AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

FARMERS' KNOWLEDGE ON ROSETTE VIRUS DISEASE AND AGRONOMIC PERFORMANCE OF RESISTANT GROUNDNUT hypogaea L.) GENOTYPES

JOSEPHINE EKUA HOPE

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FARMERS' KNOWLEDGE ON ROSETTE VIRUS DISEASE AND AGRONOMIC PERFORMANCE OF TOLERANT GROUNDNUT (*Arachis hypogaea* L.) GENOTYPES

JOSEPHINE EKUA HOPE

(8211970012)

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OCTOBER 2025

DECLARATION

Student's Declaration

I hereby declare that this thesis with the exception of quotations and references contained in published works which have been dully acknowledge; is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Name: Josephine Ekua Hope

Signature…….. Date: ……..

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised and in accordance with the guidelines on supervision of thesis as laid down by the Akenten Appiah- Menka University of Skills Training and Entrepreneurial Development.

Principal Supervisor's Name: Prof. Harrison Dapaah

Signature: …… Date: ……..

Co- Supervisor's Name: . Benard Effah

Signature: ……. Date: …….

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DEDICATION

The thesis is dedicated to my husband, Dr. Daniel Tetteh and my wonderful children Emmanuella, Daniella and Manasseh

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) is an essential oilseed crop in sub-Saharan Africa, but its production is heavily constrained by groundnut rosette disease (GRD). The study aimed at assessing farmers knowledge of groundnut rosette viral disease and its management and evaluate the agronomic performance of resistant groundnut genotypes. The study was carried out at the College of Agriculture, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ashanti Mampong campus, between April to August and September to December 2023. A mixed-methods design was employed, using semi-structured questionnaires and in-depth interviews. A total sample of 120 farmers selected through multistage sampling across three groundnut-growing communities namely, Kofiase, Asaame and Bobin. Questionnaires were pre-tested and refined before full administration. The field experiment used a Randomized Complete Block Design (RCBD) with four replications and ten groundnut genotypes. The parameters for data collection included days to 50 % emergence, days to 50 % flowering, percent plant establishment, days to maturity, number of leaves, number of branches, canopy width, stem diameter, number of pods, number of seeds per pod, pod weight, harvest index and groundnut rosette disease incidence. Farming experience differed, with Bobin farmers mostly having 1–5 years, Asaam 6–10 years, and Kofiase hosting all farmers with over 15 years' experience. Seed sourcing was largely from donors. OUG ED BEAUTY had the shortest days to 50% flowering (29 days) in the major cropping season, while OUG ICGVSM 085886 and OUG ED BEAUTY significantly recorded shorter days to 50% flowering (37 days) during the minor cropping season. Average plant height for the major cropping season was observed to have increased from week four after planting to week ten after planting with OUG ICGVSM 085886 recording the highest (40.2 cm) plant height in week ten. In the minor cropping

season, average plant height increased from week four after planting with OUG ICGVSM 085886 recording the highest (36.0) while the least plant height was recorded in NKATAE SAIRE. Mean canopy width was higher (58.8) in OUG ICGVSM 99551, whiles the lowest (51) canopy width was recorded in NKATAE SAIRE in the major cropping season. Mean number of branches was higher (54) in OUG ICGVSM 99551 while the least (47) number of branches was observed in NKATAE SAIRE in the major cropping season. OUG ICGVSM 085886 had the highest seed yield (2.68 t/ha) while the least seed yield was produced by OUG ICGVSM 99551(1.36 t/ha) and Nketae Saire (1.36 t/ha) in the major cropping season. In the minor cropping season, OUG ICGVSM 085886 and Nkatae Saire recorded the highest seed yield (2.43 and 2.32 t/ha), respectively. In the major season, OUG ICGVSM99551 recorded the highest harvest index (0.55), while Nkatae Saire had the least harvest index of 0.25.

CHAPTER ONE

INTRODUCTION

1.1 Background of study

Groundnut (*Arachis hypogaea* L.) is a highly adaptable oilseed crop grown across tropical, subtropical, and mild temperate regions in over 100 countries (Guchi *et al.,* 2014). In sub-Saharan Africa (SSA), it is widely cultivated for both commercial and household use and is globally ranked as the 13th most important food crop and the 4th most important oilseed crop (Reddy & Immanuelraj*,* 2017; Christie *et al.,* 2015). Sub-Saharan Africa accounts for 40% of the global groundnut cultivation area and contributes 26% to total global production (Abady *et al.,* 2019). Groundnuts can be consumed raw or cooked, and are also processed into oil, making them a versatile crop (Tan *et al.,* 2020). Groundnut can be grown as a cash crop to generate income for producers in developing countries and a nutrition component of their diets (Daudi *et al.,* 2018). The seeds are highly regarded in culinary applications due to their exceptional protein content of 25 % and edible oil content of 50 %. They are frequently ingested after being hulled, pulverized or processed into a variety of products including butter, paste, four and confectionary (Marloire, 2019). In addition, groundnut by-products such as oilcakes and haulms are important for livestock feed (N'Gbesso *et al*., 2019). Groundnut importance in cropping systems is derived from its nitrogen-fixing ability which enhance soil fertility and promote overall agricultural sustainability (Coulibaly *et al.,* 2021).

In Ghana, groundnut production is concentrated in the northern regions, which account for approximately 94% of the country's annual output (Masters *et al*., 2015). Cultivation is primarily carried out by smallholder farmers operating on limited land with constrained resources. Groundnut is often rotated with maize or other cereals and plays a central role

in the mixed crop-livestock farming systems (Masters *et al*., 2015). Despite the crop immense potential to satisfy the nutritional requirements of millions of individuals in sub–Saharan Africa, its production has been restricted by a variety of biotic and abiotic factors with disease being a significant importance.

Groundnut rosette viral disease (GRVD) is a major constraint to groundnut production in sub-Saharan Africa, with widespread outbreaks reported in countries such as Malawi, Nigeria, Uganda, Senegal, and Kenya (Mabele, 2020). The disease, especially when it strikes before flowering, can cause yield losses exceeding 90% (Ficke *et al*., 2018). Groundnut rosette viral disease occurs in three forms namely chlorotic rosette, prevalent throughout the region; green rosette, found in parts of West and Central Africa; and mosaic rosette, mostly confined to East and Central Africa. Its complexity arises from the interaction of three components that includes the groundnut rosette virus (GRV), the assistor virus, and a satellite RNA, all of which are essential for the disease's transmission and development (Gnanasekaran & Chakraborty, 2018).

Ntare and Olorunju (2001), note that repeated and unpredictable outbreaks of groundnut rosette disease have significantly hampered groundnut production over the past 30 years, causing substantial losses and stalling progress across the region. Major epidemics include the 1975 outbreak in northern Nigeria, which affected approximately 750,000 hectares, as well as severe losses in Zambia (1995) and Malawi (1996). According to Adu-Dapaah *et al.*, (2004), yields remain consistently low ranging between 500 and 800 kg/ha below potential levels in Ghana. Efforts to control the disease are constrained by the high cost and limited access to insecticides required to manage its insect vectors.

The sporadic and unpredicted nature of groundnut rosette viral disease outbreaks poses a substantial threat to agricultural stability, frequent resulting in the complete loss of crops (Bera *et al*., 2022). Groundnut rosette disease has been the primary cause of the significant decline in the Africa groundnut crop over the past three decades (Jones, 2020). Production and expansion efforts have been impeded by recurring epidemics throughout sub-Saharan Africa.

1.2 Problem statement and justification

Groundnut rosette disease (GRD) is widely regarded as the most destructive virus disease affecting groundnut in sub-Saharan Africa, with yield losses reaching up to 100% when infections occur before flowering (Mabele, 2020). It is transmitted by the aphid (*Aphis craccivora)* (Shah *et al*., 2015), and caused by a complex interaction of three virus agents acting synergistically. Although outbreaks do not occur every year, when they do, they can be catastrophic. For instance, in 1975, groundnut rosette disease destroyed approximately 700,000 hectares of groundnut in Nigeria, resulting in an estimated loss of 0.5 million tonnes, valued at US$250 million as reported by Bwala *et al*., (2019)**.** Similarly, in Zambia, around 43,000 hectares were affected during the 1995–1996 season, leading to losses of about US$5 million (Bwala *et al*.,2019). These outbreaks are unpredictable and can suddenly eliminate key sources of food, income, oil, and seed for replanting. Such was the case in Malawi during the 1994/95 epidemic, where the area under groundnut cultivation declined by 23 % the following year. In the 1990s, annual economic losses from groundnut rosette disease across Africa were estimated at US$155 million (Mugisa *et al*., 2016).

Although research institutions have collaborated with various partners in recent decades to address groundnut rosette virus disease, significant gaps remain. The real-world effectiveness of recommended control strategies and the extent of farmers' knowledge and understanding of the disease are still poorly understood. One key limitation has been the minimal involvement of farmers in the research process. In Africa, where agricultural challenges are highly diverse and location-specific, this exclusion has reduced the relevance and impact of research outcomes (Mapiye & Dzama, 2024). The continued reliance on a linear research, extension and adoption model where researchers develop technologies, extension agents disseminate them, and farmers are expected to adopt them limits meaningful participation and long-term uptake (Srisopaporn *et al*., 2015). Critically, questions about farmers perceived knowledge of the disease, their agronomic practices, and the actual field effectiveness of recommended interventions remain unanswered. Martin *et al*. (2013), emphasized that a detailed understanding of local farming systems is essential for designing and implementing effective integrated virus disease management strategies. Therefore, assessing farmers' knowledge and practices is not only fundamental for improving groundnut productivity in specific regions but also vital for enhancing national production and promoting agricultural sustainability. Bridging these research gaps is crucial for developing responsive, integrated disease management programs and strengthening the resilience of groundnut farming systems across affected areas.

1.3 Objectives of the study

The main objective of the study was to assess farmers knowledge of groundnut rosette virus disease and its management and the agronomic performance of resistant groundnut genotypes.

1.3.1 Specific Objective

The specific objectives were:

1. Assess farmers knowledge of groundnut rosette virus disease and its effects on the crop.
2. Evaluate the agronomic performance of nine exotic genotypes and a local groundnut genotype.
3. Assess the resistant status of nine exotic genotypes and a local groundnut against the groundnut rosette virus disease.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin, Distribution and Taxonomy of Groundnut

Groundnut (*Arachis hypogaea* L.), a member of the Leguminosae family and the Papilionoideae subfamily, was domesticated in the region encompassing Brazil, Argentina, Paraguay, Peru, and Bolivia. Its origins can be traced back to South America. Groundnut is currently widespread and has been adapted to the tropical, subtropical, and mild temperate regions of the world (Hidano *et al*., 2018; Singh, 2011).

India, China, Nigeria, Senegal, Sudan, Burma, and the United States are the primary countries that produce groundnuts worldwide. Groundnut is a significant commercial commodity in Senegal, Gambia, Nigeria, and Sudan (Verter, 2017). According to Tan *et al*., (2020), the savanna zone, located south of the Sahara, is the source of approximately 80% of the 6 million tons of groundnuts produced in Africa. Despite the fact that groundnut is cultivated in all agro-ecological zones of Ghana, the majority of groundnut production and approximately 85% of the area under groundnut cultivation occur in the Guinea and Sudan savanna agro-ecological zones in the north (Makur, 2019).

A large and diverse set of diploids (2n = 2x = 20 or 18) and allotetraploids (2n = 4x = 40) comprise the species of the genus Arachis, which are perennial or annual legumes. Most likely, Arachis hypogaea is a recent allotetraploid that was produced through the natural chromosome duplication that followed the hybridization of two native species. It is classified into two subspecies: hypogaea and fastigiata Waldron (Gantait *et al*., 2019; Levinson, 2021).

2.1.1 Botany

Groundnut is a member of the family Leguminosae, tribe Aeschynomeneae, subtribe Stylosanthinae of genus Arachis. Arachis hypogaea is an annual herb of indeterminate growth habit which has been divided into two subspecies, hypogaea and fastigiata, each with several botanical cultivars (Stalker, 1997). The groundnut flower is orange to yellow in colour, with standard, wing and keel, bisexual, zygomorphic, complete and sessile. It is produced above ground in the axils of leaves near the base of the plant about four to six weeks after planting, depending on genotype and environment, especially temperature (Stalker, 1997). The flower is inserted on top of a pedicel that curves downward and pushes the flower into the soil following pollination and fertilization where it produces seed (Stalker, 1997). Smith (1950) described the groundnut flower as having a curved beaked keel, with two petals fused along the dorsal edges to the apex but opened ventrally at the base. The peg grows down into the soil as a positively geotropic stalk-like structure (Coolbear, 1994), and the peg tip continues to enlarge, eventually forming a groundnut pod below the soil surface in 7 to 10 weeks (Coolbear, 1994). The number of kernels per pod may range from one to five and sometimes to six and is influenced by cultivar and environmental factors (Rai *et al*., 1994).

2.2 Production, Uses and Economic Importance of Groundnut

Peanut is the thirteenth most significant food commodity in the world, the sixth most significant source of consumable oil, and the third most significant source of vegetable protein (Variath & Janila, 2017). Developing countries are responsible for 97% of the global groundnut area, which contributes approximately 94% to the global production. The majority of groundnut production takes place in Asia and Africa, with Asia comprising 56% of the global area and 68% of the total global production, and Africa

accounting for 40% of the global area and 26% of the total global production (Cleasby *et al*., 2020). China is the world's largest producer, with 15.7 million metric tonnes. India, Nigeria, and the United States of America follow, with 6.6, 3.4, and 2.4 million metric tonnes, respectively (Langholtz *et al*., 2016). Ghana is currently rated ninth globally and fourth in Africa with 0.44 million metric tonnes (Otoo, 2023). In sub-Saharan Africa (SSA), groundnut is primarily produced by small-scale landowners under rainfed conditions. Nigeria, Senegal, and Sudan are the largest producers, with 1.55, 1.0, and 0.85 million metric tonnes, respectively (Kortei *et al*., 2022).

While groundnut is cultivated in all agro-ecological zones of Ghana, the Guinea and Sudan savanna agro-ecological zones account for the majority of the nation's groundnut production, with approximately 85% of the total area under cultivation. 91.4% of the national output was generated in the northern sector of Ghana during the 2003 cropping season, with a total of 439,030 metric tonnes of groundnut produced from a land area of 464,710 ha (Appiah, 2017). An average annual production of 498,134 metric tonnes was recorded in the northern sector in 2010, with an average land area of 327,550 hectares. Peanuts are a significant source of protein and vegetable oil, as well as dietary protein and vitamins (thiamine, riboflavin, and niacin) for individuals in numerous developing countries (Arya et a., 2016). Two-thirds of the world's peanut production is converted into oil, while the remaining portion is consumed as sustenance by humans (Arya *et al*., 2016; Davis & Dean, 2016). Peanut seeds are a significant source of vitamins E, K, B1, and B3, minerals, and dietary fiber, and they contain 44-52% high-quality edible oil, 26-28% readily digestible protein, and 20% carbohydrates (Singh *et al*., 2021). Peanuts are characterized by a high lipid content (approximately 46%) that is predominantly composed of monounsaturated fatty acids and lacks cholesterol, as per Mingrou (2022).

Numerous researchers have demonstrated that the regular consumption of peanuts reduces serum low-density lipoprotein (LDL) cholesterol levels, thereby enhancing cardiovascular health and reducing the likelihood of developing type II diabetes. Furthermore, its satiating effect has been demonstrated to facilitate weight management when incorporated into a moderate-fat diet. The leaves and stalk (haulms) are used as forage for livestock after harvesting, while the 'cake' that is produced after oil extraction is a valuable protein source for feeding animals. Shells are employed as fuel, as filler in animal feed, and in the production of cardboard (Ijarotimi, 2015; Tesfaye & Abera, 2022). By fixing atmospheric nitrogen, it enhances soil fertility (Adu-Dapaah *et al*., 2004). Peanuts are extensively employed in Ghana as a source of culinary oil and in confectionery products intended for human consumption. In northern Ghana, peanut hay (vine) is a critical fodder resource for livestock production, particularly during the dry season when green forage is scarce (Davis & Dean, 2016; Bimpong *et al*., 2023). Although the crop offers numerous advantages, its production has been restricted by a variety of diseases, including viral diseases that are economically significant.

2.2.1 Climatic and Soil requirements

Groundnut thrives in specific environmental conditions to ensure successful cultivation. The crop performs best in warm climates with temperatures ranging between 25-30°C throughout the growing season. This temperature range is crucial for proper flower development, pod formation, and kernel filling. The crop performs better in well-drained, loose, and sandy loam soils with good organic matter content provide the ideal growing medium. The recommended pH range for groundnut cultivation is between 6.0 and 7.0 allowing for optimal nutrient availability and root development .

2.3 Factors affecting Production and Yield of Groundnut

In Sub-Saharan Africa (SSA), groundnut cultivation is susceptible to a variety of biotic and abiotic stresses, including drought, parasites, diseases, and aflatoxin, which can result in substantial yield losses if not addressed. The primary causes of yield losses in SSA are maladies, which are the most prevalent among these constraints (Abady *et al*., 2019; Akale & Mohammed, 2020). According to Jeyaramraja *et al*., (2018), drought stress is experienced in nearly two-thirds of the global production areas. This has an impact on the quality and yield of groundnuts. The groundnut industry is also facing a significant challenge due to the decline in soil fertility levels, which is a result of inadequate crop management practices and inadequate fertilizer application. Diseases and parasites are another biotic factor that is globally disseminated. Early leaf spot (Cercospora arachidicola) and late leaf spot (Cercosporidium personatum) are the most notable among them. These maladies have an impact on groundnuts in all regions that cultivate groundnuts, as per Neya *et al*., (2023) and Kankam *et al*., (2022). In Africa and India, yield reductions can range from 50-70% as a result of a combination of late leaf spot and rust (Puccinia arachidis). Groundnut rosette disease (GRD), a viral disease of groundnuts, is another disease that is endemic to Sub-Saharan Africa (SSA) and can cause significant devastation during an epidemic.

2.4 Diseases and Pests of groundnut

Diseases and parasites are significant obstacles to the global production of groundnuts. Numerous diseases, including those caused by bacteria, fungi, nematodes, parasitic ornamental plants, viruses, and mycoplasmas, have been identified in groundnuts (Kumar & Thirumalaisamy, 2016). These diseases are responsible for low yields. The sole significant bacterial disease of groundnut, bacterial wilt, is caused by *Pseudomonas*

solanacearum and is found in groundnut-producing regions of Africa and Asia (Umadevi *et al*., 2021). Seed rots and seedling diseases, including root rot, stem rot, wilts, blight, pod rot, and foliar diseases, are caused by fungi (Kumar & Thirumalaisamy, 2016). The most significant foliar diseases of groundnut in the world are early and late spot diseases, which are caused by Cercospora arachidicola Hori and Cercosporidium personatum, respectively (Neya *et al*., 2023). Rust (Puccinia arachidis Speg.) has also been discovered to infect groundnut on a global scale, resulting in substantial losses (You *et al*., 2024). Production in all regions of the globe where groundnuts are grown is known to be impeded by a number of viral maladies (Reddy, 1991. The most catastrophic form of GRD has been identified in SSA (Mukoye *et al*., 2019).

2.5 Groundnut Rosette Disease

James *et al*. (2023) have long recognized that groundnut rosette virus disease (GRD) is a significant biotic constraint on groundnut production in Sub-Saharan Africa (SSA). The severity of GRD typically increases in groundnut crops that are introduced late in the season, despite the fact that it typically occurs in minor proportions throughout each growing season. The disease has the potential to cripple rural economies in SSA and substantially reduce groundnut production when epidemics do occur. Alhassan (2013) estimates that an epidemic in northern Nigeria in 1975 resulted in the destruction of approximately 0.7 million hectares of groundnut, resulting in a loss of US$250 million. Similarly, an epidemic in 1995 in eastern Zambia resulted in an estimated loss of US$4.89 million, affecting approximately 43,000 hectares. Groundnut production in the central region of Malawi was reduced by 23% the following year. Key market class cultivars, including landraces, have succumbed to GRD, resulting in a yield reduction of as low as 800 kg ha-1, in contrast to the 3,000 kg ha-1 reported from on-station sites in Uganda

(Kayondo *et al*., 2014). The annual potential gain from the effective management of GRD is US$121 million, with the primary focus on the enhancement of genetic resistance to the disease. GRD is a virus disease that is transmitted by the aphid, *Aphis craccivora* Koch (Insecta: Homoptera). The etiology of GRD is influenced by three causal agents: groundnut rosette assistor virus (GRAV), groundnut rosette virus (GRV), and a satellite-RNA (SatRNA) (Mabele & Were, 2020; Mahas *et al*., 2023). A unique and captivating virus disease, GRD is caused by the intricate association of the three agents. Despite significant advancements in our understanding, the origin and perpetuation of this disease in nature remain an enigma.

2.5.1 Symptoms of Groundnut Rosette Disease

Chlorotic and green rosette are the two variant symptoms of groundnut rosette disease, with variable symptoms within each type (Mukoye & Mabele, 2019). The disease causes plants to be severely diminished, resulting in an unkempt appearance due to reduced leaf size and shortened internodes for the plants. The primary cause of symptom variations is variations in the SatRNA (Obrępalska-Stęplowska *et al*., 2018). Variable climatic conditions, differences in genotypes, plant stage at infection, and blended infections with other viruses also contribute to symptom variability in field conditions. For plants that are susceptible to chlorotic rosette, the leaves are typically brilliant yellow with a few green islands. Within the green rosette, the leaves are a mosaic of light green to dark green, with a dark green appearance. Chlorotic or green rosette disease infection in immature plants (prior to flowering) typically leads to a 100% yield loss. Chlorotic or green rosette infection in immature plants (prior to flowering) typically results in a 100% yield loss. Appiah (2007), stated that plants infected during the later growth stages (between flowering and pod setting) may exhibit symptoms only in certain branches or

sections of branches, and the extent of the yield loss is contingent upon the severity of the infection. However, infection after pod setting/maturation has negligible effects on pod yield. The detrimental effects of GRAV or GRV on the host plant in a synergistic manner with SatRNA are unknown. In diseased groundnut plants that contain all three agents, stunting is more severe than in those that contain only GRV and SatRNA (Masicia & Gallitelli, 2016). GRAV or GRV infection alone in groundnut induces transient mottle symptoms that have a negligible effect on the plant's growth and yield, according to certain reports (Appiah *et al*., 2017). However, recent research has shown that GRAV infection alone has a considerable impact on plant growth and contributes to substantial yield losses in susceptible cultivars (Savary & Willocquet, 2020).

2.5.2 Groundnut Rosette Assistor Virus

Groundnut Rosette Assistor Virus belongs to the family Luteoviridae and was first identify as a causal agent groundnut rosette disease by Sreenivasulu *et al*., (2008). The virus is anti-genically related to barley yellow dwarf, bean leaf roll, beet western yellows and potato leaf roll viruses. symmetry and made of single coat protein subunits of size 24.5 kDa. It has a non-segmented genome, single molecule of linear positive-sense, single-stranded RNA of c. 6900 nucleotides that encodes for structural and non-structural proteins. GRAV is thought to encode for six Open Reading Frames (ORFs) unlike other members of the luteovirus. The virus replicates autonomously in the cytoplasm of phloem tissue and transmitted by A. craccivora in a persistent manner. The virus on its own cause symptomless infection or transient mottle, and can cause significant yield loss in susceptible groundnut cultivars (Sastry, 2013). The only known natural host of the virus is groundnut. GRV is an umbravirus but has no recognizable virus-like particle (VLP). It was first isolated and characterized by Jeger (2023). According to Taliansky and

Robinson (2003), the virus has no structural (coat) protein and thus no conventional virus particles are formed. Moreover, enveloped bullet-shaped structures discovered in the ultra-thin sections of infected cells were shown to be cytopathological structures due to GRV infection, as opposed to real virions. The virus genome is a non-segmented positive sense with RNA of size c. 4019 that codes for four ORFs and is single liner molecule. The genome of an isolate was completely sequenced and several partial sequences are available in the Gene Bank. GRV on its own cause transient symptoms, but a SatRNA associated with GRV is responsible for rosette disease symptoms (Xu *et al*., 2016). The GRAV is responsible for encapsidation of its RNA transmission in a persistent mode by A. craccivora. Waliyar *et al*., (2007) reported that the virus can be transmitted by grafting and mechanical inoculation, but not through seed, pollen or contact between the plants (Nallathambi *et al*., 2020; Umer *et al*., 2019).

2.5.3 Satellite RNA of GRV

The GRV-satRNA is 895 to 903 nt in length, and its variants have been demonstrated to be responsible for the various forms of symptoms in GRD. Additionally, it has been determined that the aphid transmission of GRV is contingent upon the GRV satellite RNA in addition to GRAV. Despite the absence of virus-like particles in plants infected with GRV alone, abundant dsRNA has been identified in these plants. This dsRNA forms a distinctive electrophoretic band pattern with three main species: 4.6 kbp (dsRNA-I), 1.3 kbp (dsRNA-2), and 900 bp (dsRNA-3). The infectivity of preparations containing the dsRNA species is contingent upon their heat-denaturement, which suggests that the infective RNA molecules are single-stranded. It has been demonstrated that dsRNA-3 is a double-stranded form of a satellite RNA that is dependent on RNA-1 for replication in

plants, whereas dsRNA-2 appears to be a double-stranded form of a sub-genomic fragment of RNA-1.

2.6 Role of Satellite RNAs in symptom expression by plant viruses

Viral satellites are viruses or nucleic acids that require a helper virus for replication, but they are not essential for the replication of the helper virus and do not share a significant degree of sequence homology with the helper virus genome (Gnanasekaran *et al*., 2018; Krupovic *et al*., 2016). SatRNAs do not encode their own coat proteins, in contrast to satellite viruses. Depending on the specific satRNA, they are either encapsidated separately within the coat protein of their helper viruses or in association with the viral RNA(s) (Badar *et al*., 2021). Satellite RNAs are typically brief molecules, with a length of less than 1,500 nucleotides.

The capacity of satellite RNAs to modify the symptoms generated by plant viruses is a distinctive characteristic that captivates plant virologists. Although the majority of viral satellites, including those of Tobacco ringspot virus (TobRV), mitigate disease, others may exacerbate symptoms of the disease caused by the virus alone or in conjunction with another, avirulent satellite (Badar *et al*., 2021). Additionally, certain satellites exhibit novel symptoms that are not exclusively linked to the helper virus. For instance, the satRNAs of Cucumber mosaic virus (CMV) are responsible for Lethal tomato necrosis, Brilliant yellowing of tobacco, and chlorosis of tomato, while a satRNA of Arabis mosaic virus (ArMV) causes hop nettle head. The satellite-like RNAs of GRV are responsible for Groundnut rosette. Some Malawian cultures of GRV, as per Kumar *et al*., (1991), induced dazzling yellow blotch mosaic symptoms in N. benthamiana, as opposed to the

typical veinal chlorosis and mild mottle. However, the typical chlorotic rosette symptoms in groundnut were still apparent.

2.7 Host Resistance to Groundnut Rosette disease

The first sources of resistance to GRD in groundnut were discovered in 1952 in landraces of the late-maturing Virginia (A. hypogaea L. subsp. hypogaea var. hypogaea) from Burkina Faso and Cote d'Ivoire (Janila *et al*., 2016). This discovery has since served as the foundation for breeding programs across Africa. The resistance was discovered to be regulated by two recessive genes and was effective against the GRV and its sat RNA. It is possible that the resistance is not inherited (Achola *et al*., 2023). Additionally, individual plants may succumb to the disease when subjected to high inoculum pressure, and GRV-resistant lines are not immune to the virus (Usman *et al*., 2015). In contrast, the virus has not been identified as a resistance to GRAV, and all rosette-resistant lines and genotypes are susceptible to it (Amoah *et al*., 2016). The identification of numerous GRV-resistant sources was the outcome of the evaluation of groundnut germplasm (Ncube-Kanyika *et al*., 2015). Some groundnut breeding lines have been found to be resistant to the aphid vector, and this resistance is regulated by a single recessive gene. Nevertheless, Herselman *et al*., (2004) have demonstrated that aphid-resistant sources are susceptible to GRAV and GRV, as well as the sat RNA.

2.8 Progress in Managing Rosette Disease

Various methods are available for protecting groundnut against rosette disease. These include the removal of volunteer groundnut plants that serve as inoculum source, cultural practices that can interfere with vector movement, use of insecticides to control aphids and use of rosette disease resistant cultivars.

2.8.1 Chemical Control

Long acquisition access feeding period required by the vector provides an opportunity to control aphids with chemical sprays before they can spread the disease. Various insecticides have been used to control A. craccivora to minimize or prevent spread of rosette disease in field trials. Timing of spray dosage and type of insecticide utilized is critical for controlling aphids. However, insecticides are an unviable option in SSA due to high costs and scarcity, thus seldom preferred by the farmers. Furthermore, insecticide applications pose detrimental effects on health and environment and their usage is being discouraged.

2.8.2 Control through Cropping Practices

Information on the control of GRD by cultural practices have widely reported (Waliyar *et al*., 2007; Mugisa *et al*., 2015; Mohammed *et al*., 2018). Early sowing in the season to take advantage of low aphid populations, and maintaining good plant density without any gaps (aphids prefer widely spaced plantings for landing) have been shown to reduce rosette disease incidence. However, early sowings may not be effective in areas where groundnut is grown continuously, as this allows perpetuation of virus and vector. Rouging of voluntary sources and early-infected plants prevent the primary and secondary spread of the disease. Intercropping with cereals such as maize, sorghum, finger millet, beans and cowpea were shown to affect aphid colonization, movement and behavior within crops, thereby GRD incidence (Farrell 1976c, Alegbejo 1997). However, control by cultural practices by smallholder farmers is difficult under subsistence farming conditions due to farmers' pre-occupation with other revenue generating practices, unpredictable climate, small-land holdings and farmers' reluctance to adopt improved cultural practices.

2.8.3 Host Plant Resistance

The most cost-effective and practicable approach to managing GRD in the field is to identify GRD-resistant varieties. Consequently, significant efforts have been made to identify durable GRD-resistant sources.

Resistance to GRD was initially identified in groundnut germplasm from Burkina Faso and Côte d'Ivoire. The development of numerous groundnut genotypes and the identification of germplasm lines with acceptable levels of field resistance to rosette disease have been contributed to by subsequent efforts in breeding for host plant resistance and evaluating the groundnut germplasm collection held in the ICRISAT genebank (Waliyar *et al*., 2007). The evaluation of 12,500 lines from ICRISAT's genebank collection of groundnut germplasm has led to the identification of 150 resistant sources. Of these, 130 are long-duration Virginia types and 20 are short-duration Spanish. 25 accessions that were resistant to rosette disease were identified through the evaluation of 116 wild Arachis accessions, which represented 28 species. In Samaru, Nigeria, 2,301 germplasm lines were just recently assessed, and 65 novel sources of resistance to rosette were discovered. Of these, 55 are long-duration Virginia types and 10 are short-duration Spanish types. It is uncertain whether these resistant sources contain identical or distinct types of resistance DNA.

In general, a genotype's resistance to rosette disease was evaluated by the absence of symptom expression. Consequently, this resistance was primarily directed against GRV and SatRNA, the two components that are responsible for rosette symptoms. It was reported that genotypes that are resistant to GRV and SatRNA experienced a decrease in yield, which may be attributed to their susceptibility to GRAV. In fact, a recent study that

separated GRAV from GRV and SatRNA and examined its impact on the agronomic performance of four groundnut genotypes confirmed this. The study also demonstrated that GRAV infection alone can significantly reduce groundnut seed yield (Usman *et al*., 2015; Bua & Opio, 2014; Mubai, 2019).

Previously, resistance to rosette disease was primarily present in latematuring cultivars that were derived from groundnut germplasm collected from the border region between Côte d'Ivoire and Burkina Faso. This resistance, which does not constitute absolute immunity, was demonstrated to be regulated by two distinct recessive alleles and is effective against both chlorotic and green forms of rosette. This resistance is ineffective against GRAV and is directed against GRV (and therefore also to SatRNA). In recent years, this form of resistance has been transformed into early-maturing cultivars that are advantageous for cultivation in regions with brief growing seasons. Among these are ICG 12991, which was released in four Eastern and Southern Africa (ESA) states; ICGV-SM 99568, which was issued as "Chitala" in Malawi; ICGV 93437, which was released as "Nyanda" in Zimbabwe; and ICGV-IS 96894, which was released as "Samnut 23" in Nigeria. Other promising elite short duration Spanish lines, like ICGV-SM 99541, ICGV-SM 01513 and ICGV-SM 01514; and medium duration Virginia lines, like ICGV-SM 01708, ICGV-SM 01731, ICGV-SM 03701 are currently under advanced testing in several countries in ESA. There are also a number of early maturing rosette resistant strains available in West Africa. A list of rosette resistant varieties released in the ESA and WCA (West and Central Africa) region is illustrated in Table 1.

Variety Name	Type	Pedigree	Source of Resistance	Released
ICGV-SM 90704	Virginia	RG1 × Mani Pintar	RG1	Malawi, Mozambique, Zambia, Uganda
ICG 12991	Spanish	Landrace	Landrace	Malawi, Mozambique, Uganda, Zambia
ICGV-SM 99568	Spanish	ICGV 93437 × ICGV-SM 93561	RMP 40	Malawi
ICGV 93437	Spanish	ICGV 86063 × ICGV 86065	Unknown (complimentary gene action?)	Zimbabwe
SAMNUT 23 (ICGV–IS 96894)	Spanish	(ICGV-SM 85048 × RG 1) F2 -P4 -B1 B1-B1 -B1-B1B1	RG1	Nigeria
SAMNUT 21 (UGA 2)	Virginia	RMP 12 × ICGS 56 (E)	RMP 12	Nigeria
SAMNUT 22 (M572.80I)	Virginia	RMP 91 × (4753.70 × 3520.71)	RMP 91	Nigeria

Sourced: Waliyar *et al*. (2007)

The wild Arachis species were also found to possess resistance to rosette disease, with several of them appearing to be immune to both GRAV and GRV and SatRNA. A hybrid derivative derived from an interspecific cross of A. hypogaea x A. chacoense exhibited a high degree of resistance to rosette, suggesting the potential of GRD resistance in interspecific breeding programs. The resistance of groundnut to Aphis craccivora (ICG 12991) was also identified, and it was demonstrated to be susceptible to all GRD agents. Nevertheless, we have recently discovered that resistance in ICG 12991 frequently yields to GRD in situations of high disease pressure. Resistance to the aphid vector is regulated by a single recessive gene, which was located on linkage Group-1 at a distance of 3.9 cM from a marker originating from a susceptible parent (ICGV-SM 93541). Studies have demonstrated this. Identification of this DNA marker provided an opportunity to create

a straightforward DNA-marker-based method for aphid resistance screening, which could potentially expedite the breeding process.

The deployment of transgenic forms of resistance that utilize genes derived from the virus itself (pathogen-derived resistance) is a potential future strategy for enhancing resistance to GRD. Plants transformed with constructs derived from a modest variant of the satellite RNA in Nicotiana benthamiana at the Scottish Crop Research Institute, UK, exhibited resistance to GRV.

Nevertheless, this approach has not been evaluated for its efficacy in safeguarding groundnuts from rosette disease. Groundnut plants (cv. JL 24) have been transformed at ICRISAT with constructs derived from the GRAV coat protein. The transgenic events are currently in the T3 generation and have not yet been assessed for GRAV resistance (Karanja, 2009).

2.8.4 Screening for GRD Resistance

Viruliferous aphids and grafting can be employed to assess the resistance of groundnut genotypes to all three GRD agents, whether they are grown in containers under greenhouse conditions or dispersed in fields. Genotypes can be assessed for resistance to only GRV and SatRN through mechanical sap inoculation (Lai *et al*., 2015). A. Test plants can be inoculated with vector aphids that have been fed on GRAV-infected groundnut plants or grafted with scions from GRAV-infected groundnut plants to assess genotypes for resistance to only GRAV. A. Diagnostic assays, including RT-PCR and TAS-ELISA, can be employed to verify the presence or absence of GRD agents during genotype evaluation (Pasupuleti & Nigam, 2013).

Two methodologies are currently employed to conduct routine assessments of GRD resistance in groundnut genotypes, as per Bangaru *et al*., (2023). Resistance to GRV-SatRNA is the primary consideration of the rating scale employed in both methods. One approach involves the use of a 1-5 disease rating score to assess the resistance of GRDs (see Table 2). The other method, which is frequently employed, is based on the percent disease incidence (PDI) that is measured during the early pod filling stage of the crop (Table 3). Each row's total number of plants and the number of plants exhibiting rosette symptoms (chlorosis with severe stunting) are tallied at 80- and 100-days post-germination. The genotype resistance to GRD is evaluated by calculating the mean percentage incidence for each plot over the two counts and the PDI in each row.

Table 2.2: Evaluation of Groundnut Genotypes based on 1 to 5 Disease Rating Score

Score	Genotype reaction	Inference
1	No visible symptoms on the foliage	Highly resistant
2	Rosette symptoms on 1-20% foliage, but no obvious stunting	Resistant
3	Rosette symptoms on 21-50% foliage and stunting	Moderately resistant
4	Severe rosette symptoms on 51-70% foliage and stunting	Susceptible
5	Severe symptoms on 71-100% foliage, stunted or dead plants	Highly susceptible

Table 2.3: Evaluation of Groundnut Genotypes based on percent disease Incidence (PDI)

PDI	Inference
Less than 10%	Highly resistant
11-30%	Resistant
31-50%	Moderately resistant
More than 50%	Susceptible

Zhang and Mothial (2016) reported that breeding for resistance was first initiated in the 1950s by the French Institut de Recherches pour les Huiles et Oléagineux (IRHO) in West Africa, using landraces from Burkina Faso and Ivory Coast as their first sources of resistance to GRD. These were used to breed for resistant cultivars and became the basis for resistance breeding in Africa. Through these efforts, long-duration varieties such as 69-101 (130 days to maturity), RMP 12, RMP 40 and RG 1 (140-150 days) and early maturing (90 days) Spanish (A. *hypogaea* L subsp. *fastigiata* var. *vulgaris*) were developed. Through the years, a number of accessions have been screened for resistance to GRV and GRAV with several sources of resistance being reported. The infector row technique was used to screen these lines and 65 accessions were reported to have high levels of resistance, while 134 breeding lines were resistant. However, all disease resistant lines were susceptible to GRAV. According to Obonyo *et al*., (2024), the major disadvantages of land race cultivars is that they take long to mature, usually 130-150 days thus making them prone to end of season drought. The available few early maturing cultivars that may be resistant are not preferred by farmers because of their poor agronomic traits leading to less adoption. The challenge then is to have short duration cultivars that are resistant with good agronomic traits like high yield that are adapted to SSA conditions. ICRISAT launched a breeding programme in the early 1980s in Malawi for the development of resistant cultivars that are early maturing using the infector row technique for screening genotypes. This technique leads to 99% infection of the susceptible plants (Waliyar *et al*., 2007). Genotypes with resistance and yield higher than the susceptible genotypes by 19-93% under natural and high disease pressure have been developed and deployed to national breeding programmes in several SSA countries where they have been released while some are still being tested (Tadessae *et al*., 2019). For example, in Zambia, ICGV SM 08503, ICGV SM 12991 and ICGV SM 90704 have

been released as resistant lines and named as MGV 7, Katete and Chishango respectively while ICGV SM 01711 and ICGV SM 01514 are been tested by the variety release committee for possible release (SCCI, 2015). All the released resistant cultivars and breeding lines that have been developed are not resistant to GRAV but only to GRV which leads to sat RNA resistance indirectly. Such genotypes do not develop symptoms. GRV resistance does not offer immunity meaning under high disease pressure, the resistance breaks down. There have been reports of GRAV immunity present in wild species. This immunity can be transferred to cultivated groundnuts through conventional and molecular breeding approaches. Mofokeng and Gerrano, (2021) noted that aphid vector resistance is one area that can be exploited in the breeding programme as it has been identified in many existing breeding lines.

2.9 Other Viruses of Groundnut

About 31 viruses have been reported to naturally infect groundnut worldwide. Those of global or regional economic importance include Tomato spotted wilt virus (TSWV), Groundnut bud necrosis virus (GBNV), Tobacco streak virus (TSV), Peanut clump virus (PCV), Peanut stripe virus (PStV), a strain of Bean common mosaic virus (BCMV), Peanut mottle virus (PeMoV) and CMV, GRV and GRAV. In addition to GRAV and GRV, the following viruses have been reported as naturally infecting groundnuts in West Africa: Cowpea mild mottle virus (CPMMV), Groundnut chlorotic spotting virus (GCSV), Groundnut eyespot virus (GEV), Peanut clump virus (PCV) 21, Peanut yellow mottle virus (PeYMV) and more recently GRSV. GRSV belongs to the genus Tospovirus in the family Bunyaviridae, is not seed borne, and is naturally vectored by several species of thrips from the genus Franklinella. GRSV is regarded as an emerging threat to crop production in several crops of economic importance, including groundnut. The virus was

first identified in groundnuts from South Africa and subsequently in Argentina, Brazil and Ghana. The virus has also been found as infecting other crops such as tomato, cubiu, cucumber and watermelon (Park *et al*., 2015; Radhakrishnan *et al*., 2016; Parameswari *et al*., 2024).

2.10 Genotype x Environment Interaction (GEI) in Groundnut

The efficiency of a selection program is primarily determined by the magnitude of genetic variation and heritability of a trait, making it crucial to determine the proportion of phenotypic variation of a trait that is heritable in order to design an appropriate breeding program (Cobb *et al*., 2019). Adaptation to specific environments has been a significant breeding objective for groundnut cultivators, in addition to achieving high haulm and kernel yield. GEI is a significant issue that complicates the interpretation of genetic experiments, reduces the efficacy of selection, and makes predictions difficult. It also involves quantitative characteristics. This interaction can be induced by changes in the absolute differences between genotypes without rank change or by genotypic rank change for quantitative characteristics (Mohammadi & Amri, 2013). Subsequently, it is crucial to possess an understanding of the extent of GEI in order to create cultivars that exhibit consistent performance and increased yields across a diverse array of environmental conditions. The analysis and interpretation of GEI encompass a wide spectrum of topics, including simple variance analysis and more detailed genotype performance analyses (Appiah *et al*., 2016). The identification of appropriate genotypes with a maximum GEI and a moderate level of resistance or susceptibility to disease has been anticipated to be of immense benefit in the improvement of groundnut production (Chaudhari, 2017). In addition, they reported a substantial linear component of GEI for kernel yield and concluded that genotypes differed in their linear response to

environmental fluctuations. The magnitude of variation due to environment for kernel yield was higher than G x E (linear) for the same trait which depicted the main part of the total variation and was deemed a linear function of environment only (Cuevas *et al*., 2016). Sae-Lim *et al*. (2016) reported that the variance of the genotype x environment interaction for PBNV was significant but modest in an earlier investigation of the G x E interaction. The genotypes that were examined exhibited equivalent field resistance in all environments. Selection may occur in any of these environments; however, it is more effective in environments that are conducive to disease development. Teressa *et al* (2021) elucidated the various forms of G x E interactions and emphasized their significance in the fields of crop production and plant breeding. Breeders are most interested in crossover interactions, which are the most significant factors in genotype selection in specific environments, as they directly influence the rankings of varieties across environments.

As a result, promising choices that demonstrate potential in one environment may not perform as well in another. Breeders are frequently compelled to implement multiple selection programs within industries based on the homogeneity of regions as a result of these crossover interactions, which results in the utilization of more resources. Neglecting substantial G x E in favour of resource savings can result in diminished genetic gains from selection. Poor productivity in environments that interact negatively with specific genotypes may result from inaccurate characterization of genotype adaptability, which has implications for industry sustainability. In terms of genetic gains from selection, heritability (the proportion of total phenotypic variance that is attributable to genetic variance) is adversely affected by large G x E interactions, which are components of total phenotypic variance. The heritability estimates decreases as the G x

E interaction component increases; consequently, the advancement from selection would be diminished (Wakchaure *et al*., 2016).

2.11 Genetic Diversity in Cultivated Groundnut

DNA-based markers provide a reliable means for estimating the genetic relationships among genotypes or taxonomic groups as compared to the morphological markers (Amom & Nongdam, 2017). Precise understanding of the degree of genetic relationships among genotypes, botanical varieties of peanut, and Arachis species could provide insights into the domestication and evolution of this crop. Furthermore, it would have a valuable impact on peanut improvement, through identification of appropriate parents, to ensure a broad genetic base by inter-variety and inter-species crosses. DNA-markers, such as, randomly amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), and simple sequence repeats (SSR) have been used for cultivar discrimination and to study the botanical relationships among the cultivated peanut varieties (Sheeja *et al*., 2021). AFLP and SSR techniques can be used to detect DNA polymorphism in the cultivated peanut. AFLP and SSR are two powerful DNA fingerprinting techniques. A number of loci can be analysed in an experiment and there is a higher reproducibility of banding patterns by AFLP. SSR markers have several advantages over other molecular markers for their codominant inheritance, large number of alleles per locus, and abundance in genomes (Grover & Sharma, 2016). These characteristics have promoted the application of SSR as molecular markers in fingerprinting (Testolin *et al*., 2023; Wang *et al*., 2019), genome mapping (Kumaraswamy & Kashyap, 2021), phylogenetic and genetic relationship studies (Surgonda, 2015), and marker assisted breeding (Patwardhan *et al*., 2014) in many crops. However, there are few reports concerning SSR and AFLP for evaluation of genetic

diversity and relationships among the Arachis species, and much remains to be discovered. Ren *et al*. (2014) reported considerable DNA polymorphism in A. hypogaea revealed by the AFLP approach, this assay has been used for molecular diversity studies in peanut by several researchers. Comparing SSR and AFLP primers, SSR primers amplified 91 polymorphic loci in total with an average of 3.14 alleles per primer, and the AFLP primers amplified 72 polymorphic loci in total with an average of 2.25 alleles per primer. Four SSR primers (14H06, 7G02, 3A8, 16C6) and one AFLP primer (P1M62) were found to be most efficient in detecting diversity. They also noted that genetic distance between pairs of Bacteria Wilt (BW) genotypes ranged from 0.12 to 0.94 with an average of 0.53 in the SSR data and from 0.06 to 0.57 with an average of 0.25 in the AFLP data. The SSR-based estimates of the genetic distance were generally larger than that based on the AFLP data. The genotypes belonging to subsp. fastigiata possessed wider diversity than that of subsp. Hypogaea (Alkaraki, 2019).

The clustering of genotypes based on the SSR and AFLP data were similar but the SSR clustering was more consistent with morphological classification of A. hypogaea. Optimum diverse genotypes of both subsp. hypogaea and subsp. fastigiata can be recommended based on this analysis for developing mapping populations and breeding for high yielding and resistant cultivars In a study of Phylogenetic Relationships in Genus Arachis based on SSR and AFLP markers, Tang *et al*., (2008) found genetic distance detected by the SSR markers ranged from 0.09 to 0.95, and the mean was 0.73; and the genetic distance detected by the AFLP markers ranged from 0.01 to 0.79 with an average of 0.42. They also reported that in all the tested BW resistant peanut genotypes, SSR primer pairs were multilocus ones, and the amplified fragments per SSR marker in each peanut genome ranged from 2 to 15 with a mean of 4.77. The peanut cultivars were

closely related to each other, and shared a large number of SSR and AFLP fragments. Sheeja *et al*., (2021) partitioned the BW resistant peanut genotypes into two main groups and four subgroups at the molecular level, and that A. duranensis is one of the wild ancestors of A. hypogaea. The lowest genetic variation was detected between A. cardenasii and A. batizocoi, and the highest was detected between A. pintoi and the species in the section Arachis (Upadhyaya *et al*., 2013). Distinct clustering pattern of wild and cultivated genotypes was also reported in genetic diversity studies through SSR and EST – derived SRR maker systems. In a related study using single nucleotide polymorphism–based genetic diversity in the reference set of peanut (Arachis spp.) Khera *et al*., (2013) reported high level of diversity between wild and cultivated peanut and affirmed that grouping pattern exhibited discrete clustering of genotypes based on subspecies, botanical varieties and genome types. Mean genetic similarity between genotype pairs was found to be 0.13 and maximum between ICG 8200 and ICG 8206 at 0.4. They also reported the average major alleles was maximum in AA genome (0.81) and minimum in EE genome (0.56) while for BB and AABB genomes, it was found to be 0.71 and 0.63, respectively. The average PIC ranged from 0.21 (AA genome) to 0.38 (EE genome) while BB and AABB genomes recorded 0.31 and 0.32 respectively (Khera *et al*., 2013). The narrow genetic base variation observed in cultivated tetraploid groundnut may be attributed to its very recent origin in its evolutionary time as compared to other crops and is a serious genetic bottle neck towards modern breeding effort (Khera *et al*., 2013). Hence tapping the maximum genetic variation in the primary gene pool is vital to groundnut improvement. From the literature reviewed so far, the genetic background of parents in breeding programs is still narrow, which may have impeded the progress of breeding (Singer *et al*., 2021). Hence, a better understanding of the genetic

diversity amongst the available GRD resistant germplasm is a prerequisite for further efficient improvement of GRD resistance.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study 1 – Field survey (Objective 1)

Location of the Study areas

The socioeconomic study was conducted in three groundnut growing communities, namely, Kofiase, Asaamu and Bobin located approximately six to sixteen kilometres from the Municipal capital (Figure 3.1). Geographically, the Ashanti Mampong Municipality lies between longitudes 0°05' and 1°30' W and latitudes 6°55' and 7°30' N and shares borders with the Sekyere Afram Plains District to the south, Sekyere Central District to the east, Ejura-Sekyedumasi District to the north and Afugya Sekyere District to the West.

The study area experiences two distinct rainy seasons: a major rainy season (April-August) and a minor season (September-December). The average annual temperature is 27ºC, with monthly temperature variations ranging from 22 to 30ºC. The area is situated within the forest Savannah transition agroecological zone.

Figure 3.1: Map of showing the study locations

Source: Ashanti Mampong Municipal Assembly annual report

3.1.1 Research design

The study employed both qualitative and quantitative methods. For the quantitative study both close and open-ended questionnaires (a semi-structured questionnaire) were designed and administered to select respondents. Qualitative data was collected using in-depth interviews. For respondents with no formal education, questionnaires were interpreted to them in their native language and their responses recorded and transcribed.

3.1.2 Instrument for data collection

Data collection was done using semi structured questionnaire (open and closed ended questions).

3.1.3 Sample size and sampling technique

For the study, a total sample size of 120. Sample size determination following studies of of Krejcie &Morgan (1970) as cited by Wanjohi &Gicheru, 2012. For each community, a sample size of 40 groundnut farmers was purposively selected with the help of Agricultural extension agents for questionnaire administration and interviews. The study employed multistage sampling technique to select respondents from the different groundnut growing communities. The questionnaire was pre-tested using twenty groundnut farmers from each community and adjustments were made following previous study by Larson *et al.,* (2014).

3.1.4 Data Analysis

Descriptive statistics were used to summarize responses from respondents from the different groundnut growing communities. Data collected were analysed using cross-tabulation. Statistical differences were compared using chi-square and a P-value of < 0.05

was considered significant. Statistical analyses were achieved using Statistical Package for Social Sciences (SPSS) version 27.0.

3.2. Study 2 - Field Experiment (Objective 2 and 3)

The study was conducted at the research fields of the College of Agriculture on the Asante Mampong campus of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development from April to July, 2023 for major cropping season and August to December for minor cropping season, 2023. The study area lies between longitudes 0°05' and 1°30'W and latitudes 6°55' and 7°30'N, with an average annual rainfall of 1270 mm and has an attitude of 425.7m above sea level. The area experiences a dual rainy season, with the major rainy season from March to August and a secondary season between September and December. The average annual temperature is 27°C, with monthly temperatures ranging from 22°C to 30°C. The soil at the experimental site is classified as a Savannah Ochrosol, belonging to the Bediesi series, formed for the Voltain sandstone. It has been classified as chromic on the Luvisol according the FAO/UNESCO soil classification system (FAO/UNESCO, 1990).

3.2.1 Experimental Design and Treatments

The experimental design was a Randomized Complete Block Design (RCBD) with four (4) replications and made up of ten groundnut genotypes as shown Table 3.2

Table 3.2: Genotypes of groundnut

S/N	Groundnut genotype
1	OUG ED BEAUTY
2	OUG ICGVSM 99537OUG
3	ICGVSM 08556
4	OUG ICGVSM 01504
5	OUG ICGVSM 9955
6	OUG ACHOLI WHITE
7	OUG ICGVSM 99551
8	OUG ICGVSM 08577
9	OUG ICGVSM 085886
10	NKATIE SAIRE(CONTRO-LOCAL)

Each plot size measured 2 m wide x 3 m long made up of four ridges/plots. The plants spacing used was 50 between rows and 20 cm within rows. The seeds were planted on ridges of three seeds per drill which was thinned to two plants per hill, two weeks after planting.

3.2.2 Cultural and management practices

The field was ploughed and harrowed, ridges raised using a hand hoe. Weeds were controlled on the plots mainly by hand-hoeing. Uprooting of weeds around the plants was occasionally done. Fungi disease symptoms were controlled with Forum TMR fungicide (dimethyl dithiocarbamate) at the rate of 37.3 g per litre of water. A CP15 Knapsack sprayer was used in spraying the pesticides.

3.2.3 Data Collection

3.2.3.1 Phenology

3.2.3.1.1 Days to 50 % Emergence

The number of days to emergence was estimated as the number of days after planting, when 50 % of the two harvestable middle rows had actually emerged.

3.2.3.1.2 Days to 50 % flowering

The number of days to 50 % flowering was estimated as the number of days after planting, when the plants in the two middle harvestable rows had produced at least one flower.

3.2.3.1.3 Percent Plant establishment

The percentage of plants that successfully established in the two middle harvestable rows on each plot was calculated and recorded at 2 weeks after planting (WAP).

3.2.3.1.4 Days to Maturity

The number of days to maturity was estimated as the number of days after planting when the plants in the two middle harvestable rows had matured, that is when the pod colour changed from white to dark brown and the surface of the pod changed from spongy to coarse texture.

3.2.3.2 Growth

3.2.3.2.1 Plant Height

Plant height was measured from the soil level to the apical tip of two harvestable middle rows from four weeks after planting and every other two weeks to ten weeks after planting.

3.2.3.2.2 Number of leaves

The number of leaves was determined by counting all opened leaves on five selected plants in the two harvestable rows from the week four after planting to ten weeks after planting.

3.2.3.2.3 Number of branches

The number of branches was determined by counting all the number of branches on five selected plants in the two harvestable rows from four weeks after planting to the ten weeks after planting.

3.2.3.2.4 Canopy width

Canopy width of five selected plants in the two middle rows was measured with a meter rule at the widest part of the canopy from week four to week ten after planting.

3.2.3.2.5 Stem diameter

The stem diameter of five selected plants in the two middle rows was measured with a vernier calliper from four to week ten after planting.

3.2.3.3 Yield and Yield components

3.2.3.3.1. Number of pods

Number of pods per plants were counted and recorded from five selected plants from the middle rows.

3.2.3.3.2 Number of seeds per pod

The number of seeds per pod were counted and recorded for ten selected pods from the plants in the harvestable middle rows.

3.2.3.3.3 Pod weight per plant

The weight of pods per plants was done by weighing from the five selected plants from the harvestable middle rows.

3.2.3.3.4 hundred (100) seeds weight

The weight of 100 seeds from three lots per plot were measured and recorded

3.2.3.3.5 Seeds Yield (kg/ha)

Seed yield was calculated from the plants harvested from the two middle rows.

3.2.3.3.6 Harvest Index

Harvest index was calculated using the formular: Harvest index (%) = [Grain yield / Biological yield] x 100 (Mukhtar *et al*., 2013)

3.2.3.3.7 Groundnut rosette disease Incidence

The incidence of the groundnut rosette disease was recorded at 30, 40, 50 and 60 days after symptoms (DAS) and assessed using the disease incidence formula as cited by Gwa (2019), as $Z = \frac{K}{N} \times 100$

Disease incidence was calculated as follows:

Z = Disease incidence, K =Number of infected plants stands in the plot and Y = total number of., plants stand (infected and uninfected) in the plot.

3.2.3.3.8 Severity of groundnut rosette disease

The severity of groundnut rosette disease was assessed at 40, 50, 60 and 70 days after symptoms (DAS). For each plot, ten test plants randomly selected and tagged. Scoring for disease severity were recorded using 1-5 disease rating scale as cited by (Olorunju *et al.,* 2001), where (1) = no visible symptoms on leaf (highly resistant), (2) = rosette symptoms covering 1- 20 % of leaf area but no obvious stunting (resistant),(3) = rosette symptoms on 21-50% area of leaf with stunting (moderately resistant),(4) = severe symptoms on 51-70 % leaves with stunting (susceptible) and (5) = severe symptoms on 71-100 % leaves with stunting (Highly susceptible). The disease severity was determined as follow:$= \frac{\sum n \times 10}{\text{Number of graded plants x maximum graded plants}}$

Where : $\sum n$ = summation of all individuals assessments (rating)

3.2.4 Data Analysis

The treatment effects were subjected to the Analysis of variance (ANOVA) using Genstat version 23 Statistical Package. The means that showed significant differences were separated at 5% probability rate using HSD test.

CHAPTER FOUR

RESULTS

4.1 Study 1 – Field Survey

4.1.1 Demographic Characteristics of Groundnut Farmers

The results indicated that most farmers were aged between 31 and 40 years, accounting for 52.5% in Kofiase, 70.0% in Asaam, and 50.0% in Bobin, while the under-20 age group had the least representation (Table 4.1). In terms of gender distribution, male farmers were the majority in Asaam (72.5%) and Bobin (82.5%), whereas Kofiase had a higher proportion of female farmers (75.0%). Regarding marital status, married individuals dominated across all three communities, but single farmers were more prevalent in Bobin (54.5%). Asaam recorded the highest percentage of divorced individuals (64.7%) (Table 4.1). Educational levels varied, with basic education being most common in Kofiase (60.5%), senior high school education in Bobin (46.2%), and tertiary education in Asaam (45.5%). Notably, respondents without formal education were found only in Kofiase. In terms of farming experience, most farmers in Bobin had 1–5 years of experience (54%), while Asaam had the highest percentage (56.6%) of farmers with 6–10 years of experience (Table 4.2)

Table 4.1 Demographic characteristics of respondents

Variable	Category(years)	Kofiase	Asaam	Bobin	Total frequency
Age	Under 20	5(12.5)	2(5.0)	3(7.50)	10(25)
	21-30	2(5.0)	5(12.5)	2(5.0)	9(22.5)
	31-40	21(52.5)	28(70.0)	20(50.0)	69(172.5)
	Above 40	12(30.0)	5(12.5)	15(37.5)	32(80)
Total		**40**	**40**	**40**	**120**
Gender	Male	10(25.0)	29((72.5)	33(82.5)	72(180)
	Female	30(75.0)	11(27.5)	7(17.5)	48((120)
		40	**40**	**40**	**120**
Marital status	Single	5(15.2)	10(30.3)	18(54.5)	33(100)
	Married	28(42.4)	19(28.8)	19(28.8)	66(100)
	Divorce	3(17.6)	11(64.8)	3(17.6)	17(100)
	Separate	2(100)	0	0	2(100)
	Widow	2(100)	0	0	0(100)
		40	**40**	**40**	**120**
Educational level	Basic	23(60.5)	11(28.9)	4(10.6)	38(100)
	SHS	9(17.3)	19(36.5)	24(46.2)	52(100)
	Tertiary	0	10(45.5)	12(54.5)	22(100)
	Vocational	1(100)	0	0	1 (100)
	None	7(100)	0	0	7 (100)
Total		**40**	**40**	**40**	**120**
Years of experience in groundnut cultivation	1-5 years	13(26)	10(20)	27(54)	50(100)
	6-10 years	12(22.6)	30(56.6)	11(20.8)	53(100)
	11-15 years	3(60)	0	2(40)	5 (100)
	Above 15 years	12(100)	0	0	12 (100)
Total		**40**	**40**	**40**	**120**

Values in bracket represent percentage

4.1.2 Farmers Knowledge on groundnut rosette virus disease

From figure 4.1, most 31(43.7%) of the farmers in Kofiase preferred cultivating the red seed type of groundnut, while few 19(26.7%) of them in Bobin community also cultivate the red seed type. About 21(48.8%) of the farmers in Bobin cultivate the Brown seeds whiles farmers from Kofiase community cultivate the least 3(6.9%).

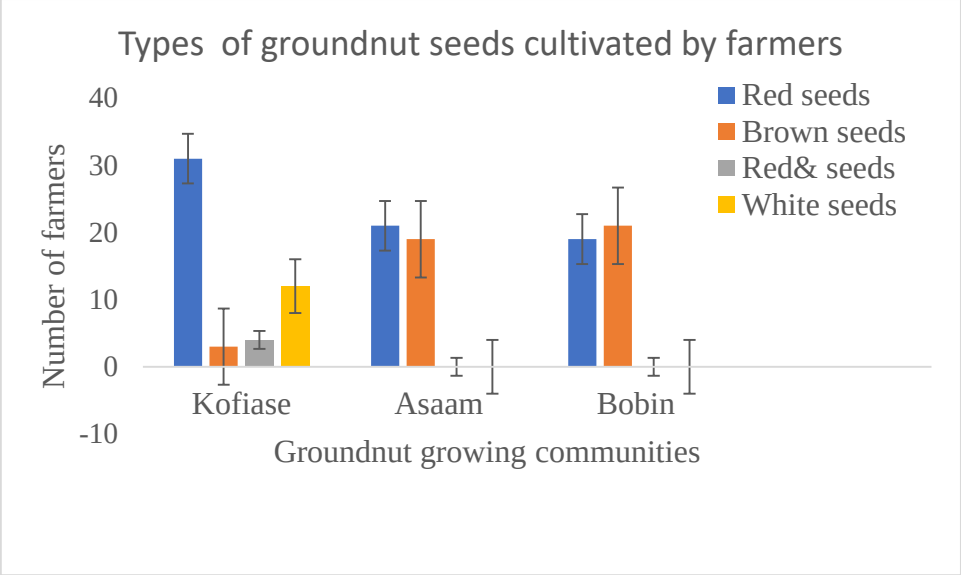


Figure 4.1: Types of groundnuts seed colour cultivated by farmers in the different communities

Regarding the source of seeds for groundnut cultivation, about 26(39.7%) of the farmers in Bobin obtained their seed from colleague farmers. Results of the study also indicates that most 24(34.5 %) of the farmers in Kofiase obtained their seeds from colleague farmers (Fig 4.2).

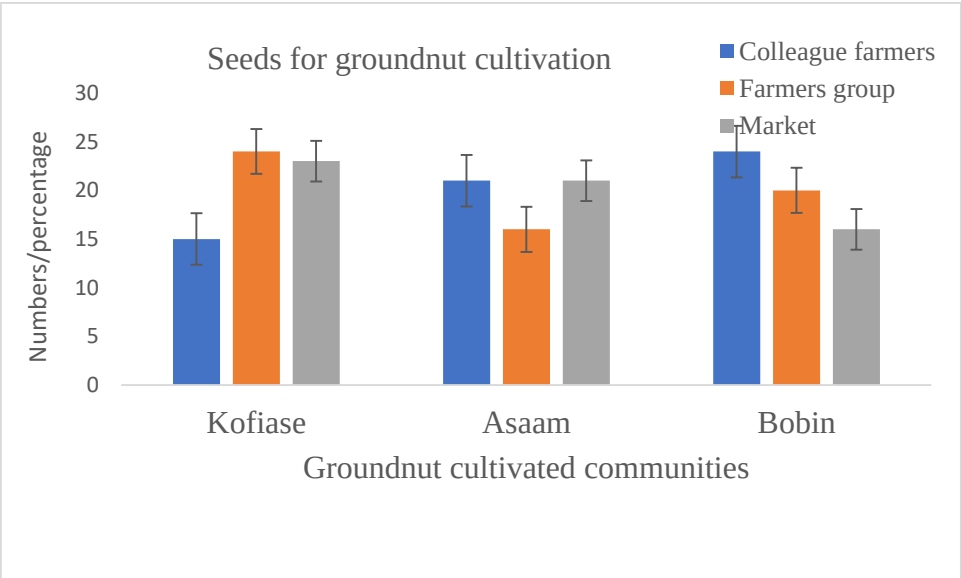


Figure 4.2: Acquisition of groundnut seeds for cultivation

Majority (95%) of the respondents were of the view that they are aware of the groundnut rosette disease (Table 4.2). More than half (59.2%) of the respondents were of the view that they became aware of the disease through field observation whiles few (20%) claim they became aware through friends. Majority (85%) of the farmers claim the disease is \caused by lack of rainfall whiles only about 15% were of the view that the disease is caused by virus infection. In view of the trend of occurrence of the disease over the years, about (38.3%) of the respondents claim that the trend of the occurrence of the disease is the same while few (10 %) were of the view that it is unpredictable (Table 4.2). Regarding the type of groundnut rosette disease symptom observed, majority (73.3%) of the respondents were of the view that they observe yellow rosette symptoms on their fields (Table 4.2). The study also indicates that majority (75.8%) of the respondents interviewed were of the view that they experience the disease in the rainy season while few (14.2 %) of them indicated the disease often occur during the dry season (Table 4.2).

Table 4.2: Farmers' perception of the groundnut rosette virus disease

Variable	Category	Kofiase	Asaamu	Bobin	Total
Awareness of GRVD	Yes	35(30.7)	40(35.1)	39(34.2)	114(100)
	No	5(80)	0	1(20)	6(100)
Total		**40**	**40**	**40**	**120**
Channel of awareness of the disease	Field Observation	37(52.1)	11(15.5)	23(32.4)	71(100)
	Friends	1(4.2)	19(79.2)	4(16.6)	24(100)
Total	Research institutions	2(8)	10(40)	13(52)	25(100)
		40	**40**	**40**	**120**
Causes of the disease	Lack of rainfall	34(33.3)	40(39.2)	28(27.5)	102(100)
Total	Viral disease	6(33.3)	0	12(66.7)	18(100)
		40	**40**	**40**	**120**
Trends of occurrence	Increasing	3(13.6)	11(50)	8(36.4)	22(100)
	Same	9(19.6)	19(41.3)	18(39.1)	46(100)
	Decreasing	16(40)	(10(25)	14(35)	40(100)
	Unpredictable	12(100)	0	0	12(100)
Total		**40**	**40**	**40**	**120**
Seasons disease is Experienced	Rainy season	23(20.3)	40(47.3)	28(32.4)	91(100)
	Dry season	16(80)	0	1(20)	17(100)
	Both	1(3.8)	0	11(96.2)	12(100)
Total		**40**	**40**	**40**	**120**

4.2 Study 2- Field Experiment

4.2.1 Climatic conditions of the experiment site

Total annual rainfall for the major season during the period of the experiment was 784 mm while the minor season recorded 786.9 mm rainfall (Table 4.3). The experimental site also recorded a total temperature of 158.5°C in the major season and 159.2°C temperature in the minor season (Table 4.3). Total relative humidity for the major season at 15 hours was 315 % and for the minor season was 308 % and at 6 hours relative humidity was 452 % for the major season and 440 % for minor season respectively.

Table 4.3: Climatic Data for Major and Minor Cropping Seasons of 2023

Month	**Total Rainfall (mm)**	**Mean Relative Humidity (%)**		**Monthly Temperature (^{0}C)**	
		Major Cropping Season			
Months	Total rainfall	6:00 hrs	15:00hrs	Min temp	Max temp
MAR	57.8	88	55	23.1	33.8
APR	258.8	91	59	22.7	33.3
MAY	71.3	90	60	23.2	32.8
JUN	198	92	70	23.0	30.3
JUL	198.9	91	71	21.8	28.4
Total	**784.8**	**452**	**315**	**113.8**	**158.6**
		Minor Cropping Season			
AUG	213.4	93	74	22.5	29.0
SEP	196	92	69	22.4	30.6
OCT	286.4	90	62	23.0	32.0
NOV	91.1	91	59	23.5	33.1
DEC	0	74	44	22.7	34.5
Total	**786.9**	**440**	**308**	**114.1**	**159.2**

Ghana Meteorological Agency, Mampong

4.2.2 Phenology

4.2.2.1 Days to 50% Emergence and flowering

The mean number of days to 50% seedling emergence as affected by different groundnut varieties is presented in Table 4.4. There were no significant ($p > 0.05$) differences in days to 50% emergence in the major cropping season, but there were significant ($p <$

0.05) differences in days to 50% emergence in the minor cropping season. Days to 50 % seedling emergence ranged from 7-8 days and 7-10 days for the major and minor seasons, respectively. In the minor cropping season, OUG ICGVSM 08577 and NKATAE SAIRE took lesser number of days (7 days) to attain 50% emergence, followed by OUG ED BEAUTY, OUG ICGVSM 99537OUG, ICGVSM 08556, OUG ICGVSM 99551 and OUG ICGVSM 085886 which took 8 days while OUG ACHOLI WHITE again took more (10 days) days to attain 50% seedling emergence (Table 4.4).

Table 4.4. Days to 50 % Emergence

Genotype	Days to 50 % Emergence	
	Major Season	Minor season
OUG ED BEAUTY	9	8
OUG ICGVSM 99537OUG	9	8
ICGVSM 08556	9	9
OUG ICGVSM 01504	8	8
OUG ICGVSM 9955	9	9
OUG ACHOLI WHITE	9	10
OUG ICGVSM 99551	9	8
OUG ICGVSM 08577	9	7
OUG ICGVSM 085886	9	8
NKATAE SAIRE (Control- local)	8	7
CV	6.57	9.12
HSD(0.05)	NS	1.89

Table 4.5 shows the mean number of days to 50 % flowering of the different groundnut varieties. There were significant ($P < 0.05$) differences in the days to 50 % flowering among the genotypes for both minor and major cropping seasons. The days to 50 % flowering ranged from 29-37 days in the major season and 37-45 days in the minor season (Table 4.5). During the major cropping season, NKATAE SAIRE and OUG ACHOLI WHITE took fewer (29) days to attain 50% flowering, OUG ICGVSM 99537OUG took 30 days, OUG ICGVSM 085886 also took 32 days and three varieties (OUG ED BEAUTY, OUG ICGVSM and OUG ICGVSM 08577) took 33 days and the longest

number of days (37) to 50% flowering was recorded in OUG ICGVSM 99551. In the minor cropping season, OUG ICGVSM 085886 and NKATAE SAIRE again significantly took fewer days (37) to attain 50% flowering, ICGVSM 08556 and OUG ED BEAUTY took 38 days and 40 days, respectively. Two varieties (OUG ICGVSM 9955 and OUG ICGVSM 99551) both took the same number of days (41) to attain 50% flowering, both OUG ICGVSM 01504 and OUG ICGVSM 08577 also took 42 days, OUG ICGVSM 99537OUG took 43 days and then OUG ACHOLI WHITE attained 50% flowering in 45 days after sowing.

Table 4.5. Days to 50% Flowering in Ten Varieties of groundnut

Genotype	Days to 50 % Flowering	
	Major Season	Minor season
OUG ED BEAUTY	33	40
OUG ICGVSM 99537OUG	30	43
ICGVSM 08556	35	38
OUG ICGVSM 01504	33	42
OUG ICGVSM 9955	35	41
OUG ACHOLI WHITE	29	45
OUG ICGVSM 99551	37	41
OUG ICGVSM 08577	33	42
OUG ICGVSM 085886	32	37
NKATAE SAIRE (Control- local)	29	37
CV	6.88	4.68
HSD(0.05)	5.43	4.60

4.2.2.2 Percent Plant establishment

The mean percentage plant establishment and days to maturity as affected by varieties are presented in Table 4.6. The percentage plant establishment and days to maturity were significantly ($p < 0.05$) influenced by varieties during both major and minor cropping seasons. The percentage plant establishment ranged from 87.5-94.5 % and 62.3-79.5 % for the major and minor seasons respectively. During the major cropping season,

NKATAE SAIRE had the highest plant establishment (94.5%), two varieties (OUG ICGVSM and OUG ICGVSM 99551) had the next highest (94.0% establishment), both OUG ICGVSM 9955 and OUG ICGVSM 08577 recorded the same (93.8% establishment) and the lowest was recorded on ICGVSM 08556 as 87.5%. During the minor cropping season, NKATAE SAIRE again recorded the highest % plant establishment as 79.5%, followed by OUG ICGVSM 9955 and then OUG ICGVSM 99537OUG (74.8% and 73.5% respectively), followed by two varieties (OUG ICGVSM 99551 and OUG ICGVSM 08577) which both recorded 71.3%, and the, lowest was recorded on OUG ED BEAUTY as 62.3%. Generally, percentage plant establishment was higher in the major season than the minor season.

Days to Maturity

During the major cropping season, OUG ICGVSM 085886 had the shortest days to maturity (89 days), OUG ICGVSM 99537OUG also had 91 days, both OUG ICGVSM 08577 and OUG ED BEAUTY0 had 96 days, while ICGVSM 08556 recorded 97 days and there were delayed in maturity for OUG ICGVSM and OUG ACHOLI WHITE as they recorded 102 days and 101 days, respectively. In the minor cropping season, OUG ICGVSM 085886 again had the shortest days to maturity (97 days), followed by OUG ICGVSM 99537OUG (98 days). Both OUG ICGVSM 08577 and OUG ED BEAUTY0 recorded 102 days and the most delayed varieties were OUG ICGVSM and OUG ACHOLI WHITE (which both recorded 109 days).

Table 4.6: % Plant Establishment and Days to Maturity as affected by Varieties

Genotype	% Plant Establishment		Days to Maturity	
	Major Season	Minor Season	Major Season	Minor Season
OUG ED BEAUTY	89.0	62.3	98	104
OUG ICGVSM 99537OUG	88.8	73.5	91	98
ICGVSM 08556	87.5	66.3	97	105
OUG ICGVSM 01504	94.0	70.8	102	109
OUG ICGVSM 9955	93.8	74.8	98	106
OUG ACHOLI WHITE	93.3	69.5	101	109
OUG ICGVSM 99551	94.0	71.3	99	107
OUG ICGVSM 08577	93.8	71.3	96	102
OUG ICGVSM 085886	92.8	64.8	89	97
NKATAE SAIRE (Control-local)	94.5	79.5	96	102
CV	3.68	8.24	3.95	3.18
HSD (0.05)	8.25	14.11	9.31	8.03
Season (HSD =0.05)	2.147	1.569		

4.3 Vegetative Growth

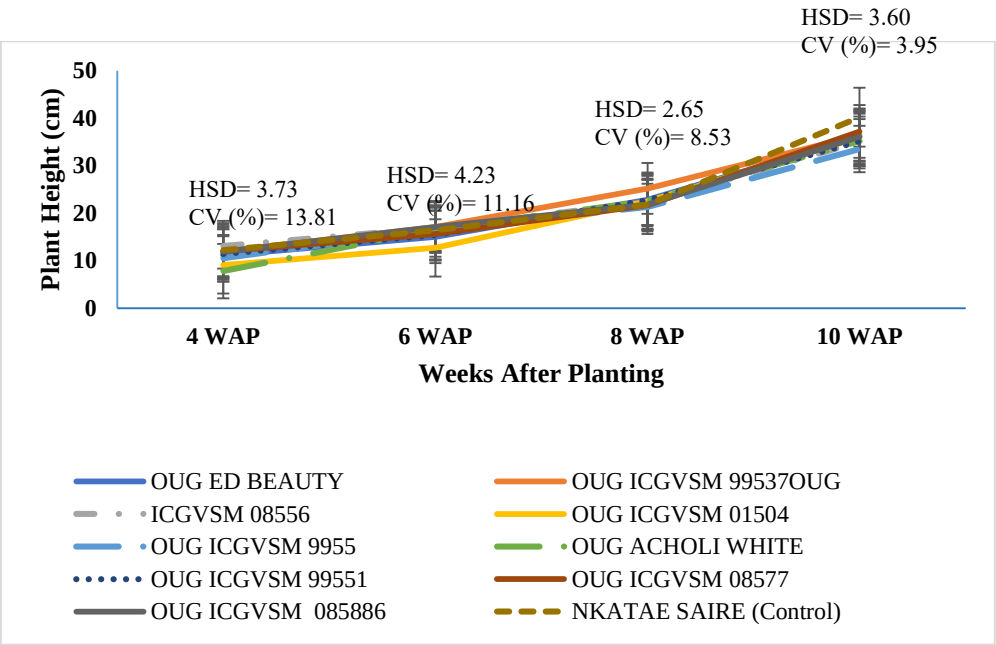
4.3.1 Plant Height (cm)

Average height of groundnut as affected by the different varieties at 4 to 10 WAP for both major and minor cropping seasons are indicated in Figure 4.3. There were significant ($p< 0.05$) differences in plant height from 4 to 10 WAP as influenced by the different genotypes.

Average plant height for the major cropping season was observed to have increased from 4 to 10 WAP, with OUG ICGVSM 085886 having the tallest (40.2 cm) at 10 WAP, followed by OUG ICGVSM 08577 with plant height of (37.2 cm) while the shortest plants were observed in OUG ICGVSM 9955 (33.5 cm) (Figure 4.3a). However, for the minor cropping season, average plant height also showed a steady increased from 4 WAP with OUG ICGVSM 085886 recording the highest (36.0), followed by OUG ICGVSM

08577 with plant height of (32.8 cm) while the least plant height was recorded in OUG ICGVSM 9955 (29.3 cm) as indicated in Figure 4.3b.

(a) Major Cropping Season



(b) Minor Cropping Season

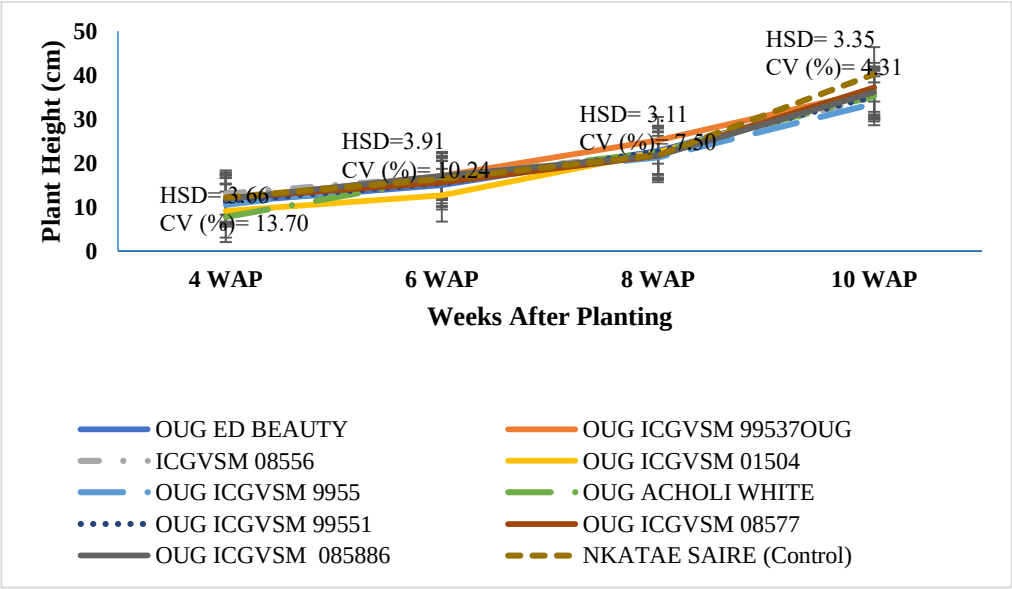
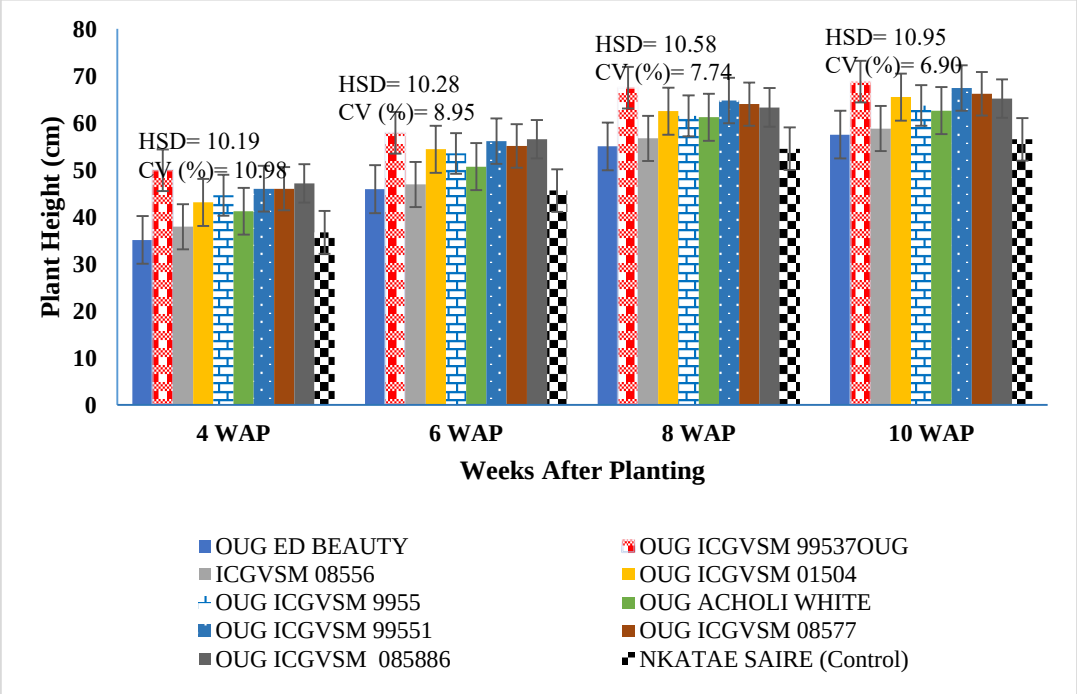


Figure 4.3: Plant Height of 10 Groundnut Genotypes during Major and Minor Cropping Seasons, 2023

Number of Leaves per Plant

Mean number of leaves per plant of groundnut as affected by the different varieties at 4 to 10 WAP for both major and minor cropping seasons are indicated in Figure 4.4. Mean number of leaves per plant varied significantly ($p<0.05$) among the different groundnut genotypes at 4 to 10 WAP in the major season. Results of the study showed that mean number of leaves per plant was highest (69 leaves) in OUG ICGVSM 99537OUG, followed by OUG ICGVSM 99551 (67 leaves) whiles the lowest (57 leaves) number of leaves per plant was recorded in NKATAE SAIRE in the major cropping season at the end of 10 WAP (Figure 4.4a). Generally, the results showed that mean number of leaves was higher (71 leaves) in OUG ICGVSM 99537OUG, followed by OUG ICGVSM 99551 (70 leaves) while the least (58 leaves) number of leaves was rather found in OUG ED BEAUTY in the minor cropping season (Figure 4.4b).

(a) Major Cropping Season, 2023



(b) Minor Cropping Season, 2023

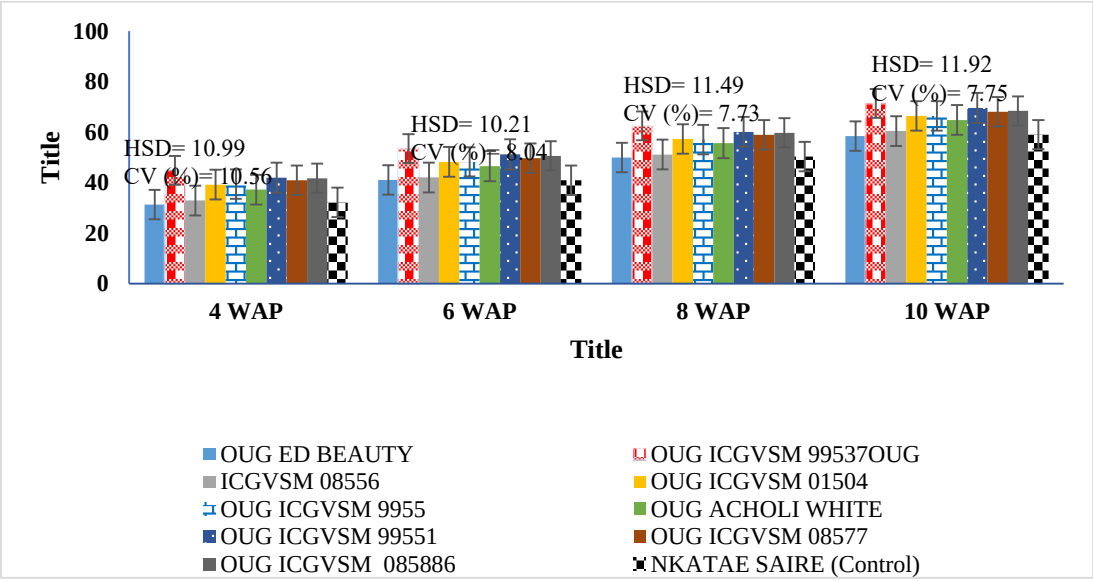


Figure 4.4: Number of Leaves Per Plant of 10 Groundnut Genotypes during Major and Minor Cropping Seasons, 2023

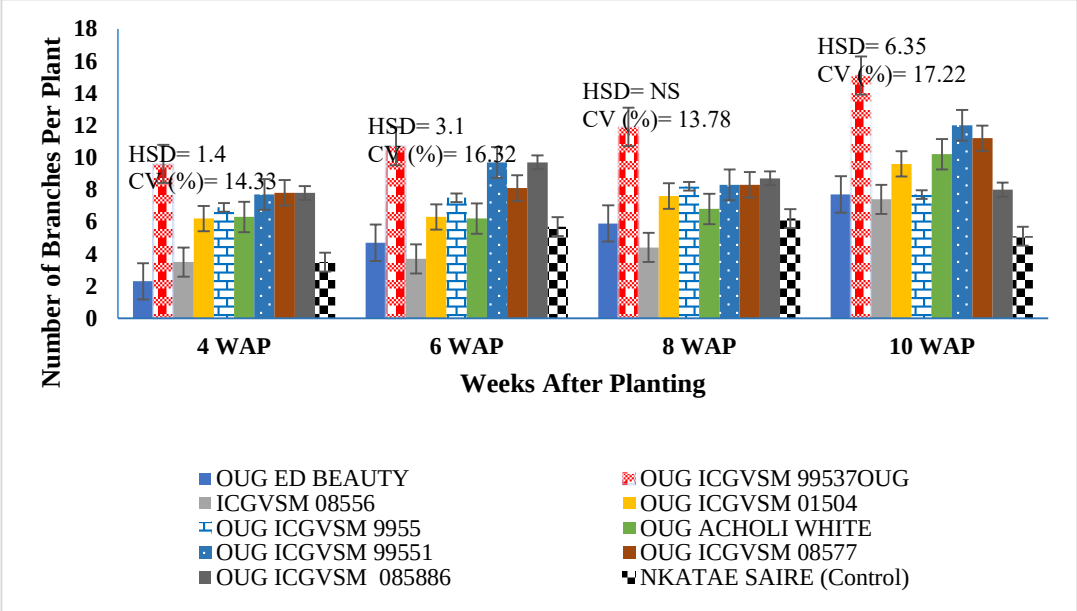
Number of Branches per Plant

The number of branches of the different groundnut genotypes for both major and minor cropping seasons is presented in Figure 4.5. There were significant differences ($P<0.05$) in the number of branches at 4 to 10 WAP for both cropping seasons except at 8 WAP.

Results of the study showed that mean number of branches was highest (54) in OUG ICGVSM 99537OUG throughout the days of records from 4 to 10 WAP during the major cropping season, it recorded produced 15 branches at 10 WAP. The least number of branches was produced by OUG ED BEAUTY throughout, except at 10 WAP where NKATAE SAIRE rather produced the least number of branches as 5 (Figure 4.5a). Similar trend was observed during the minor cropping season, number of branches per plant was highest from 4 to 10 WAP in OUG ICGVSM 99537OUG. (Figure 4.5b), while the least number of branches per plant was observed in OUG ED BEAUTY from 4 to 8

WAP, except at 10 WAP where NKATAE SAIRE produced the least number of branches per plant in the minor cropping season (Figure 4.5b).

(a) Major Cropping Season, 2023



(b) Minor Cropping Season, 2023

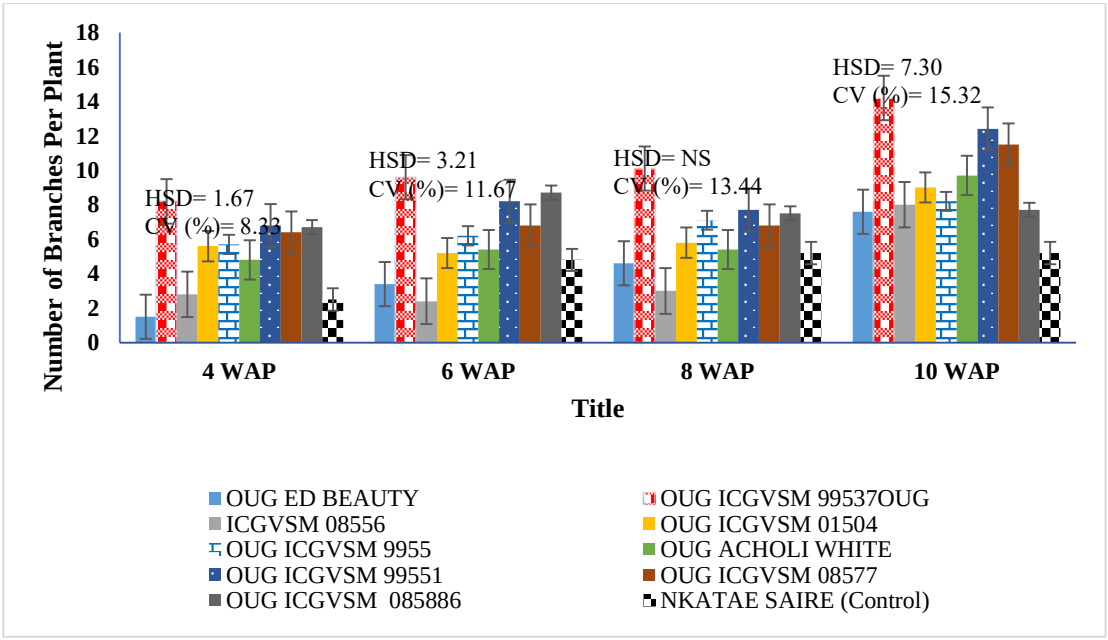


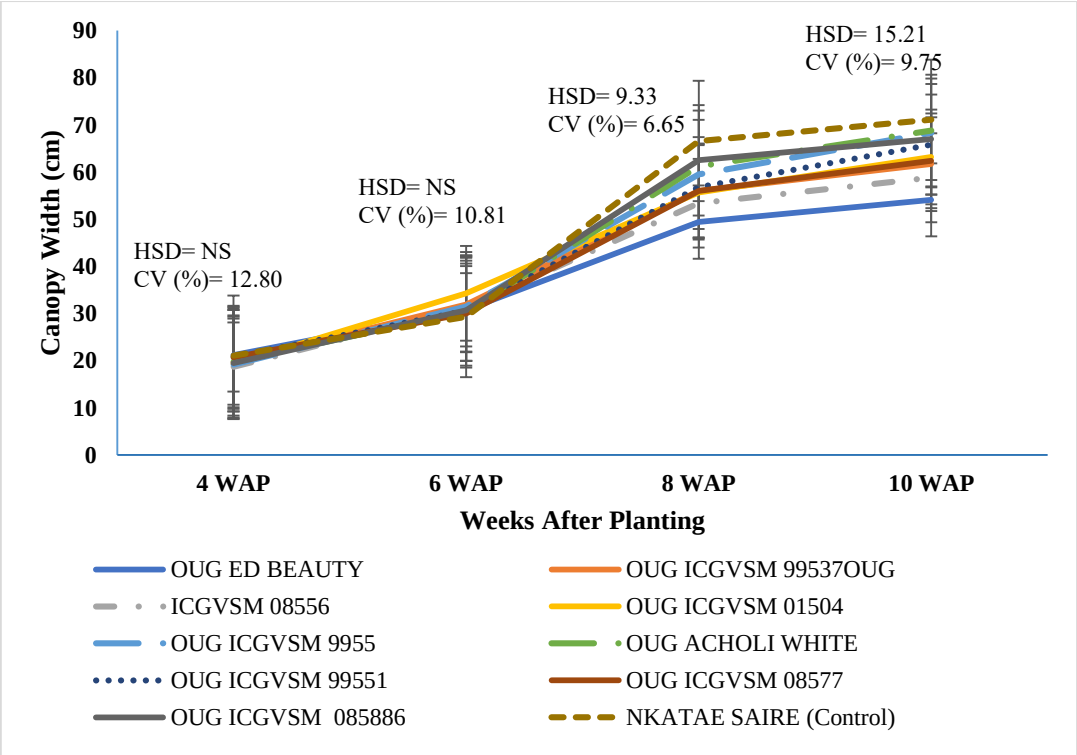
Figure 4.5: Number of Branches Per Plant of 10 Groundnut Genotypes during Major and Minor Cropping Seasons, 2023

4.3.4 Canopy Width

The results of groundnut canopy width are shown in Figure 4.6 for both major and minor season. There were significant ($P<0.05$) differences in the canopy width of groundnut at 8 to 10 WAP for both cropping seasons. However, there were no significant ($P>0.00$) difference in canopy width at 4 to 6 WAP. Season also significantly influenced the canopy width at 4 to 10 WAP except at 6 WAP.

Generally, from 8 to 10 WAP, results of the study showed that mean canopy width was higher in NKATAE SAIRE, followed by OUG ACHOLI WHITE and while the least canopy width was observed in OUG ED BEAUTY in the major cropping season (Figure 4.6a). In the minor cropping season, NKATAE SAIRE rather produced the greatest canopy width from 8 to 10 WAP (61.4 cm and 65.3 cm for 8 and 10 WAP respectively), followed by OUG ICGVSM 085886 (56.6 cm and 61.4 cm for 8 and 10 WAP respectively) whiles the lowest (43.8 cm and 48.5 cm for 8 and 10 WAP respectively) canopy width was recorded in OUG ED BEAUTY in the minor cropping season (Figure 4.6b).

(a) Major Cropping Season, 2023



(b) Minor Cropping Season, 2023

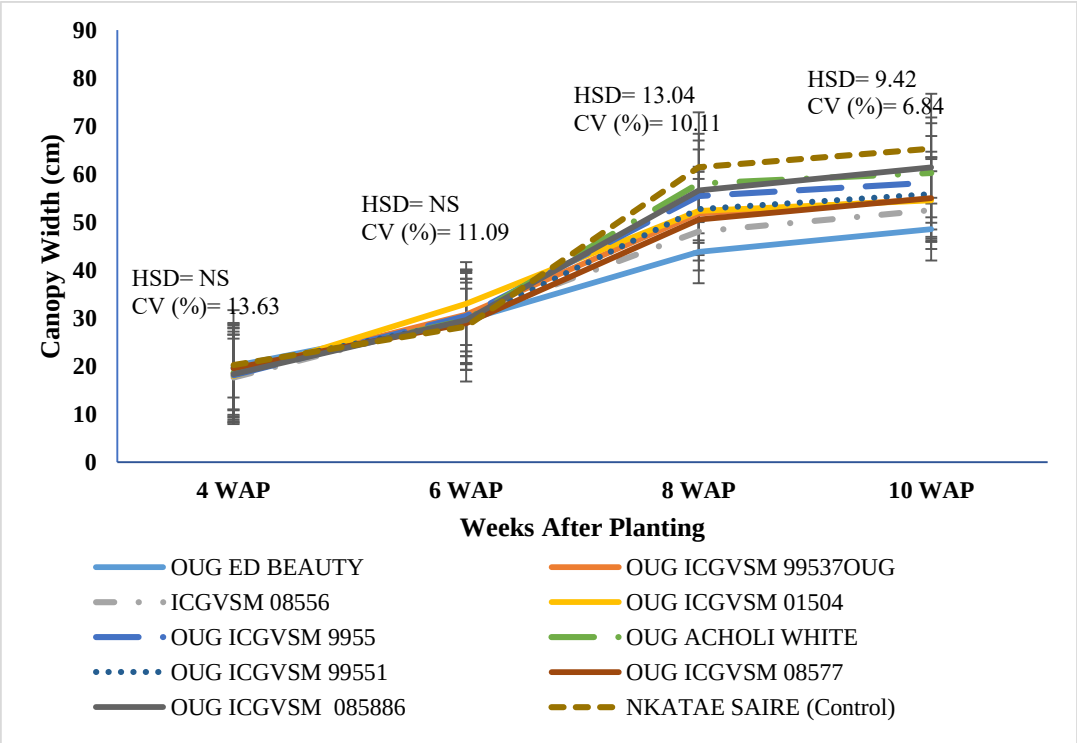


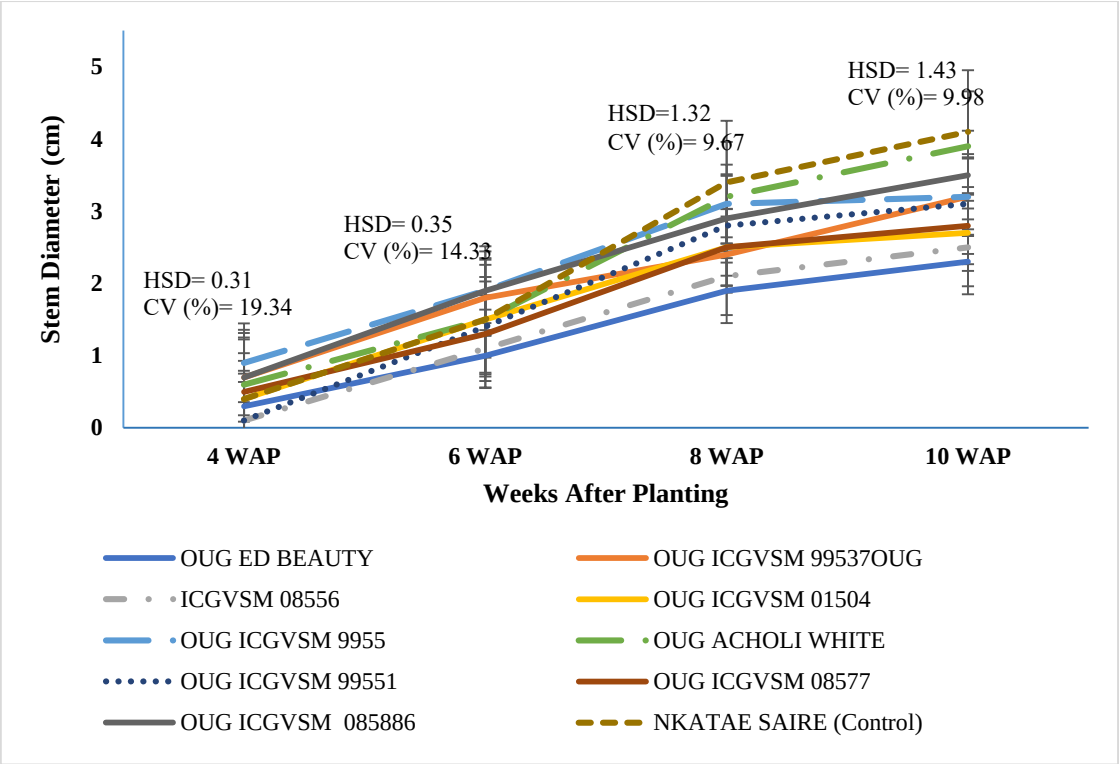
Figure 4.6: Canopy Width of 10 Groundnut Genotypes during Major and Minor Cropping Seasons, 2023

4.3.5 Stem Diameter

The stem diameter (cm) of groundnut plants as affected by the different varieties was analysed and the means are presented in Figure 4.7. There were significant ($P<0.05$) differences in stem diameter of groundnut from 4 to 10 WAP during both the major and minor cropping seasons.

Generally, the results of the study revealed that mean stem diameter was widest stem from 4 to 6WAP was produced by OUG ICGVSM 9955, but NKATAE SAIRE rather produced the widest stem from 8 WAP to 10 WAP, followed by OUG ACHOLI WHITE whiles the lowest stem diameter was recorded in ICGVSM 08556 during the major cropping season (Figure 4.7a). During the major cropping season (Figure 4.7b). The study again showed that mean stem diameter was generally highest in NKATAE SAIRE from 8 to 10 WAP but was highest in OUG ICGVSM 99537OUG and OUG ICGVSM 085886 at 4 WAP and 6 WAP respectively, while the least stem diameter was observed in ICGVSM 08556 from 4 to 6 WAP and on OUG ED BEAUTY from 8 to 10 WAP in the minor cropping season (Figure 4.7b).

(a) Major Cropping Season, 2023



(b) Minor Cropping Season, 2023

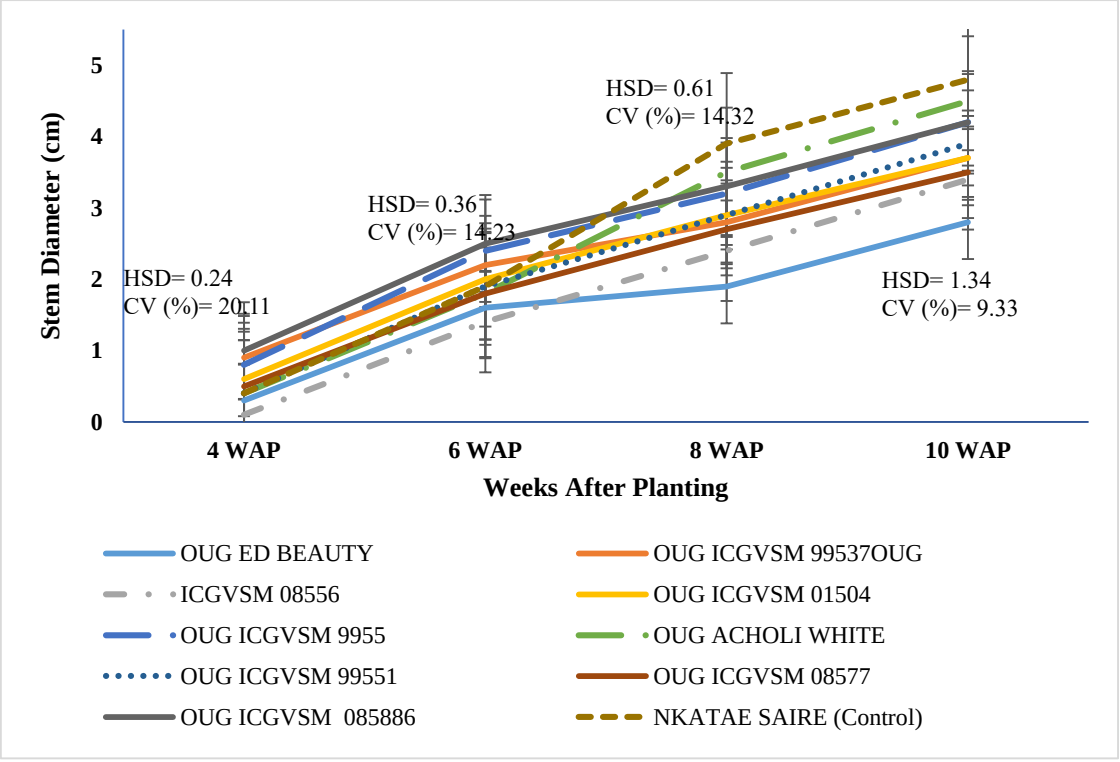


Figure 4.7: Stem Diameter of 10 Groundnut Genotypes during Major and Minor Cropping Seasons, 2023

4.4 Yield and yield components

4.4.1 Number of Pods Per Plant

The number of pods per plant of groundnut for both major and minor cropping seasons as affected by varieties are shown in Table 4.4. The varieties were significantly ($p<0.05$) different in both number of pods per plant and pod weight per plant in both cropping seasons. The number of pods per plant ranged from 20-33 pods for the major rainy season and 14 -25 pods per plant, for the minor rainy season. In the major cropping season, OUG ICGVSM 085886 had the highest number of pods the plant (33 pods), NKATAE SAIRE had 31 pods while ICGVSM 08556 also had 27 pods. The least number of pods per plant was recorded on OUG ACHOLI WHITE as 20 pods.

Table 4.7: Number of pods per plant as influenced by varieties

Genotype	Number of Pods Per Plant	
	Major Season	Minor Season
OUG ED BEAUTY	25	16
OUG ICGVSM 99537OUG	26	19
ICGVSM 08556	27	19
OUG ICGVSM 01504	22	15
OUG ICGVSM 9955	24	20
OUG ACHOLI WHITE	20	14
OUG ICGVSM 99551	22	15
OUG ICGVSM 08577	24	17
OUG ICGVSM 085886	33	25
NKATAE SAIRE (Control- local)	31	25
CV	13.15	12.01
HSD (0.05)	8.12	5.40
Season =HSD (0.05)	1.246	
Genotype =HSD (0.05)	NS	
Season x Genotype = HSD (0.05)		

4.4.2 Number of Seeds Per Pod and 100 Seed Weight

The number of seeds per pod and 100 seed weight of groundnut for both major and minor cropping seasons as affected by varieties are shown in Table 4.8. There were no significant differences in the number of seeds per pod in both seasons ($p > 0.05$), also no significant ($p>0.05$) differences in 100 seed weight in both major and minor cropping seasons. The number of seeds per pod ranged from 22 to 33 for all the genotypes during the major cropping season and from 15 to 25 seeds during the minor cropping season (Table 4.8). The average 100 seed weight ranged from 35.5 -37.96 g for the major season and 30.47 -33.27 g for the minor season.

Table 4.8: Number of Seeds Per Pod and 100-Seed Weight as influenced by Genotype

Genotype	Number of seeds per pod		100- seed weight(g)	
	Major season	Minor season	Major season	Minor season
OUG ED BEAUTY	25	16	37.96	33.10
OUG ICGVSM 99537OUG	26	19	37.17	32.20
ICGVSM 08556	27	19	36.13	31.03
OUG ICGVSM 01504	22	15	35.00	30.47
OUG ICGVSM 9955	24	20	37.17	33.17
OUG ACHOLI WHITE	20	14	36.80	32.27
OUG ICGVSM 99551	22	15	35.86	30.80
OUG ICGVSM 08577	24	17	36.17	31.63
OUG ICGVSM 085886	33	25	37.93	33.27
NKATAE SAIRE (Control-local)	31	25	35.50	31.83
CV	5.27	4.52	4.27	2.92
HSD (0.05)	NS	NS	NS	NS
Season = HSD (0.05)		6.32		4.32
Genotype = HSD (0.05)		NS		NS
Season × Genotype = (HSD= (0.05)		3.10		1.54

4.4.3 Seed Yield and Harvest Index

The seed yield and harvest index of groundnuts as affected by varieties in both the major and minor cropping seasons are presented in Table 4.9. There were significant ($p<0.05$) differences among the varieties for both seed yield and harvest index for the major and minor cropping seasons. The seed yield ranged from 1.36 -2.68 t/ha and 1.33-2.43 t/ha for the major and minor seasons respectively.

The OUG ICGVSM 085886 had the highest seed yield (5.35 t/ha), followed by OUG ICGVSM 9955 (3.75 t/ha) while the least seed yield was produced by both OUG ICGVSM 99551 and NKATAE SAIRE (2.72 t/ha) in the major cropping season. In the minor cropping season, both OUG ICGVSM 085886 had the highest seed yield (4.86 t/ha), followed by NKATAE SAIRE (4.63), followed by OUG ICGVSM 9955 (3.27 t/ha) and then the least seed yield was produced by OUG ACHOLI WHITE (2.29 t/ha).

The harvest index ranged from 0.25- 0.65 for both the major season and minor seasons respectively. In the major season, OUG ICGVSM99551 had the highest harvest index (0.55), while Nkatae Saire had the least harvest index of 0.25. Similarly, in the minor season, OUG ICGVSM99551 had the highest harvest index (0.65), while OUG ACHOLI WHITE had the least harvest index of 0.25. Generally, there were no significant difference in harvest between the seasons nor season x genotype interaction.

Table 4.9: Seed Yield(t/ha) and harvest index as influenced by Genotype

Genotype	Seed Yield(t/ha)		Harvest index	
	Major season	Minor season	Major season	Minor season
OUG ED BEAUTY	3.10	2.66	0.45	0.45
OUG ICGVSM 99537OUG	3.46	3.10	0.35	0.40
ICGVSM 08556	3.63	3.19	0.35	0.35
OUG ICGVSM 01504	3.09	2.65	0.35	0.40
OUG ICGVSM 9955	3.73	3.27	0.45	0.55
OUG ACHOLI WHITE	2.74	2.29	0.25	0.25
OUG ICGVSM 99551	2.72	2.34	0.55	0.65
OUG ICGVSM 08577	3.02	2.67	0.35	0.40
OUG ICGVSM 085886	5.35	4.86	0.50	0.55
NKATAE SAIRE (Control- local)	2.72	4.63	0.25	0.30
CV	6.34	5.99	13.17	9.06
HSD (0.05)	0.55	0.46	0.24	0.19
Season = HSD (0.05)	0.091	0.0195		
Genotype =HSD (0.05)	0.337	0.0715		

4.5 Resistance to Groundnut Rosette Virus Disease

4.5.1 Incidence of Rosette Disease

Results on the incidence of groundnut rosette at 60 days in the major and minor seasons are presented in Table 4.10. The results revealed that there were significant ($p< 0.05$) differences among the various groundnut genotypes in their levels of rosette incidence at 60 days after planting in the major season. The results indicated that, NKATAE SAIRE had the highest incidence throughout the days of records during the major cropping season. followed by OUG ICGVSM 9955, followed by OUG ICGVSM 085886 and the least was recorded in OUG ED BEAUTY. During the minor season, similar trend was observed, NKATAE SAIRE again had the highest incidence throughout the days of records, followed by OUG ICGVSM 085886, followed by OUG ICGVSM 01504 and the least was recorded in OUG ED BEAUTY (Table 4.10).

Severity of Rosette Disease

Results on severity of groundnut rosette disease at 60 days after planting on the different groundnut genotypes are presented on Table 4.11. Results showed that groundnut genotype exhibited significant variations ($p < 0.05$) in the disease severity at 60 days after planting. The results indicated that the exotic groundnut genotypes had no disease infection. In contrast, NKATAE SAIRE significantly ($p < 0.05$) recorded the highest rosette severity at 60 and days after symptoms appearance (Table 4.10).

Table 4.10: Incidence of Groundnut rosette virus disease during both the major and minor cropping seasons, 2023

Genotype	Major Cropping Season	Minor Cropping Season
	60 DAP	**60 DAP**
OUG ED BEAUTY	45.41	42.21
OUG ICGVSM 99537	40.67	38.84
ICGVSM 08556	47.61	44.46
OUG ICGVSM 01504	45.45	42.20
OUG ICGVSM 9955	48.21	45.84
OUG ACHOLI WHITE	44.52	39.49
OUG ICGVSM 99551	40.22	37.68
OUG ICGVSM 08577	49.45	46.52
OUG ICGVSM 085886	44.47	40.73
NKATAE SAIRE (Control- local)	61.26	55.76
CV	26.23	22.42
HSD (0.05)	23.54	20.57

Season = HSD (0.05) = 13.53
Genotype = HSD (0.05) = 10.00
Season x Genotype HSD (0.05) = NS

Table 4.11: Severity of Groundnut rosette virus disease during both the major and minor cropping seasons, 2023

Genotype	Major Cropping Season	Minor Cropping Season
	60 DAP	**60 DAP**
OUG ED BEAUTY	50.30	46.45
OUG ICGVSM 99537	53.34	51.73
ICGVSM 08556	52.43	49.92
OUG ICGVSM 01504	56.75	54.82
OUG ICGVSM 9955	54.82	50.81
OUG ACHOLI WHITE	50.56	42.82
OUG ICGVSM 99551	58.03	44.46
OUG ICGVSM 08577	42.31	39.43
OUG ICGVSM 085886	52.62	46.75
NKATAE SAIRE (Control- local)	66.40	54.64
CV	23.56	24.32
HSD (0.05)	22.44	21.76

Season = HSD (0.05) = 10.89
Genotype = HSD (0.05) = 11.94
Season x Genotype HSD (0.05) = NS

CHAPTER FIVE

DISCUSSION

5.1 Farmers Knowledge of Groundnut Rosette Virus Disease

The present study agrees with previous studies that groundnut farming is a male dominated occupation (Mwakiwa, *et al.,* 2018). Generally, most of the farmers were in the middle age group suggesting that the future of groundnut production in the study area is certain. More than half of the famers had received basic education which is an indication that farmers could easily adopt research recommendations for higher productivity. High farmers' educational level has often been associated with the adoption of research recommendations (Matthews-Njoku, 2005).

The study revealed that groundnut seeds were obtained from diverse sources, including colleague farmers, farmer groups, and local markets a pattern similarly observed in several African countries. For instance, Okello *et al*., (2010) reported that in Uganda, farmers often rely on informal seed systems, such as market purchases and farmer-to-farmer exchanges, which increases the risk of distributing disease-infected seeds. This widespread reliance on informal seed systems underscores a common challenge across many groundnut-producing regions and highlights the urgent need for certified seed distribution systems to curb disease spread.

Farmer awareness of GRVD's presence and its yield impact was also noted in this study. Similar findings were reported by Mugisha *et al*. (2016) in East Africa, where farmers identified GRVD as a major cause of yield reduction. Diallo *et al*. (2020) in Senegal also found that farmers were aware of GRVD symptoms but lacked knowledge about its epidemiology and long-term impact, emphasizing a common gap in disease education.

One notable divergence in the findings lies in farmers' misconceptions about GRVD's causes. In this study, many farmers attributed the disease to drought, pod maturity, and leaf changes, while only a few identified it as a virus infection. Similar misconceptions were documented in Ntare *et al*. (2008) in Mali, where farmers often associated GRVD with environmental stress rather than viral transmission. In contrast, Kalule *et al*. (2014) clearly established Aphis craccivora Koch as the primary vector responsible for efficiently spreading the virus, with Aphis gossypii (Glover) acting as a less effective secondary vector. This knowledge gap highlights the need for widespread education and training programs to address misinformation and improve disease management practices.

5.2 Agronomic Performance of Groundnut Genotypes

The phenological traits such as days to first and days to 50% emergence, days to first and days to 50% flowering, % plant establishment and days to maturity and growth attributes such as plant height, number of leaves, number of branches, canopy width and stem diameter, and yield parameters such as number of pods per plant, pod weight per plant, number of seeds per plant, 100 seed weight, seed yield and harvest index were significantly influenced by the different groundnut genotypes and the different cropping seasons.

Phenologically, groundnut genotypes generally performed well in major cropping season as compared to minor cropping season. Phenology is the examination of the timing of developmental events in relation to the calendar. Crop physiology is crucial for three reasons (Rashid *et al.*, 2022) which includes the life cycle of the crop corresponding to the length of the growing season, temperature and phenology. Phenology, is a critical element of the whole crop simulation model, which can be employed to determine the

most suitable rate and duration of a specific developmental process in order to optimize yield (Hossain *et al*., 2022).

The analysis showed that genotype and season was significant ($p > 0.05$) in days to first emergence and days to 50% emergence, where NKATAE SAIRE and OUG ICGVSM 08577 had shorter days to emergence as compared to the other genotypes in the minor season. This finding is in contradiction to that of Olanrewaju *et al*., (2021), where genetic diversity of Bambara groundnut did not significantly affect days to emergence. Days to 50% flowering was significantly influenced by both season and genotype. Major season had shorter days to flowering. NKATAE SAIRE also had shorter days to flowering than the other genotypes. Odhiambo *et al*., (2022) reported that low supply of soil moisture early in the growth of an annual crop can reduce the number of nodes formed before flowering, which can delay flowering. In contrast, restricting soil moisture at the time of flower-bud initiation in perennial fruit crops can encourage or hasten flowering.

Days to maturity was shorter in OUG ICGVSM 085886 and during the major cropping season, % plant establishment was also higher on NKATAE SAIRE during both the major and minor cropping seasons. The findings of Iddrisu *et al*., (2024) confirms that rainfall can affect the days to maturity of groundnut plants, that groundnut plants require well-distributed rainfall and soil moisture for germination, emergence, flowering, vegetative growth, and pod development. Moreover, Appropriate soil moisture management is crucial to achieve early germination, uniform plant establishment and high productivity in the crop (Bhattacharya & Bhattacharya, 2021).

Plant height, stem diameter and canopy width were significantly influenced by cropping season with the major season recording the highest and was also significantly influenced by genotype where NKATAE SAIRE repeatedly recorded the highest throughout the days of records. Increase in plant height, canopy width and stem diameter under less rainfall condition as in the major cropping season may be explained by the report made by Ahanger *et al*., (2016), where they reported that moisture stress did not cause stomatal closure and reduced minerals uptake by plants, and thereby did not affect plant growth. This result disagrees with the findings of Nikale *et al*., (2022) who reported that moisture stress condition reduced plant height and again disagrees with the findings of Mabhaudhi *et al*., (2013) who indicated that there was a trend for both seasons, of decreasing plant height in response to increasing water stress. The report of Tana & Urage (2017) again support the current finding, they reported that, different genotypes have different vegetative growth due to their unique genetic makeup, which influences traits like plant structure and overall vigour. These genetic differences mean that some genotypes may grow more vigorously, have more branches, and produce a larger leaf area compared to others, even under the same environmental conditions. Other factors like water stress can exacerbate these genotypic differences in vegetative growth.

This might be due to inhibition of leaf area expansion which depends on leaf turgor and temperature. This is in line with the findings of Shinde *et al*., (2010) who reported that growth involves both cell growth and development which is a process consisting of cell division, cell enlargement and differentiation. The inhibition of cell expansion is usually followed closely by a reduction in cell wall synthesis. This may have affected plant height of the groundnut varieties. Enlargement of optimal canopy is essential for photosynthesis

as well as dry matter production but moisture stress has inhibited the leaf area expansion as a survival mechanism of groundnut (Mayes *et al*., 2019)

In this study, OUG ICGVSM 085886 and NKATAE SAIRE repeatedly recorded higher number of pods per plant, number of seeds per plant, seed weight and pods weight per plant than the other genotypes, major cropping season also recorded higher number of pods per plant, number of seeds per plant, seed weight and pods weight per plant. Environmental conditions during the flowering and pod set period can have a significant impact on the number of pods and seeds produced (Egli, 2010). Similar to previous studies, peanut seed weight varied widely among the genotypes (Wang *et al*., 2018; Zhang *et al*., 2019). Also, harvest index was higher on NKATAE SAIRE and was also greater during the minor cropping season, the decreased in harvest index during the major cropping season might be due to the low rainfall recorded at the major cropping. The results are in fine tune with the findings of Mukhtar (2013).

5.3 Resistant Status of groundnut Genotypes

The incidence of GR disease varied significantly among the various genotypes and cropping seasons. The existence of variability in the genetic makeup of the various genotypes in GRVD was revealed by the significant differences in their incidence (Muhammad *et al.*, 2020). The divergence in agronomic traits was also a contributing factor to the variation in yield, in addition to the differences in disease response demonstrated by the accessions. The disease had an impact on seed yield, and in plants that were less affected, the yield reduction may have been a result of GRVD infection. Genetic variability in the genotypes for GRVD incidence and severity was limited, as evidenced by the significant differences in GRVD severity between the two cropping

seasons. This discrepancy may be attributable to the genotypes being exposed to varying levels of inoculum as a consequence of variations in disease pressure. Groundnut varieties that are resistant to GRD expend energy to express resistance genes, which leads to a decrease in yield potential, as per Janila *et al*., (2016). Nevertheless, the severe infection was the cause of the extremely low yields of OUG ACHOLI WHITE and OUG ICGVSM 99551. Mugisa *et al*., (2016) had previously reported that yield was substantially reduced by severe GRVD infection. In the same vein, Mukoye & Mabele (2019) reported a decrease in the yield of groundnut plants that were infected with GRD.

The existence of a wide range of genotypes and a differential response of genotypes to the seasons was confirmed by this finding of difference variance owing to genotype effect. Azharudheen and Gowda (2013) reported comparable findings when they examined productivity characteristics and resistance to late leaf spot disease over two seasons, observing significant differences ($p < 0.05$). Mugisa *et al*., (2015) also investigated the factors that influence the occurrence and severity of groundnut rosette disease. They discovered that the disease incidence, severity, and groundnut yields were significantly ($P < 0.05$) influenced by the genotype x season interaction. This suggests that these genotypes were a source of high yielding and resistant to groundnut rosette disease, which could be used to improve the current low yielding and susceptible groundnut varieties.

The variance in the performance of the genotypes that were tested during the two seasons may be significantly altered by rainfall. The dispersal of aphids, which are the vectors of GRD, is known to be negatively impacted by rainfall. Aphids may be exposed to predation by persistent rain, which dislodges them from plants onto the soil surface, or

they may be directly killed by soil particulates that are splashed onto their colonies (Crossley *et al.,* 2022; Schmitz, 2020). Crossley *et al*., (2015) found that aphid populations in fields at various periods of the day were reduced rapidly by even minor amounts of rainfall.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Most of the farmers interviewed during the study were male aged between 31 and 40 years. Majority of the groundnut farmers had basic education. Most of the farmers preferred cultivating the red seeded type of groundnut and obtained their sources of planting materials from colleague farmers. Most of the farmers were aware of the groundnut rosette viral disease and the trend of occurrence is the same

Plant height increased significantly from week four to week ten with OU ICGVSM 085886 recording the highest while OUG ICGVSM 9955 recorded the least in the major and minor seasons. The number of leaves was high in OUG ICGVSM 99551 and low in Nkatae Saire for the major and minor seasons. Number of branches was also found to be higher in OUG ICGVSM 99537 and lower in Nkatae Saire for both seasons. Stem diameter was observed to be high in Nkatae Saire and low in OUG ED BEAUTY in the major season and minor season.

For yield and yield components, the number of pods per plant ranged from 20-33 pods with OUG ICGVSM 085886 recording the highest number of pods per plant while OUG ACHOLI WHITE had the least pods per plants in the major. However, in the minor season, OUG ICGVSM 085886 had the highest pods per plant while OUG ACHOLI WHITE recorded the least. Seed yield ranged from 2.72 to 5.35 t/ha and 2.34 to 4.86 t/ha for the major and minor seasons respectively.

The incidence of the groundnut rosette disease was high in Nkatae Saire and low OUG ED BEAUTY in the major season. Regarding the severity of the disease, it was observed that the disease was also more severe in Nkatae Saire and low in OUG ED BEAUTY in both seasons.

6.2 Recommendations

6.2.1 Recommendation for adoption

The following are recommended for consideration for adoption by farmers

1. Groundnut farmers should be encouraged to cultivate OUG ICGVSM 085886 or Nkatae Saire genotype as the two demonstrated superior agronomic traits and higher yields compared to other genotypes.
2. There should be awareness program to educate farmers on the identification, impact and management of groundnut diseases to increase productivity.

6.2.2 Recommendation for future studies

For future studies, the following can be recommended:

1. Investigate how seed policy, certification, and local multipliers influence dissemination of the disease
2. Evaluate how resistance durability may be affected by emerging variants.
3. Study how resistant genotypes perform under integrated pest management (IPM) and intercropping systems.

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APPENDICE

APPENDIX 1