **Internode's length (cm):** The length of the internodes between the 5 th and 6th node will be measured at time of maturity before the first tender fruit harvest.
10. **Leaf length (cm):** The length of 15 leaves on the main stem from each plot will be sampled randomly from 9 th and 11th node taken at the time of flowering. As the leaves from 7th node onwards are representative of the shape and the size of the variety. Leaves will be

measured from the attachment of the base of the leaves and petiole to the tip of the leaves using ruler.

11. **Leaf width (cm):** The width of 15 leaves on the main stem from each plot will be sampled randomly from 9 th and 11th node at the time of flowering. Leaves will be measured from the widest part of the leaf.
12. **Number of epicalyxes**: The number of epicalyxes flowers taken five flowers per plant from 10 plants at flowering stage from each genotype.

Fruit Character and Yield

Fruits will be harvested two times per week and number and weight of all tender fruits will be recorded in each harvest. Five randomly tender fruits from each harvest in each lot which a totally not less than fifty tender fruits from each plot will be used to record tender fruit characteristics while mature pods which produced between the 6th and 20^{th} nodes will be harvested at the end of the growing season to estimate mature pod length, seed number/pod and 100 seed weight.

13. **Peduncle length (cm):** Pedicel length of the five fruits per plant prior to picking will be measured at fully matured stage.
14. **Fruit length (cm):** The length of five tender fruits per plot in each harvest will be measured from the base of calyx to the tip of the fruit. The average will be calculated by dividing the sum of all tender fruit's length by the total number of fruits measured.
15. **Fruit diameter (mm):** the five tender fruits per plot which fruit length will be measured as indicated above will be also used to measure tender fruits diameter of with the help of a venire caliper at the center of the fruit and the average will be calculated like that of the fruit length.
16. **Average fruit weight (g):** Each of five tender fruits per plot that will be used to measure fruit length and width will be weighed using sensitive balance and the average weight of tender fruit will be calculated and recorded accordingly.
17. **Number of tender fruits per plant:** Fruits of ten plants in each plot at each harvest will be counted and summed at the end of the harvest and the average number of tender fruits per plant will be calculated and considered for statistical analysis.
18. **Number of ridges on fruit:** The number of ridges will be counted and the average also will be calculated from five tender fruits per plot at each harvest that will be used to measure fruit length and width.
19. **Yield per plot (kg):** Weight of tender fruits from each plot in each harvest will be recorded and summed to record yield per plot.
20. **Yield per hectare (t/ha):** This will be estimated from the 10 plants tender fruit yield in each plot.
21. **Number and weight of matured pods per plant:** Matured pods of the two plants next to the side plants/border plants in each plot will be harvested, counted and weighted to estimate and record number and weight (g/plant) of matured pods per plant.
22. **Dry weight of matured pods per plant (g/plant):** All the harvested matured pods of the two plants next to the side plants/border plants in each plot will be dried, weighted and the average dry weight of matured pods per plant will be calculated and recorded.
23. **Number of seeds per pod:** Ten fully matured and dried pods will be collected randomly from the two plants in each plot as indicated above and seeds will be extracted, counted and average number of seeds per pod computed.
24. **Hundred seed weight (g):** Seeds extracted from ten matured pods as indicated above will be kept in open air under sun and the dried 100 seeds will be randomly counted and weighted to estimate 100 seeds weight.

Qualitative Traits

The qualitative traits will be recorded on plot basis according to International Plant Genetic Resources Institute (IPGRI, 1991) descriptor list for okra species as follows.

25. **Plant habit:** This will be identified how the plants in each plot branched and described as: 1) Densely branched at apex (DBA), 2) Densely Branched Base (DBB) 3) Densely branched all over (DBO). 4. Non branched growth habit (NB)
26. **Flower color:** red coloration of petals base will be assessed at both side and described as 1) red color inside only or 2) red color at both sides.
27. **Leaf color**: This will be assessed from leaves lamina and ribs and described as 1) totally green and 2) green with red vein.
28. **Leaf petiole color:** It will be assessed from petioles color at both side and described as 1) Green, 2) Red above but green below and 3) Red on both sides.
29. **Pod color:** Main color of the pods will be observed at harvesting stage and described as 1) Green and 2) Red. 3. Green yellow
30. **Stem color:** This will be assessed from stems color of plants at first harvest stage and described as: 1) Green 2) Green with red patch and 3) Red or Purple. Color chart will be used for all color identification of pod, stem and leaf (Okra http://w3schools.Com/ html/html colorfullasp).
31. **Shape of leaf:** This will be assessed from leaves of plants that will be produced up to the first harvest and described as 1) oval undulate 2) heart-shaped 3) broadly ovate 4) star shaped (palmately lobed) 5) palmately triangular lobes 6) palmately lobed with dentate margins 7) palmately lobed with serrated margins and 8) linear-oblong or tri angular lobes.
32. **Position of fruits on main stem:** The positions of fruits on the main stem of the accessions will be observed and it will be described in five distinct variations as 1) Erect 2) Intermediate 3) Horizontal 4) slightly falling and 5) Totally falling.
33. **Fruit pubescence:** this will be observed at harvesting stage and described as 1) smooth and 2) rough.
34. **Fruit shape:** This will be assessed from fruit at harvest stage and described as with shape scores of 1, 2, 3, 4, 12, 14 and 15, according to the descriptor (IPGR, 1991).

CARROT DATA COLLECTION PROCEDURES

Background

Carrot (*Daucus carota* L.) is a widely grown root vegetable of the Apiaceae family. The first certain recorded use of carrot roots as a vegetable was in the 10th century in what is today known as Afghanistan. Orange carrots first appeared as a genetic variant in Europe in the 16th century and these more refined orange carrots quickly spread around the world, and by the early 20th century they became the predominate carrots in most growing regions of the world (www.seedalliance.org). Carrot is an important source of alpha- and beta-carotene, the precursors of vitamin A in human nutrition in many countries worldwide.

1. **Average root length**: Samples will be taken from treatment plots and the root length will be measured using a ruler and expressed in centimeters.
2. **Average root juice content**: Carrot juice will be extracted from the sample with a juice extractor (Type 6001x model No. 31JE35 6x.00777 U.S.A.) and clear juice will be used for measuring average root juice content.
3. **Average root base diameter**: The average root base diameter will be determined by measuring the base diameter of the root with the help of a verneer caliper.

4. **Core diameter**: The cores of the roots will be taken out using knives and average core diameter will be determined by measuring the core of the root at middle portion with the help of a verneer caliper.
5. **Bolting dates:** A shoot will be described bolted when the first visible flower bud appear. The dates will be recorded when 50% of the plants had visible flower buds.
6. **Flowering dates:** The date when 50% of the plants had open flowers on the primary umbel.
7. **Number of days to seed harvest:** The number of days from sowing to the day when the second order umbels (secondary) will be harvested.
8. **Seedstalk height at flowering**: It will be measured from the root crown to the top of the primary umbel. The mean will be calculated by dividing the total height by the number of plants.
9. **Number of umbels per umbel order per plant:** The total number of umbels per umbel order will be recorded at harvest and divided by the number of plants to calculate the number of umbels per umbel order per plant.
10. **Number of umbellets per umbel:** For primary umbels, the total number of umbellets will be divided by the number of plants. For secondary and tertiary umbels, total number of umbellets will be calculated from 5 randomly selected umbels from each order in each plant and divided by the number of plants.
11. **Fresh root weight**: Immediately after harvest, the total carrot roots obtained from each treatment plot will be taken and their fresh weight will be measured with the help of an analytical balance. Then after mixing the replications of each treatment, ten randomly selected carrot samples from each treatment will be taken to measure the fresh weight of individual roots to determine average root weight.
12. **Average root volume**: The average root volume will be measured by taking random samples from each treatment and immersing in a beaker containing known amount of water. The volume of the root will be determined by observing the displacement of the water by the root, so that the difference will be taken as the volume of the root.
13. **Leaf Number**: Ten randomly selected carrot plants per experimental plot will be taken for leaf counting every 15 days up to the time of harvesting. In the process the number of true leaves will be counted and recorded
14. **Seed weight per umbel:** Total seed weight of each umbel order will be divided by the number of umbels in each umbel order.
15. **Seed weight per plant:** Total seed weight divided by the number of plants.
16. **One thousand seed weight:** Weight of 200 seeds from the representative sample multiplied by 5.
17. **Root dry weight:** Total root dry weight divided by the number of plants.
18. **Shoot dry weight:** The total dry weight of above ground plant material including the seed divided by the number of plants. This value plus the mean root dry weight per plant will give the biological yield.
19. **Root-to-shoot ratio:** The quotient of mean root dry weight and mean shoot dry weight.
20. **Harvest index:** The quotient of the seed weight and the biological yield.
21. **Germination percentage**: The proportion of the number of seeds that have produced seedlings classified as normal under the conditions and within the period specified.
22. **Vigour index**: The sum of the number of seedlings removed daily from the germination test divided by the sum of the number of days.

SWEET POTATO DATA COLLECTION PROCEDURES

Background

Sweet potato *(Ipomoea batatas (L.)* Lam.) is a member of the Convolvulaceae family (Purseglove, 1972). Approximately 900 different species of Convolvulaceae in 400 genera have been identified around the world. Yen (1974) and Austin (1978, 1988) recognized 11 species in the section batatas, which includes sweet potato. The closest relative of the sweet potato appears to be *Ipomoea trifida* that is found wild in Mexico, and *Ipomoea tabascana.* Sweet potato has a chromosome number of 2n = 90. Since the basic chromosome number for the genus *Ipomoea is* 15, sweet potato is considered to be a hexaploid.

1. **Days to emergence:** It will be recorded when 50% of the vine cuttings sprout.
2. **Number of branches (Number plant^{-1}):** The average number of branches/stems emerging from the main stem. This will be counted at maturity.
3. **Vine length (m):** The length of the vine from the base of the plant to the terminal tip at which the maximum height is attained.
4. **Shoot fresh weight (g/plant):** Includes fresh mass of vines and leaves. It will be recorded by taking random samples of five plants per plot.
5. **Shoot dry weight (g/plant):** Includes dry mass of vine and leaves. It will be recorded at physiological maturity. The above ground biomass will be harvested by cutting vines close to the soil surface and putting them in a forced air circulation oven at 80^{o}C for 12 to 24 hours until a constant weight is attained.
6. **Days to physiological maturity:** It will be recorded when the vines of 50% plant population in each plot turned yellowish.
7. **Root fresh weight (g/plant):** Storage roots, pencil roots, fibrous roots and parts of stem remaining underground will be dug out and weighed.
8. **Root dry weight (g/plant):** Underground plant parts will be first air-dried and the roots sliced in to small pieces, and further dried in a ventilated oven at 80 ^{o}C until a constant weight is obtained.
9. **Biomass yield:** It will be determined by summing up the shoot fresh weight and root fresh weight.
10. **Harvest Index:** Harvest index will be calculated from each sample as the ratio of dry mass of roots (economic yield) to total biomass (biological yield) at harvest as described by (Chan, 1996).
11. **Average root number (number plant^{-1}):** It will be recorded by counting the actual number of roots collected from five randomly selected mature plants at harvest and dividing the total number of roots by five.
12. **Average root weight (g plant^{-1}):** It will be determined by dividing the total fresh roots weight per plant to the total number of roots.
13. **Marketable root number (count ha^{-1}):** the number of marketable roots per plot (it includes the number of clean, uninfected storage roots that fall in the size range of 100 g to 500 g) (Yohannes, 2007) and converted to hectare.
14. **Unmarketable root number (count ha^{-1}):** the number of unmarketable roots per plot (it includes all storage roots other than marketable roots) and converted to hectare.
15. **Total root number (count ha^{-1}):** It is the number of marketable and unmarketable roots that are taken from harvestable plot and converted to hectare.
16. **Marketable root yield (t ha^{-1}):** the weight of clean, uninfected storage roots that fall in the size range of 100 g to 500 g. It will be recorded by weighing all the fresh marketable roots harvested from the plot using sensitive balance and calculated on the basis of ton ha^{-1}.

17. **Unmarketable root yield (t ha^{-1}):** the weight of unmarketable roots per plot (it includes all storage roots other than marketable roots such as small size, rotten and green) and it will be calculated on the basis of ton ha^{-1}.
18. **Total root yield (t ha^{-1}):** it is the sum of marketable and unmarketable roots yield taken from harvestable plot and calculated on the basis of ton ha^{-1}.
19. **Percent root dry matter yield:** This will be estimated as a ratio of the weight of dried root and fresh root, expressed as percentage (**RDM (%) = [WDR / WFR] x 100)** Where; RDM (%) = Root Dry Matter Percentage, WDR = Weight of Dried Root and WFR = Weigh of Fresh Root
20. **Top-to-Root Ratio or Shoot-to-Root Ratio:** it will be determined by dividing the above ground dry biomass to the total root dry biomass at maturity.
21. **Leaf area:** it is the total one-sided area of leaf tissue and measured using leaf area meter.
22. **Leaf Area Index (LAI):** it will be determined by dividing the total one-sided area of leaf tissue per unit ground surface area as defined by Watson (1947).
23. **Leaf Number (count hill^{-1}):** numbers of the hall plants per hill will be counted.
24. **Vine length:** the height of plant from the base of the plant to the terminal tip at which the maximum height will be attained (m).
25. **Internode's diameter (mm):** it will be measured at harvest between the fourth and fifth nodes from the tip with the aid of caliper.
26. **Internode's length (cm):** it will be measured at harvest between the fourth and fifth nodes from the tip with the aid meter.
27. **Chlorophyll contents:** it will be measured at two and half month after planting between the fourth and fifth nodes from the tip with the aid of SPADS.
28. **Specific gravity:** it will be determined by collecting a sample of 5 kg roots from each plot randomly. It will be will behed and dried and determined using the weight in air and water method as described by Fong and Redshaw (1973).
    Sg = WA / (WW – WA)
    Where; WA = Weight in Air, WW = Weight in Water and Sg = Specific gravity.
29. **Nutrient Uptake:** it will be calculated based on plant samples collected for estimation of dry matter accumulation at harvest maturity. Total uptake of N and P will be calculated separately by the following formula: Uptake of N or P g plant^{-1} = (N% or P% × dry matter g plant^{-1}) /100

POTATO DATA COLLECTION PROCEDURES

Background

Potato (Solanum tuberosum L.) is one of the most important tuber crops in the world (Albiski et al. 2012) and is a critical crop in terms of food security (Birch et al. 2012). The crop is an essential source of starch, antioxidants, protein, vitamins, macro and micronutrients, polyphenols, carotenoids and tocopherols in the human diet (Brown 2005).

1. **Days to tuber initiation:** It will be recorded when the stolon tip attains a size at least twice the diameter of the stolon (Ewing and Struik, 1992). For this purpose, three plants per plot will be tagged and tuber initiation monitored every second day.
2. **Plant height:** Measured from the base of the stem to shoot apex at maturity from those tagged plant samples used for leaf area measurement.
3. **Total leaf area and leaf area index:** To determine leaf area and leaf area index, five plants (hills) from each subplot will be randomly selected and tagged. The leaf area and leaf area index will be measured 30 days after the last treatment application date. Individual leaf area of the potato plants will be estimated from individual leaf length using the following

formula developed by Firman and Allen (1989) and leaf area index will be determined by dividing the total leaf area of a plant by the ground area covered by a plant.
{Log 10 (leaf area in cm2) =2.06xlog 10(leaf length in cm)-0.458}

4. **Biomass yield:** To determine dry mass of aboveground parts (stem, branch, and leaves) and underground parts (root, stolon, and parts of the stem remaining underground) five randomly selected plants will be harvested from each treatment category at about six weeks after pollination (CIP, 1983) when the vines will be still green but had practically cease growth. Both above and underground parts dry mass will be determined after drying the samples in an oven at 72oC to a constant mass.
5. **Days to physiological maturity:** It will be recorded when the haulms of 50% plant population
in each plot turned yellowish.
6. **Tuber yield and number:** Tubers from second, fourth and sixth rows (five plants in each rows) of each subplot will be harvested on the same date according to the maturity date of the cultivars. Tubers which will be rotten, green and weighing less than 60 g will be considered unmarketable tubers while determining marketable and unmarketable tuber yield and number.
7. **Average tuber mass:** It will be determined by dividing the total fresh tuber yield to the respective total number of tubers.
8. **Harvest index:** It will be calculated as the ratio of dry mass of tubers to the dry mass of total
biomass. Dry mass of tubers will be determined by multiplying the total fresh tuber yield by the respective dry matter percentage.
9. **Specific gravity:** At harvest, a representative tuber sample from each subplot will be taken and will behed. Tuber specific gravity will be determined by weighing in air and under water
method (Murphy and Goven, 1959).
10. **Dry matter content:** To determine dry matter content of the tubers, the samples will be predried at a temperature of 60oC for 15 hour and followed by 105oC for 4 hours. Tuber dry matter content is the ratio between dry and fresh mass expressed as a percentage.

CASSAVA DATA COLLECTION PROCEDURES

Background

Cassava (*Manihot esculenta*) is the fourth most important source of food calories for humans in the tropics (Roca and Thro, 1992). It grows exclusively as food in 39 African countries, stretching through a wide belt from Madagascar in the south-east to Senegal in the Northwest (IITA, 1990). It is a staple food for more than a tenth of the world's populations, and in tropical countries it is the third source of calories after maize and rice (Sis, 2013).

Descriptors to be Scored at Three Months After Planting

1. **Color of apical leaves:** Record color that the most frequent occurrence as Light green, Dark green, Purplish green and Purple
2. **Pubescence on apical leaves:** Record the most frequent occurrence of leaf apical shoot.

Descriptors to be Scored at Six Months After Planting

1. **Leaf retention:** Measure 5–6 months after planting. Visually score for leaf retention using a scale of 1–5. 1 = Very poor retention 2 = Less than average retention 3 = Average leaf retention 4 = Better than average retention 5 = Outstanding leaf retention

2. **Shape of central leaflet:** Leaf taken from a mid-height position and check its shape: 1 Ovoid 2 Elliptic-lanceolate 3 Obovate-lanceolate 4 Oblong-lanceolate 5 Lanceolate 6 Straight or linear 7 Pandurate 8 Linear-piramidal 9 Linear-pandurate 10 Linear-hostatilobalate
3. **Petiole color:** Leaf taken from a mid-height position check for its petiole color: 1 Yellowish-green 2 Green 3 Reddish-green 5 Greenish-red 7 Red 9 Purple
4. **Leaf color:** Observe a leaf from the middle of the plant and recorded leaf color: Light green, Dark green, purple green and Purple
5. **Number of leaf lobes:** Assess on five leaves and take the predominant number of lobes: Three lobes, Five lobes, Seven lobes, Nine lobes and Eleven lobes
6. **Length of leaf lobe:** Measure from the intersection of all lobes to the end of the middle lobe. Express in cm and record to one decimal place.
7. **Width of leaf lobe:** Measure from the widest part of the middle lobe. Express in cm, and record to one decimal place.
8. **Ratio of lobe length to lobe width of central leaf lobe:**
9. **Lobe margins:** Observe from the middle third of the plant: Smooth and Winding
10. **Petiole length:** Observe from the middle third of the plant. Measure two leaves/ plant. Express in cm.
11. **Color of leaf vein:** Observe near the base of the lobes, on the upper side of the leaf, on the central lobe from a leaf from the middle of the plant: Green, Reddish-green in less than half of the lobe, Reddish-green in more than half of the lobe and all red
12. **Orientation of the petiole:** Take a general picture across the row and observe the middle plant part and express as Inclined upwards, Horizontal, Inclined downwards and Irregula
13. **Flowering:** At least one flower on each plant. Scoring should be repeated at regular intervals until harvest to determine whether flowering occurs.
14. **Pollen:** Scored at the same time as flowering for presence and absence of pollen

Descriptors to be Scored at Nine Months After Planting

1. **Prominence of foliar scars:** Observe from the middle third of the plant for Semi-prominent and Prominent
2. **Color of stem cortex:** Make a small shallow cut and peel back the epidermis and check its color: Orange, Light green and Dark green
3. **Color of stem epidermis:** Peel epidermis back and look at underside of epidermis (skin): Cream, Light brown, Dark brown and Orange
4. **Color of stem exterior:** Observe on the middle third of the plant: Orange, Greeny-yellowish, Golden, Light brown, Silver, Gray and Dark brown
5. **Distance between leaf scars:** Measure from the middle of stem on the middle third of the plant, where the scars are not flat express in cm.
6. **Growth habit of stem:** check plant growth weather Straight or Zig-zag
7. **Color of end branches of adult plant:** Observation to be taken on top 20 cm of plant: Green, Green-purple and Purple
8. **Length of stipules:** Observation from upper third of plant for long or short stipules
9. **Stipule margin:** Observation from upper third of plant whether Entire or Split or forked

Descriptors to be Scored at Harvest

1. **Fruit:** observe whether it has fruit or not and recorded accordingly
2. **Seed:** observe whether it form seed or not and recorded accordingly

3. **Plant height:** Measure vertical height from the ground to the top of the canopy average of three plants Express in cm.
4. **Height to first branching:** Measure vertical height from ground to first primary branch. Zero = no branching. Ignore side branching. Express in cm. average over three plants.
5. **Levels of branching:** Record number of divisions of branching. Zero (0) for no branching Ignore if side branching
6. **Branching habit:** Observed at the lowest or first branching: Erect, Dichotomous, Trichotomous and Tetrachotomous
7. **Angle of branching:** Measure at first primary branching (not side branches). Record the angle measured, later divide the angle by two.
8. **Shape of plant:** Record the most frequent occurrence on the plot: Compact, Open, Umbrella and Cylindrical
9. **Number of storage roots/plant:** Record from each of three plants.
10. **Number of marketable roots/plants:** Record the number of roots from three plants with length greater than 20 cm.
11. **Extent of root peduncle:** Main roots only: Sessile, Pedunculate, Mixed
12. **Root constrictions:** Measure on a mature root. This can be affected by nematodes and/or cassava brown streak diseases: Few to none, Some and Many
13. **Root shape:** Record the most frequent occurrence: Conical, Conical-cylindrical, Cylindrical and Irregular
14. **External color of storage root:** Record the most frequent occurrence: White or cream, Yellow, Light brown and Dark brown
15. **Color of root pulp (parenchyma):** Record the most frequent occurrence: White, Cream, Yellow, Orange and Pink
16. **Color of root cortex:** Record the most frequent occurrence: White or cream, Yellow, Pink and Purple
17. **Cortex: ease of peeling:** check whether it is Easy or Difficult to peel
18. **Texture of root epidermis:** Record the most common root type. Please touch the root! As if is Smooth, Intermediate or Rough
19. **Root taste:** test raw root only: Sweet, Intermediate or Bitter
20. **Cortex thickness:** Measure from three roots, at the proximal (closest to stem), mid- and distal (furthest from stem) ends. Use calipers if available. Check if Thin, Intermediate or Thick express mm
21. **Dry matter content:** Heritability for DM in cassava is relatively high; 0.87 broad sense heritability and 0.51 – 0.67 narrow sense heritability (Kawano et al. 1987). Estimation of DM and starch content in cassava is based on the principle of a linear relationship between specific gravity with DM and or starch content. Percentage DM = 158.3x – 142, while starch content = 112.1x – 106.4; where x = specific gravity. Specific gravity is measured according to the following methodology: Compute specific gravity at Ww / (Wa – Ww) where Ww = weight of root in water and Wa = weight of root in air
22. **Starch content:** starch content = 112.1x – 106.4; where x = specific gravity.
23. **Harvest index:** Harvest index (HI), defined as the proportion of the fresh root weight in biomass, is a valuable trait in cassava breeding. As opposed to selections based solely on fresh root yield, HI-based selections are stable across evaluation stages and will truly represent genotype yield potential under monoculture. It is likely that true genetic progress in cassava will be achieved through utilization of HI (Kawano 1990). The assessment of HI is relatively simple and straightforward.
    HI = Weight of roots / (Weight of roots + weight of aboveground biomass)

24. **Cyanogenic potential:** 1. There are large effects of environments on root cyanogens; nevertheless, both broad and narrow sense heritabilities for CNP are high, ranging between 0.87–1.07. 2. Because CNP varies considerably between plants, analysis will be done using 4 plants/clone, and on 3 roots per plant. 3. Materials required include knives, glass tubes (12 cm long with tightly fitted rubber stops) and the scoring scale. 4. Consumables required include filter papers (Whatman No. 1.6 cm x 1 cm) picric acid anhydrous sodium carbonate, and toluene. Please note that both picric acid and toluene (methylbenzene or phenyl methane) are hazardous chemicals, and NEED TO BE HANDLED WITH EXTREME CARE AND WITH APPROPRIATE PROTECTION. 5. For each root sample, make a cross-sectional cut at the mid-root position. 6. Pinpoint the mid position between the peel and the center of the parenchyma (root flesh) and make a 1 cm3 cube cut. 7. Place the cut root cube into a glass tube and add 5 drops of toluene onto it; tightly seal the glass tube with the stopper. 8. Take a strip of Whatman filter paper and dip it into freshly prepared alkaline picrate mixture until saturated. 9. Suspend the picrate-saturated filter paper above the cut root cube in the glass tube; ensure that the tube is tightly fitted with the rubber stopper. 10. After 10–12 hours, score for color intensity using the 1–9 scale.
25. **Postharvest deterioration:** 1. randomly select five commercially sized roots (minimum length 18 cm) to represent each clone. 2. Cut off a section about 1 cm from both the proximal and distal ends; cover the distal end with cling film. 3. Store the roots under ambient conditions. 4. After 7 days make seven 2-cm transversal slices starting from the proximal end. 5. Score each slice on a scale of 1–10, corresponding to the percentage of the cut surface showing discoloration (with 1 = 10% and 10 = 100%). 6. Take average of the seven slices to represent the deterioration of the root.

DATE PALM DATA COLLECTION PROCEDURES

Background

Phoenix dactylifera is a palm with a long and interesting history. Its origin goes back to ancient times, well before written history. It is a member of the genus *Phoenix*, which contains about one dozen species of palms. Although other species in this genus produce fruits that are eaten by birds and other animals, *Phoenix dactylifera* is the only *Phoenix* species cultivated for its fruit. The date palm is the characteristic vegetation found in the oases of arid areas in the Middle East.

1. **Average Bunch weight:** will be calculated by weighting bunch averaged over five bunches
2. **Average Fruit Length:** the height of the fruit measured in cm averaged over 30 sample from different bunch and cluster.
3. **Average Fruit Weight:** the weight of the fruit measured in gm averaged over 30 sample from different bunch and cluster.
4. **Average Fruit Width:** the width of the fruit measured in caliper averaged over 30 sample from different bunch and cluster.
5. **Average length of cluster:** the height of the cluster measured in cm averaged over 30 sample from different bunch at different point eg. Lower, middle and tip.
6. **Average number of clusters per bunch:** number of the cluster averaged over 30 sample of different bunch.
7. **Average number of Fruits per Cluster:** number of the fruit averaged over 30 sample of cluster from different bunch.
8. **Average Seed Length:** the height of the seed measured in cm averaged over 30 sample from different bunch and cluster.

9. **Average Seed Weight:** the weight of the seed measured in gm averaged over 30 sample from different bunch and cluster.
10. **Average Seed Width:** the width of the seed measured in caliper averaged over 30 sample from different bunch and cluster
11. **Canopy Diameter:** distance between the longest opposite two leaves round the main stem measured by meter
12. **Fruit Color:** color of fruit observed at different stages eg. Kimiri, Khalal, Rutab and Tamar stages.
13. **Date Harvest:** Number of days from pollination to last date of fruit harvest
14. **Date of pollinated:** the time of first day of pollination takes place
15. **Date of Spathe Emergency:** the time in which the spathe emerges between leaf and stem.
16. **Date of Spathe Flower:** the time in which the spathe crack to show spathe
17. **Number of Fruit per Bunch:** total number of fruits of bunch averaged over three bunches in kg
18. **Number of leafs pruned per plant:** number of the leaves pruned per tree annually based
19. **Number of Leafs per plant:** number of the leaves per tree
20. **Plant Height:** the height of the plant measured in meter from ground level to the growth tip of the plant
21. **Pulp Thickness:** the thickness of pulp measured by calipers after seeds are removed from fruit after harvest
22. **Steam Circumference:** the round length of the tree measured in meters at breast height of middle height man
23. **Steam Diameter:** the diameter of the tree measured in caliper at breast height of middle height man
24. **Total bunch number per plant:** total number of bunches annually produced by a single plant
25. **TSS:** An aliquot of juice will be extracted using a juice extractor (Type 6001x, USA). An Atago N, hand refractometer with a range of 0 to 32°Brix and resolutions of 0.2°Brix will be used to determine TSS by placing 1 to 2 drops of clear juice on the prism. Between samples the prism of the refractor meter will be beheld with distilled water and dried with tissue paper before use. The refractometer will be standardized against distilled water (0 percent TSS).
26. **Weight of Fruit per Bunch:** the weight of the fruit measured in km of each bunch produced by plant.
27. **Weight of fruit per cluster:** weight of the fruit averaged over 30 sample of cluster from different bunch at different point eg. Lower, middle and tip.
28. **Spathe length:** length of spathe at the time spathe opening of both male and female plants: take average of all spathes produced by plants
29. **Spathe diameter:** diameter of spathe at the time spathe opening of both male and female plants: take average of all spathes produced by plants in both sides of spathe at widest and narrow independently
30. **Offshoot produced per year:** number of offshoots annually produced by plant
31. **Weight of pollen per spathe:** weight of pollen produced by one spathe
32. **Number of male spathes per plant:** total number of spathes produced by plant
33. **Average length of male Custer:** length of male cluster sampled at different point eg. Lower, middle and tip.
34. **Number of male clusters per spathe:** number cluster produced in one spath

35. **Yield (marketable and unmarketable per bunch:** marketable, unmarketable and total yield per bunch and per plant in kg
36. **Number of aborted fruits:** number of fruits aborted before mature that remain in covering nets
37. **Percent of aborted fruit:** it is calculated by dividing aborted number of fruits by total number of fruit and multiplied by hundred expressed in percentage
38. **Leaf length:** the height of the middle leafs averaged over 30 leaves

MANGO DATA COLLECTION PROCEDURES

Background

Mango, *Mangifera indica* L., is the most economically important fruit crop in the Anacardiaceae family. Mangifera contains about 30 species, up to 15 other species produce edible fruit, including the water mango M. laurina, and M. sylvatica, the wild, forest mango from which M. indica is thought to have descended. Mango tree is erect, 30 to 100 ft (roughly 10-30 m) high, with a broad, rounded canopy which may, with age, attain 100 to 125 ft (30-38 m) in width, or a more upright, oval, relatively slender crown. In deep soil, the taproot descends to a depth of 20 ft (6 in), the profuse, wide-spreading, feeder root system also sends down many anchor roots which penetrate for several feet. The tree is long-lived, some specimens being known to be 300 years old and still fruiting.

Vegetative Data

1. **Tree height(m):** the height of the plant measured in meter from ground level to the growth tip of the plant
2. **Canopy spread (m):** distance between the longest opposite two branches round the main stem measured by meter
3. **Number of branches:** total number of branches from the main stem
4. **Height to first branching:** Measure vertical height from ground to first primary branch. Zero = no branching. Ignore side branching. Express in cm. average over three plants.
5. **Girth measurement (cm):** the diameter of the tree measured in caliper at Above union and Below union

Yield Data

6. **Marketable yield:** marketable yield per plant in kg expressed as
   a. Number
   b. Weight (kg)
7. **Un-marketable yield:** unmarketable yield per plant in kg expressed as
   a. Number
   b. Weight (kg)
8. **Total yield:** total yield per plant (the sum of marketable and unmarketable yield) in kg expressed as
   a. Number
   b. Weight (kg)
9. **Fruit size:** fruit length and diameters expressed in cm
   a. Length (cm)
   b. Diameter (cm)
10. **Reason for un-marketability:** any reason for unmarketable (under sized, mechanical damage, diseased or physiological disorder)

Fruit Appearances and Quality Data

11. **Fruit weight per tree:** weight of individual marketable, unmarketable and total in kg per tree
12. **Skin color:** skin color of individual fruit per tree
13. **Firmness:** fruit firmness by pressing fruits between two figures
14. **Marketability:** any fruit free from any disease, mechanical damage, physiological disorder and unrotten.
15. **Disease sign, symptom or lesion (+/-):** recorded any disease or insect pest symptom or sign throughout the growth period of the plant
16. **TSS:** An aliquot of juice will be extracted using a juice extractor (Type 6001x, USA). An Atago N, hand refractometer with a range of 0 to 32°Brix and resolutions of 0.2°Brix will be used to determine TSS by placing 1 to 2 drops of clear juice on the prism. Between samples the prism of the refractor meter will be beheld with distilled water and dried with tissue paper before use. The refractometer will be standardized against distilled water (0 percent TSS).
17. **TTA**
18. **pH:** pH level of fruit juice
19. **Juice (fresh) weight**: fresh weight of juice in gm after removal of seed and peal
20. **Seed weight:** weight of fresh seed just after extract from fruit expressed in gm.

ANANAS DATA COLLECTION PROCEDURES

Background

Pineapple (*Ananas comosus* var. *comosus* (L.) Merril) belongs to the bromeliaceae, monocotiledonae family, originated from warm climates in the Americas, being the main producers: Thailand, Brazil, Philippines, india and China. Brazil is actually the second main pineapple producer, being Thailand the main producer (FAo, 2010). In Brazil, the main producing states are Pará, Paraíba and Minas Gerais (IBGE, 2011). Cultivars most grown in Brazil are 'Pérola' and 'Smooth Cayenne' (CRESTANI, 2010). Between the two cultivars, 'Pérola' is the most planted due to its good acceptance on the domestic market and its pleasant taste, being the ideal cultivar for fresh fruit consumption.

1. **Biotic Stress Susceptibility:** Specify the infestation or infection using 1 - 9 scale. Note: For Additional information as common name(s) of disease(s)/pest(s) and causal rganism(s) may be appended in the biotic notes descriptor. 1 Very low or no visible sign of susceptibility 3 Low 5 Intermediate 7 High 9 Very high
2. **Crown foliage attitude:** 1 Erect 3 Semi-erect 5 Horizontal 7 Drooping
3. **Crown leaf color:** 1 Greenish/green 2 Green with yellow mottling 3 Green with red mottling 4 Reddish orange 5 Red 6 Dark red 7 Purplish/pinkish 8 Dark red-purple/pink 9 Silvery white 99 Others
4. **Crown shape:** To be recorded on ripe fruit 1 Cone 2 Oblong blocky 3 Acron (heart shaped) 4 Long conical 5 Lengthened cylindrical 6 Lengthened cylindrical with bunchy top 99 Others
5. **Date of first flowering (dd/mm/yyyy):** To be recorded when untreated and unforced plant shows first flower open
6. **Distribution of spines:** To be observed on middle leaves 1 Spines behind tip or near base only 2 Spines behind tip and near base 3 Spines along all margins 4 Spines occur irregularly along both margins
7. **Eye depth:** To be recorded on ripe fruit 3 Shallow 5 Medium 7 Deep
8. **Eye pattern (eye profile):** To be recorded on ripe fruit 3 Flat 5 Normal 7 Prominent

9. **Foliage attitude:** 1 Upright 3 Slightly open 5 Open 7 Spreading 9 Drooping
10. **Fruit diameter (cm):** To be recorded as average of same 5 fruits
11. **Fruit firmness:** To be recorded on ripe fruit 3 Soft 5 Intermediate 7 Firm
12. **Fruit length (cm):** To be recorded as average of 5 random mature fruits
13. **Fruit shape:** To be recorded on maturity of fruit. 1 Square like 2 Oval 3 Round 4 Conical 5 Long conical 6 Pyramidal 7 Cylindrical slight taper 8 Cylindrical sharp taper 9 Pyriform 10 Reni form 99 Others
14. **Fruit skin thickness (mm):** To be recorded as average of same 5 fruits
15. **Fruit weight (g):** To be recorded as average of same 5 fruits
16. **Leaf length (cm):** To be recorded as average of 10 random leaves below the fruit
17. **Leaf width (cm):** To be recorded as average of same 10 leaves
18. **Middle leaf color:** To be recorded as upper surface color of the 15th leaf from the top of the plant. 1 Green 2 Green with yellow mottling 3 Green with red mottling 4 Reddish orange 5 Red 6 Dark red 7 Purplish/pink 8 Dark red purple/pink 9 Silvery white 99 Others
19. **Number of aerial suckers:** 0 None 3 Few 5 Medium 7 Abundant
20. **Number of leaves per plant:** To be recorded as average of 10 random plants
21. **Number of peduncle slips:** 0 None 3 Few 5 Medium 7 , Abundant
22. **Number of underground suckers (ratoons):** 0 None 3 Few 5 Medium 7 Abundant
23. Peduncle color: To be recorded at mature fruit stage 1 Green 2 Greenish yellow/red mottling 3 Dark green 4 Red 5 Reddish orange 6 Dark red 7 Dark red purple 8 Purplish pink 9 Silvery white 99 Others
24. **Peduncle length (cm):** To be recorded as average of 10 random peduncles at mature fruit stage
25. **Peduncle width:** To be recorded as average of same 10 peduncles at mature fruit stage
26. **Petal color:** To be recorded during flowering 1 White 2 Yellow 3 Cream 4 White purple 5 Purple 99 Others
27. **Petal fusing:** To be recorded during flowering 3 Free 5 Imbricate 7 Adnate
28. **Petal orientation:** To be recorded during flowering 1 Open 9 Closed
29. **Plant habit (without fruit):** 3 Erect 5 Normal 7 Procumbent
30. **Plant height (cm):** To be recorded from ground level to fruit crown top
31. **Plant spread (cm):** To. be measured as canopy diameter (average of East - West and North – South dimensions)
32. **Presence of seeds:** 0 Absent 1 Present
33. **Presence of spines on crown leaves:** 1 Smooth 2 Spines at tip 3 Spiny serrate 4 Piping
34. **Productivity status:** To be recorded at the time of harvest 3 Low 5 Medium 7 High
35. **Pulp aroma:** To be recorded on ripe fruit 3 Mild 5 Moderate 7 Strong
36. Pulp color: To be recorded on ripe fruit 1 White 2 Light cream 3 Cream 4 Pale yellow 5 Golden yellow 6 light orange 7 Deep orange Pineapple (Ananas comosus (L.) Merrill) 99 Others
37. **Pulp fibrousness:** To be recorded on ripe fruit 0 Absent 3 Low 5 Medium 7 High
38. **Pulp texture:** To be recorded on ripe fruit 3 Smooth 5 Medium 7 Rough
39. **Ripe fruit color homogeneity:** 3 Poor 5 Medium 7 Good
40. **Ripe fruit color:** 1 Green 2 Silvery green 3 Yellow with green mottling 4 Dull yellow 5 Bright yellow 6 Golden yellow 8 Reddish orange 9 Brownish 99 Others
41. **Seed color:** 1 Grey 2 Brown 99 Others
42. **Seediness (seed crowdness):** To be recorded on ripe fruit 3 Few 5 Medium 9 Very seedy
43. **Stem girth (mm):** To. be measured at the base of plant
44. **Total soluble solids (%):** To be measured with refractometer

BANANA DATA COLLECTION PROCEDURES

Background

Banana (Musa acuminata cv.) is a commercially significant tropical fruit with innumerable varieties (Prabha and Bhagyalakshmi, 1998). Ten of the major bananas producing countries accounted for about 75% of world production in 2003, whereas India, Ecuador, Brazil and China provided almost 50% of the total production in that year (Zhang et al., 2005).

Data from mother plants (first plant), daughter plants (second plant) and granddaughter plants (third plant) depending on your study

1. **Biotic Stress Susceptibility:** Specify the infestation or infection using 1-9 scale. Banana (Musa paradisiaca L.) Note: For Additional information as common name(s) of disease(s)/pest(s) and causal organism(s) may be appended in the biotic notes descriptor. 1 Very low or no visible sign of susceptibility 3 Low 5 Intermediate 7 High 9 Very high
2. **Bract apex shape:** To be recorded during flowering 1 Pointed 2 Slightly pointed 3 Intermediate 4 Obtuse 5 Obtuse and split
3. **Bract behavior:** To be recorded at just before bract falling 1 Revolute (rolling) 2 Not revolute (not rolling)
4. **Bunch weight per plant:** Before harvest, take a photo of the mature bunch. Harvest the mature bunch by cutting the peduncle above the proximal hand and weigh the bunch, including the rachis, using scales (kg). To be recorded as average of 3 random plants
5. **Date of First Fruiting:** the number of days in which the fruit emerge from Peduncle.
6. **Date of Harvesting:** Number of days from planting to last date of fruit harvest
7. **Date of Inflorescence/ Date of shooting:** At shooting, record the approximate date that the inflorescence emerges from the pseudo stem and is still in an erect position.
8. **Date of Last Fruiting:** the number of days in which the last fruit formed on Peduncle.
9. **Date of Sucker emergency:** Number of days from planting to the date of sucker formation
10. **External bract color:** To be recorded on the dorsal side during flowering stage 1 Yellow 2 Green 3 Orange red 4 Red 5 Red purple 6 Purple 7 Purple brown 8 Blue
11. **Finger circumference (mm):** Measure the circumference of the finger at its widest point, using a tape measure (mm).
12. **Finger diameter (mm):** Measure the lateral diameter of the finger, from the left to the right side (not from the ventral to the dorsal side), at the widest point, using calipers (mm).
13. **Fruit apex:** To be recorded on ripe fruit Pointed 2 Prominently pointed 3 Blunt tipped 4 Bottle-necked 5 Rounded
14. **Fruit length:** the height of the fruit measured in cm averaged over each bunch. To be recorded as average of 10 random middle fingers. Measure the length of the finger, along the external (dorsal) arc, excluding the pedicel and the fruit tip, using a tape measure (mm).
15. **Fruit shape:** To be recorded on ripe fruit Straight, straight at the distal part, Curved, Curved in "S" shape
16. **Fruit skin color:** To be recorded on ripe fruit 1 Yellow 2 Bright yellow 3 Orange 4 Grey spots 5 Orange red, red or pink / pink purple 6 Red purple 7 Br6wnfrusty browr:l. 8 Black 99 Others (Specify in the 'Remarks' descriptor)
17. **Fruit weight:** the weight of the fruit measured in gm averaged over each bunch. To be recorded as average of same 10 fingers
18. **Hand weight per bunch:** total weight of hands per each bunch. Average over five hands
19. **Internal bract color:** To be recorded on the ventral side during flowering 1 Whitish 2 Yellow 3 Orange red 4 Red 5 Purple, 6 Purple brown 7 Pi'1k purple

20. **Leaf blade base shape:** To be recorded on mature leaf 1 Both sides rounded 2 One side rounded, one side pointed 3 Both sides pointed
21. **Leaf habit:** To be recorded on mature leaf: 1 Erect 2 Intermediate 3 Drooping
22. **Leaf length:** the height of the middle leaves averaged over all leaves from leaf seize to the tip of leafs
23. **Leaf width:** the maximum width of leaf measured by cm
24. **Male bud shape:** To be recorded as the shape of the male bud t -r·' \. 1 2 3 4 5 2 Like a top Lanceolate Intermediate Ovoid Rounded
25. **Male bud:** The male bud contains the male flowers enclosed in their bracts. It is sometimes called the bell. As the fruits mature, the rachis and male bud continue to grow. In some cultivars, the male bud ceases to grow after the fruits have set and can be more or less exhausted by the time the bunch reaches maturity. The presence or absence of the male bud is one of the traits used to distinguish cultivars.
26. **Midrib dorsal surface color:** To be recorded on mature leaf 1 Yellow 2 Light green 3 Green 4 Pink purple 5 Red purple 6 Purple to blue 99 Others (Specify in the 'Remarks' descriptor)
27. **Number of fingers per hand:** Count how many fingers are in the hand. Collect the data from three fingers in the middle section of the outer whorl of the hand.
28. **Number of functional leaves per plant:** On a monthly basis, at shooting and at harvest, count the number of functional leaves. A functional leaf has 50% or more of the leaf surface area as green, healthy, photosynthetic tissue. Consider all leaves between, and inclusive of, the newest leaf and the oldest standing leaf.
29. **Number of hands per bunch:** Count total number of hands produced per bunch. To be recorded as average of 3 random bunches
30. **Number of suckers per plant:** To be recorded as average of 5 random plants at flowering stage
31. **Peduncle hairiness:** To be recorded at the time of harvest 0 Smooth/glabrous 1 Pubescent
32. **Peduncle length (cm):** To be recorded on ripe fruit 3 Short « 30) 5 Medium (30 - 60) 7 Long (> 60)
33. **Peel thickness (mm):** Remove the peel of the finger and measure the thickness of the peel, using calipers (mm).
34. **Petiole base blotches:** To be recorded on mature leaf 1 Sparse blotching 2 Small blotches 3 Large blotches 4 Extensive pigmentation 5 Without pigmentation
35. **Petiole canal shape:** To be recorded on mature leaf 1 Open 2 Partially closed 3 Closed
36. **Petiole length (cm):** To be recorded on mature leaf 3 Short < 40) 5 Medium (40 - 60) 7 Long (> 60)
37. **Pigmentation of the underlying pseudo stem:** To be recorded after removing the outermost sheath from the pseudo stem
38. **Plant height at harvest:** To be recorded from the base of pseudo stem to the emerging point of the peduncle in meter. Peduncle is the peduncle is the stalk that supports the inflorescence and attaches it to the rhizome.
39. **Position of fruits on the crown (fruit series):** 1 Uniseriate 2 Biseriate
40. **Presence of male axis (rachis):** 0 Absent 1 Present
41. **Pseudo stem color:** To be recorded without removing the external sheaths. The color of oldest dry sheaths should not be considered eg. Green yellow, Medium green, Green, Dark green, Green red and Red
42. **Pulp color:** To be recorded on ripe fruit 1 White 2 Cream 3 Ivory 4 Yellow 5 Orange 6 Pinkish 99 Others (Specify in the 'Remarks' descriptor)

43. **Pulp diameter (mm):** Remove the peel of the finger and measure the lateral diameter of the fruit pulp, from the left to the right side (not from the ventral to the dorsal side), at the widest point, using calipers (mm).
44. **Pulp taste:** To be recorded on ripe fruit 1 Astringent 2 Mild 3 Sweet 4 Highly sweet 5 Sweet and acidic 99 Others (Specify in the 'Remarks' descriptor)
45. **Pulp texture:** To be recorded on ripe fruit 3 Firm 5 Intermediate 7 Soft
46. **Rachis appearance:** To be recorded at the end of flowering 1 Barren 2 With persistent flowers 3 With persistent bracts Banana (Musa paradisiaca L.) 4 With both persistent flowers and bracts
47. **Rachis hand:** To be recorded at the end of flowering 1 Falling vertically (Pendulous) 2 At an angle (Oblique) 3 With a curve 4 Horizontal 5 Erect
48. **Rachis length (cm):** The rachis is the stalk of the inflorescence from the first fruit to the male bud. It can be bare or covered with persistent bracts. The scars on the rachis indicate where the bracts were attached. They are called nodes.
49. **Steam girth:** At shooting, measure the circumference of the pseudo stem of the plant at 1 m from the ground and at 20 cm from the ground, using a tape measure (cm).
50. **Tallest sucker height:** At shooting and at harvest, on the tallest sucker, measure the distance from the pseudo stem base at the ground to the intersection of the petioles of the two youngest leaves (leaf ranks "1" and "2"), using a measuring pole or sliding ruler (cm).
51. **Tallest sucker number of functional leaves:** At shooting and at harvest, count the number of functional leaves of the tallest sucker. A functional leaf has 50% or more of the leaf surface area as green, healthy, photosynthetic tissue. Consider all leaves between, and inclusive of, the newest leaf and the oldest standing leaf.
52. **Tip of male bud:** To be recorded during flowering 1 Imbricate 2 Non-imbricate
53. **Total soluble solids (%):** To be measured with refractometer

CITRUS DATA COLLECTION PROCEDURES

Background

The leading acid citrus fruit, because of its very appealing color, odor and flavor, the lemon, *Citrus limon* Burm. f. (syns. C. *limonium* Risso, C. *limonia* Osbeck, *C. medica* var. *limonium* Brandis), is known in Italy as*limone;* in most Spanish-speaking areas as *limón, limón agria, limón real,* or *limón francés;* in German as *limonen;* in French as *citrónnier;* in Dutch as *citroen.* In Haiti, it is *limon France;* in Puerto Rico, *limon amarillo.* In the Netherlands Antilles, *lamoentsji,* or *lamunchi*, are locally applied to the lime, not to the lemon as strangers suppose.

1. **Adherence of epicarp to mesocarp:** To be recorded on mature fruit 3 Slight 5 Moderate 1 Strong
2. **Adherence of segments to each other:** To be recorded on mature fruit 3 Slight 5 Moderate 7 Strong
3. **Arrangement of flowers:** To be recorded during flowering 1 Solitary 2 In an inflorescence 3 Both
4. **Attachment of fruit to tree:** To be recorded on mature fruit 3 Weak 5 Medium 7 Strong
5. **Biotic Stress Susceptibility:** Specify the infestation or infection using 1-9 scale. Note: For Additional information as common name(s) of disease(s)/pest(s) and causal organism(s) may be appended in the biotic notes descriptor. 1 Very low or no visible sign of susceptibility 3 Low 5 Intermediate 7 High 9 Very high
6. **Branch density**: sparse, Medium, Dense

7. **Bud color:** To be recorded just before flowering 1 White 2 Yellow 3 Green 4 Pink 99 Others (Specify in the 'Remarks' descriptor)
8. **Date of end of flowering (dd/mmlyyyy):** To be recorded when 85-90% flower buds have opened
9. **Date of fruit maturity (dd/mmlyyyy):** To be recorded when 50% fruits attain maturity
10. **Date of start of flowering (dd/mm/yyyy):** To be recorded when 5% flower buds have opened
11. **Flower type:** To be recorded at flowering stage 1 Hermaphrodite 2 Male 3 Female 99 Others (Specify in the 'Remarks' descriptor)
12. **Fruit acidity (%):** To be recorded on mature fruit
13. **Fruit apex shape:** To be recorded on mature fruit 1 Mammiform 2 Angular 3 Convex 4 Truncate 5 Depressed 3 Truncate 6 Collared with neck 99 Others (Specify in the 'Remarks' descriptor)
14. **Fruit base shape**: To be recorded on mature fruit 1 Necked 2 Convex 3 Truncate 4 Concave 5 Concave collared 6 Collared **with** neck **99** Others (Specify in **the** 'Remarks' descriptor)
15. **Fruit length (cm):** To be recorded as average of same 5 fruits
16. **Fruit shape**: To be recorded on mature fruit 1 Spheroid 2 Ellipsoid 3 Pyriform 4 Oblique 5 Oblate 6 Ovoid-oblique 7 Ovoid **99** Others (Specify in the 'Remarks' descriptor)
17. **Fruit skin color:** To be recorded on mature fruit 1 Yellow 2 Green 3 Orange 99 Others (Specify in the 'Remarks' descriptor)
18. **Fruit skin surface:** To be recorded on mature fruit 1 Smooth 2 Rugose 3 Papillate 4 Pitted 5 Bumpy 6 Longitudinal grooved and ridges 7 Hairy
19. **Fruit weight (g):** To be recorded as average of same 5 fruits
20. **Fruit width (cm):** To be recorded as average of same 5 fruits
21. **Inflorescence position:** To be recorded during flowering 1 Axillary 2 Terminal 3 Both
22. **Juice aroma:** To be recorded on mature fruit 3 Mild 5 Moderate 7 Strong
23. **Juice color:** To be recorded on mature fruit 1 White 2 Pale yellow 3 Yellow 4 Greenish 5 Orange 6 Reddish 99 Others (Specify in the 'Remarks' descriptor)
24. **Juice content**: To be measured as volume (ml) per weight (g) basis
25. **Juice taste:** To be recorded on mature fruit 1 Very poor 3 Poor 5 Fair 7 Good 9 Excellent
26. **Leaf length (cm):** To be recorded as average of 10 random mature leaves (including petiole)
27. **Leaf margin:** To be recorded on mature leaf 1 Crenate 2 Dentate 3 Entire 4 Wavy 99 Others (Specify in the 'Remarks' descriptor)
28. **Leaf or leaflet shape:** To be recorded on mature leaf 1 Elliptic ~ Ovate 3 Obovate 4 Lanceolate 5 Orbicular 99 Others (Specify in the 'Remarks' descriptor)
29. **Leaf persistency:** 1 Evergreen 2 Deciduous 3 Semi persistent
30. **Leaf type:** To be recorded on mature leaf 1 Trifoliate 2 Simple
31. **Leaf width (cm):** To be recorded as average of same 10 leaves from the wider part
32. **Mesocarp color:** To be recorded on mature fruits 1 White 2 Yellow 99 Others (Specify in the 'Remarks' descriptor)
33. **Nature of oil glands:** To be recorded on mature fruit 1 Inconspicuous 2 Conspicuous 3 Very conspicuous
34. **Number of flower buds per inflorescence:** To be recorded as average of 10 random inflorescences
35. **Number of fruit segments:** To be recorded as average of 5 random fruits
36. **Number of fruits per cluster:** To be recorded as average of 5 random clusters
37. **Number of fruits per tree:** To be recorded as average of 3 random trees

38. **Number of oil glands Citrus *(Citrus* species)**: To be recorded as number of glands per square centimeter on fruit surface
39. **Number of petals per flower:** To be recorded as average of 10 random flowers
40. **Number of seeds per fruit:** To be recorded as average of same 5 fruits
41. **Petal color:** To be recorded just after flowering 1 White 2 Yellow 3 Purple 99 Others (Specify in the 'Remarks' descriptor)
42. **Petiole wing shape:** To be recorded on mature leaf 1 Cordiform 2 Deltoid 3 Obovate 99 Others (Specify in the 'Remarks' descriptor)
43. **Productivity status:** To be recorded at the time of *harvest* 3 Low 5 Medium 7 High
44. **Pulp color:** To be recorded on mature fruit 1 Yellow 2 Green 3 Orange 4 Pink 5 Red 99 Others (Specify in the 'Remarks' descriptor)
45. **Pulp texture:** To be recorded on mature fruit 3 Tender 5 Firm 7 Tough
46. **Seed color:** To be recorded on mature fruit 1 Cream 2 Yellow 3 Green 5 Brown **99** Others (Specify in the 'Remarks' descriptor)
47. **Seed length (mm):** To be recorded as average of 20 random seeds
48. **Seed shape:** To be recorded on mature fruit 1 Fusiform 2 Clavate 3 Cuneiform 4 Ovoid 5 Deltoid 6 Globose 7 Semi – spheroid 99 Others (Specify in the 'Remarks' descriptor)
49. **Seed weight (g):** To be recorded as average of same 20 seeds
50. **Seed width (mm):** To be recorded as average of same 20 seeds
51. **Total soluble solids (%):** To be measured with refractometer
52. **Tree habit:** Upright, Spreading, Compact, Drooping
53. **Tree height (m) :** to be measured from ground level to the tip of the highest shoot
54. **Tree shape:** Ellipsoid, Spheroid, Ellipsoid – oblate, Citrus (Citrus species), Others (Specify in the 'Remarks' descriptor)
55. **Tree spread (m):** To be measured as canopy diameter (average of East - West and North· South dimensions)
56. **Trunk - rootstock diameter ratio:** 1 Smaller «1.0), 2 Same (1.0), 3 Larger (>1.0)
57. **Trunk girth (cm) :** to be measured at 20 cm above the ground level in case of trees raised from seed! Layering/cutting and at 15 cm above the graft union in grafted/budded ones

PAPAYA DATA COLLECTION PROCEDURES

Background

Cultivation of fruits played a pivotal role in diversification of agriculture along with food and nutritional security of ever-growing population. Papaya (Carica papaya) is a tropical fruit having commercial importance because of its high nutritive and medicinal value. India leads the world in papaya production with an annual output of about 3.6 million tonnes (Anonymous, 2009). It is used as ripened fruit and vegetable and easy to digest. Papaya in prepared from dried latex of its raw fruits is used in meat tendering, manufacturing chewing gum, cosmetics, for degumming silk and to give shrink resistance to wool. In addition, it is also used in pharmaceutical, textile and garment industries, cleaning paper and adhesive manufacturing, sewage disposal and so on (Anonymous, 2002).

1. **Plant height (cm):** To be recorded from ground level to apical meristem just before first fruit harvest
2. **Trunk girth (cm):** To be measured as canopy diameter (average of East - West and North· South dimensions) during active growth period
3. **Stem pigmentation:** To be recorded just before first fruit harvest 1 Only or mostly basal 2 Only or mostly lower 3 Only or mostly central 4 Only or mostly upper 5 Indiscriminate

4. **Leaf teeth shape:** To be recorded on mature leaf. 1 Straight 2 Convex 3 Concave 99 Others (Specify in the 'Remarks' descriptor)
5. **Leaf petiole color:** To be recorded on mature leaf. 1 Pale green 2 Normal green 3 Dark green 4 Green and shades of red purple 5 Red purple 99 Others (Specify in the 'Remarks' descriptor)
6. **Leaf petiole length (cm):** To be recorded as average of 5 random mature middle leaves
7. **Leaf length (cm):** To be recorded as average from base of middle leaflet of same 5 leaves
8. **Leaf width (cm):** To be recorded as average from base of middle leaflet of same 5 leaves
9. **Flower type:** To be recorded during flowering. 1 Solitary 2 Inflorescence 3 Both
10. **Inflorescence density on trunk:** To be recorded during flowering 3 Sparse 5 intermediate 7 Dense
11. **Inflorescence stalk colour:** To be recorded during flowering. 1 Greenish 2 Purplish/ pinkish 3 Dark red purple/pink 99 Others (Specify in the Hemarks' descriptor)
12. **Inflorescence main axis length (cm):** To be recorded as average of 5 basal inflorescences
13. **Date of first female flowering (ddlmm/yyyy):** To be recorded as date when first female flower appears
14. **Sex form:** 1 Staminate flower and few hermaphrodite flowers 2 A few staminate flowers and many hermaphrodite flowers 3 A few staminate, many hermaphrodites and few pistillate flowers 4 Hermaphrodite flowers only 5 Mostly hermaphrodite and few pistillate flowers 6 Few hermaphrodites and many pistillate flowers 7 Only pistillate flowers 8 Only staminate flowers
15. **Female flower color:** To be recorded on completely developed and open flower 1 White 2 Cream 3 Yellow 4 Deep yellow to orange 5 Greenish 6 Dark green 7 Yellow/green and red purple shades 8 Red purplish (pinkish) 9 Dark red purple (pink) 99 Others
16. **Hermaphrodite flower color:** To be recorded on completely developed and open flower 1 White 2 Cream 3 Yellow 4 Deep yellow to orange 5 Greenish 6 Dark green 7 Yellow/green and red purple shades 8 Red purplish (pinkish) 9 Dark red purple (pink) 99 Others
17. **Male flower corolla tube color:** To be recorded on completely developed and open flower 1 White 2 Cream 3 Yellow 4 Deep yellow to orange 5 Greenish 6 Dark green 7 Yellow/green and red-purple shades 8 Red purplish (pinkish) 9 Dark red purple (pink) 99 Others
18. **Days to first fruit set:** To be recorded as number of days from planting to first fruit set
19. **Number of fruits per plant:** To be recorded as average of 5 random plants
20. **Height to first fruit (cm):** To be recorded as average of same 5 plants
21. **Fruit shape:** To be recorded on fully developed fruit 1 Globular 2 Round 3 High round 4 Elliptic 5 Oval 6 Oblong 7 Oblong – ellipsoid 8 Oblong blocky 9 Elongate10 Lengthened cylindrical 11 Pear shaped (pyriform) 12 Club 13 Blossom end tapered 14 Acron (heart shaped) 15 Reni form 16 Turbinate inferior 17 Plum shaped 99 Others
22. **Fruit skin color:** To be recorded as overall colour of the skin of ripe fruit 1 Yellow 2 Deep yellow to orange 3 Yellowish green 4 Green 5 Red purple 99 Others
23. **Fruit skin thickness:** To be recorded on ripe fruit 3 Thin 5 Medium thick 7 Thick
24. **Fruit length (cm):** To be recorded as average of 5 random fruits
25. **Fruit width (cm):** To be recorded as average of same 5 fruits
26. **Fruit weight (g):** To be recorded as average of same 5 fruits
27. **Stalk end fruit shape:** 1 Depressed 2 Flattened 3 Inflated 4 Pointed
28. **Pulp color:** To be recorded on ripe fruit. 1 Light yellow 2 Bright yellow 3 Deep yellow to orange 4 Red 5 Reddish orange 6 Scarlet 99 Others
29. **Pulp thickness (mm):** To be recorded as average of same 5 fruits

30. **Central cavity shape:** To be recorded on fruit transverse section at maximum diameter. 1 Irregular 2 Round 3 Angular 4 Slightly star shaped 5 Star shaped 99 Others
31. **Pulp aroma:** To be recorded on ripe fruit 3 Mild 5 Moderate 7 Strong
32. **Total soluble solids (%):** To be measured with refractometer
33. **Organoleptic test:** To be recorded as a combined assessment of flavour, sweetness and aroma of ripe fruit 3 Poor 5 Intermediate 7 Good 9 Excellent
34. **Number of seeds per fruit:** To be recorded as average of same 5 fruits
35. **Seed color:** To be recorded on ripe fruit 1 Tan 2 Greyish yellow 3 Grey 4 Brown black 5 Black 6 Variable 99 Others
36. **Productivity status:** To be recorded at the time of harvest 3 Low 5 Medium 7 High
37. **Biotic Stress:** Susceptibility Specify the infestation or infection using 1 - 9 scale. Note: For Additional information as common name(s) of disease(s)/pest(s) and causal organism(s) may be appended in the Biotic notes descriptor 1 Very low or no visible sign of susceptibility 3 Low 5 Intermediate 7 High 9 Very high