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The Groundnut Rosette Disease at a Glance: Basics, Management and the Future

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Abstract: Groundnut (*Arachis hypogea* L.) is an allotetraploid derived from hybridization of the ancestors *Arachis duranensis* and *Arachis ipaensis*), followed by spontaneous chromosome doubling. The crop is predominately grown under low-input production system with an average yield ranging between 700 to 900 $Kgha^{-1}$. Yields are low, and several biotic and abiotic factors, constraint the production. The groundnut rosette disease, caused by synergistic interaction of three viral components, is considered to be the most devastating where it is grown in Africa. The disease is spread by aphid in a persistent manner. The use of aphid and virus resistant cultivars is the most economical means to control the disease. Few reports on DNA markers linked to GRD resistance are available and effort is needed to identify more DNA markers to assist future breeding programmes. Understanding the host-vector-disease interaction at the molecular level would form a stronger basis to breed for resistance while adapting modern technologies. Efforts to identify resistant sources, development of resistant cultivars and identification of DNA marker linked to resistance has been underway and substantial progress made though not fully. A multidisciplinary approach is necessary to contribute towards understanding the dynamics of the disease in different countries within SSA so as to resolve the underlying causes of the epidemic.

Keywords: Groundnut Rosette Disease, Aphid, DNA Markers, Virus, Vector

1. Introduction

Groundnut contributes to poverty alleviation and livelihoods as a source of food and income in developing countries [1]. The groundnut rosette disease (GRD) is among the thirty two (32) viruses reported to infest groundnut; a major virus disease endemic to sub-Saharan Africa; known to only attack groundnut [2]. The main countries where it is found includes Burkina Faso, Ghana, Nigeria, Côte d'Ivoire, Gambia, Malawi, Tanzania, Mozambique and Uganda [3]; and has also been reported in Angola, Kenya, Madagascar, Niger, Senegal, South Africa, Sudan, Swaziland and Zaire. The virus is considered to be the most destructive groundnut disease which can lead to 100% yield loss in susceptible varieties [3]; and generally, the disease is responsible for annual loss worth over US$150 million [2]. Epidemics often significantly reduce the production and affect the rural economy.

2. The Groundnut Rosette Disease

The disease is caused by a synergistic interaction between groundnut rosette assistor virus (GRAV), groundnut rosette virus (GRV) and satellite-RNA (satRNA) associated with GRV [2]. GRAV belongs to the family *Luteoviridade* and has autonomous replication in the phloem tissue cytoplasm. GRV is a member of the genus *Umbravirus* and has no structural protein, thus cannot be transmitted by aphids. They can only be transmitted with existence of a suitable luteoviruses (assistor virus) that act as helper viruses [4]. Further, GRV has a replicating single-stranded, positive sense RNA (ssRNA) genome with four open reading frames (ORF); and does not encode for a coat protein [5]. The transmission characteristics of the disease is greatly influenced by GRAV, but not by GRV or sat RNA since they are encapsidated within the GRAV particles. GRAV has isometric particles about 28 nm with hexagonal outlines, contains a single nucleic acid species, is phloem limited as opposed to the other two and causes symptomless infection in several species of Leguminosae and a few other families. The GRAV and GRV components are transmitted in a persistent manner by aphids (*Aphids craccivora* Koch) purely through plants in the field. The vector should be carrying the three components for the spread of the disease to be effective which is not always the case [6], and diseased plants that possess the three are important in secondary spread of the disease. GRV is also transmitted by mechanical inoculation as opposed to GRAV.

The SatRNA is linear, with no segments, made up of 4 open reading frames, and cannot function on its own without GRV. The sat RNA depends on GRV for replication and GRV need the sat RNA for aphid transmission, that is, for GRAV-dependent transmission of GRV, sat RNA must be present in the source plants [4]. The open reading frames are not necessary for the development of the disease. The rosette disease symptom expression is fully under the influence of different variants of the satellite RNA [2]. The GRV and sat RNA are packaged in the coat protein of GRAV to form virus particles that can be transmitted by aphids. The three agents are dependent on each another to facilitate the biology and perpetuation of the disease in addition to the host, vector and the prevailing environmental conditions [7].

3. Transmission of the Groundnut Rosette Disease

Transmission and manifestation of GRD involves co-existence of two viruses and a sat RNA, the aphid vector, and the host plant. The vector for the disease infests the crop after emergence and this enhances rapid secondary infection. The initial source of inoculum is believed to be from off-season infected plants or alternate hosts [8]. Each of the infected plant enhance spread of the disease since it is polycyclic in nature and the winged aphids are the disease carriers [9]. The aphids are polyphagous in nature and feed on upper parts of the herbaceous plants including the stem [10]. Only female aphids are found in the tropics, and they reproduce parthenogenetically, a factor that contributes to fast increase in population as dictated by prevailing climatic conditions and nutritional status of the host plant [8, 10]. The aphid has narrow pierce–sucking mouthparts that help in phloem sap ingestion while causing more pronounced damage on the leaves [11]. The transmission of the virus can be effected by all different stages of the insect, thus the spatial spread of the disease is expected to be widespread [12].

Sometimes, natural spatial and temporal separation of GRAV from GRV and satRNA occur, thus the vector can only transmit either GRAV or GRV plus satRNA separately [7]. This is associated with varying feeding regime whereby in a shorter feeding time, only GRV and satRNA will be transmitted while a longer period will enable all the three to be transmitted [2]. Studies to document the dynamics of vector population, distribution and initial source of inoculum are important in predicting the disease epidemics for informed decision to take preventive and control measures.

4. Symptoms of the Groundnut Rosette Disease and Effect on Yield

The groundnut rosette disease is of three forms, namely the chlorotic, green rosette and mosaic rosette which have variable distinct symptoms as a result of diversity in the causal agent i e., different strains of satRNA, host response, climatic factors and possibility of co-infections [8, 2]. Visible symptoms of the disease include stunted growth, shortened nodes responsible for the bushy appearance of the infected plants and small-sized leaves.

The chlorotic rosette is the most predominant while green rosette is common in West Africa countries, Uganda, Malawi and Angola [13]. The chlorotic rosette is manifested by bright yellow leaves with a few green islands and the leaf lamina is curled, whereas in green rosette, leaves are dark green, with light to dark green mosaic [14]. The Green rosette is characterized by mild mottling and flecking, but mostly dark green, severe stunting, while mosaic rosette involves green blotching and severe chlorosis. The leaves are dark green, or show a light green and dark green mosaic, and are much reduced in size. Symptom variability is associated with diversity among casual agents, differences in genotypes, plant stage at infestation, variable climate condition and mixed infection with other viruses [8]. According to [2], if GRD infection occurs at early stages of growth particularly at flowering, severe stunting is evident due to shortened internodes and reduced leaf size, whereby yield loss may reach 100 percent. Plants infected late in their growth stage may show symptoms only in some branches or parts of branches, yield loss is lower and depends mainly on stage of infestation [2]. The chlorotic and green rosette symptoms are most prevalent in SSA [15] whereas the mosaic symptom caused by GRV containing a mixture of chlorotic satellite and a mottle variant was only reported in Tanzania [13].

5. Groundnut Rosette Disease Diagnosis

The disease is visually recognizable at farmers' fields and this can further be elucidated in the laboratory though antibody and molecular diagnosis such as ELISA tests and real time-polymerase chain reaction [2]. The triple antibody sandwich enzyme-linked immunosorbent assay (TAS-ELISA) is suitable for detection of GRAV [16] but not GRV and satRNA, dot blot hybridization (DBH) for detection of GRV and sat RNA [17], and reverse transcription polymerase chain reaction (RT-PCR) that allows detection of each of the three agents in diseased plants and viruliferous aphids (15). Further diagnostic studies can be carried out using indicator plants for virus indexing such as, *Arachis hvpogaea, Nicotiana* clevelandii, and *Chenopodium amaranticolor.*

6. The Aphid Vector

The *Aphis craccivora* Koch (Homoptera: Aphididae) is the only aphid vector that can transmit groundnut rosette disease agents efficiently [18, 19]. *Aphis gossypii* (Glover) has been reported to transmit the virus though not efficiently [20]. *Aphis craccivora* (Koch) has a wide distribution in many countries around the world. Females reproduce parthenogenetically throughout the year. The adults have a black shiny body with a prominent tail-end and are either winged (alatae that produce half the progeny produced by aptcrae) or wingless (aptcrae) [10].

The life cycle of aphids is complex, with options such as: females reproducing with or without mating and may lay eggs or directly give birth to nymphs. It has been reported that in warm regions such as the tropics male aphids are not produced and females bear small nymphs without laying eggs. The nymphs grow fast in four nymphal stages, into adults within a week when conditions are favourable ready to reproduce a characteristic that lead to rapid population build up. Reproduction is dependent on climatic factors, especially temperature and the nutritional status of the host plant to a large extent [21].

Studies have shown that there is evidence for behavioural response of aphids to colours [22]. This is explained by a considerable number of probing made by aphids on differently coloured and illuminated papers. Current knowledge on epidemiology with respect to the predominant colours for groundnut (green, dark green and light green) and general plant architecture is scanty and yet these may be important factor for attracting or promoting migration of aphids. Such information may help shape groundnut breeding programs or to form the basis designing comprehensive disease management strategies.

7. Epidemiology of the Groundnut Rosette Disease

Volunteer plants from previous season and alternate hosts are regarded as the key sources of disease inoculum. The vector is polyphagous in nature that can survive in about 142 plant species (83 from the leguminosae family) in addition to groundnut, thus a justification why alternate hosts can be major sources of the inoculum [10]. Although host for GRV, GRAV and or satRNA have been found, these three components responsible for GRD can only be found in groundnut [7]. The disease is not seed borne, thus can only be spread by the vector and the magnitude of secondary spread would further be influenced by the number of plants infected with the virus complex. The nature and intensity will further depend on stage of crop development, planting population, timing and efficiency of transmission by viruliferous aphid vectors, climatic factors, and predators of the vector population [7].

8. Groundnut Rosette Disease Management

Viral plant diseases are not curable and therefore prevention and or delay of infections remains the most viable strategy for their control [23]. Management of the disease is possible through a number of ways ranging from chemical control to reduce aphid population, practices that impede vector movement and reduction of inoculum source, and host resistance achieved through breeding [2]. The control can be achieved by spraying the aphids with an insecticide before they can spread the disease; and effective control is achieved by ensuring timely spraying, with the right insecticide at the correct dosage. However, the use of chemicals is not economically feasible to smallholder farmers, not environmentally friendly and at the same time improper use might possibly result in development of insecticide-resistance [8]. Agronomic practices like early planting at optimum density minimize the disease infestation, since it allows ground cover before the aphid's main period of flight activity [7]. The early sown crops would cover the ground before the aphids' main period of flight activity. Intensification approaches such as intercropping groundnuts with cereals and other legumes reduce rosette incidence [14]. Further, field hygiene including uprooting of voluntary/early-infected plants and common weeds limit the spread of the disease [14]. The control through these cultural practices might be a challenge to subsistence smallholder farmers, thus the need for more awareness creation and technical support.

The development and deployment of GRD resistant and resilient varieties is the most economically feasible option and over time efforts have led to the development of stable sources of resistance. The first source of resistance was late-maturing Virginia type landrace from West Africa [14], and additional sources have been found including early-maturing Spanish type. The resistant landrace of Virginia type have been used in breeding programs in sub-Saharan Africa and varieties such as such as RG1, CG9, CG11, CG12, CG13, have been released in Malawi. Studies have confirmed that two recessive genes that are independent of each other confer resistance; and resistance mechanism involves restriction of virus movement and production of satRNA [24]. Wild species have also been confirmed to harbor genes of resistance to GRAV [25], and others to the three components of the visrus, thus a rich genetic base is available for exploitation. The resistance is mostly linked to GRV that provides indirect resistance to satRNA, and as such the varieties appear disease free; though the resistance can be overcome under high inoculum or where environment is not favorable [26]. The key defense mechanisms which can be targeted includes: resistance to and or delayed initial infection, inactivation of virus mobility, and restricted production of sat RNA which stimulate the disease symptoms.

9. The Future in Groundnut Rosette Disease Management

As an advancement initiative, novel approaches to control aphids are needed and this would be made possible if there is detailed insights at the molecular level on the host-aphid interactions. Several plant–aphid interactions studies have been carried out with focus on the host to provide information about the defense mechanisms [27], but this is a gray area in case of groundnuts. Thus, this is an opportunity to invest in this initiative to unveil the defense mechanisms linked to GRD resistance in resistant groundnut varieties. Current knowledge on epidemiology with respect to the predominant colours for groundnut (green, dark green and light green) and general plant architecture is scanty and yet these may be important factor for attracting or promoting migration of aphids. Host plants offer defense action once they recognize conserved parasite molecules, or pathogen-associated molecular patterns (PAMPs); and in such plant-microbe interaction interface, the success of the pathogen will depend on its ability to deliver effectors into the host that suppress the defense apparatus by interacting with and modifying the mode of action of the plant defense signaling components. Further, aphids have been denoted to affect the physiological functioning of the host, such as nutrient allocation [28]; and masking defense response [29], and such studies can be expanded to groundnut-aphid relationship. There is a hypothesis that more biochemical reactions in the cell are targeted by aphid effectors to influence the disease development [30], thus an opportunity to exploit this novel aspect in the vector-host relationship in the case of the groundnut rosette disease.

10. Conclusion

The availability and access to resistant cultivars is the most economical and practical means to control the groundnut rosette disease, thus effort in identifying resistant sources, developing resistant cultivars and molecular tools linked to resistance have been made. Special attention should be given to the development and deployment of molecular markers to improve the breeding efficiency targeting GRD and aphid resistance. A multidisciplinary approach is necessary to contribute towards understanding the dynamics of the disease in different countries within SSA to further refine strategic approaches of dealing with disease epidemics.

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