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Research Application Summary

Fungal foliar diseases infecting groundnut: their management, status and the future

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Abstract

Cultivated groundnut (*Arachis hypogaea* L.) is an important oilseed crop widely grown in the tropics and subtropics. The yield for this crop is significantly affected by fungal foliar diseases namely leaf spots and rust to the tune of 60% in susceptible varieties. The fungal foliar disease menace can be addressed by development and deployment of high yielding resistant varieties with farmer preferred traits. Such achievement can be realized through use of conventional approaches complemented with genomic tools in identification of key genes, their introgression and the use of molecular markers to quicken selection. This review gives an overview of the fungal foliar diseases, epidemiology, their management, genetic highlights in breeding approaches for resistance and the future.

Key words: *Arachis hypogaea,* genetic enhancement, leaf rust, leaf spot, modern breeding, polygenic, resilient, yield gap

Résumé

L'arachide cultivée (*Arachis hypogaea* L.) est une importante plante oléagineuse largement cultivée dans les régions tropicales et subtropicales. Le rendement de cette culture est significativement affecté par les maladies foliaires fongiques à savoir les taches foliaires et la rouille à hauteur de 60% chez les variétés sensibles. La menace de la maladie foliaire fongique peut être combattue par le développement et le déploiement de variétés résistantes à haut rendement avec des traits préférés des agriculteurs. Une telle réalisation peut être réalisée grâce à l'utilisation d'approches conventionnelles complétées par des outils génomiques dans l'identification des gènes clés, leur introgression et l'utilisation de marqueurs moléculaires pour accélérer la sélection. Cette revue donne un aperçu des maladies foliaires fongiques, de l'épidémiologie, de leur gestion, des faits saillants génétiques dans les approches de sélection pour la résistance et l'avenir.

Mots-clés: *Arachis hypogaea*, amélioration génétique, rouille des feuilles, tache foliaire, sélection moderne, polygénique, résilient, écart de rendement

Introduction

Groundnut (*Arachis hypogaea* L.*)* is grown for oil, food, feed and as a soil fertility nourishing crop across the world. Production statistics as of 2015 indicated that 24 million ha worldwide was under groundnut whereby 42.4 million tons were produced (FAO, 2016). The crop is cultivated under rain fed conditions with low input use, a characteristic common among smallholder farmers in the Semi-Arid areas. Groundnut provides energy and protein from its kernels and other health enhancing nutrients such as antioxidants and vitamins among other compounds of biological importance (Birthal *et al.,* 2011). Groundnut production at farmers' fields is constrained by a variety of factors, and similar to most other crops, a big yield gap exist between genetic potential of improved groundnut varieties and actual yield in the field, with yields varying between 500-700 kg/ha compared to 4 tons/ha obtained at research stations. Among the major constraints are biotic stresses that include foliar diseases classified into fungal and viral diseases. Productivity can be unlocked through technology development and scaling, modernization of agricultural research owing to advancements in molecular biology, promotion of environmentally sustainable agronomic practices, and refining research focus to include both input and output traits in final research products. An entry point to underpin production and farmer livelihood strategies would be deployment of high yielding resilient varieties, supported by modern breeding approaches to accelerate the design and development of such superior products. Genetic enhancement for groundnut is possible due to the availability of diverse germplasm sources in gene banks across the world from where to tap superior alleles.

Fungal foliar diseases of groundnut and existing opportunities. Significant reduction in yield is evident when diseases strike (Nigam *et al.,* 2012). The early leaf spot disease caused by *Cercospora arachidicola* Hori, late leaf spot (*Cercosporidium personatum* Berk. and Curtis.) and rust disease caused by *Puccinia arachidis* Spegazzine are the most prevalent fungal diseases globally. The leaf spots and rust cause yield losses of 60% on average in non-resistant varieties (Khedir *et al.,* 2010; Tshilenge *et al.,* 2012; Meena *et al.,* 2014). Despite the highlighted constraints and associated challenges, opportunities exist such as through modern breeding approaches to tag key genes of interest and their introgression through marker assisted selection to speed up delivery of superior varieties, availability of genetic information such as sequenced maps and refined genomes, existence of genetic diversity including exploitation of wild relatives and the upsurge of new innovations such information technology based breeding management systems.

Leaf spots

The Early leaf spot (ELS) symptoms appear as brown to reddish brown coloration with a yellow halo, and the sporulation occur on the upper part of the leaf. The lower part of the leaf remains smooth. On the other hand, late leaf spot (LLS) is depicted by dark brown to black spots without a yellow halo. The late leaf spot sporulation is confined to the lower surface that makes it rough while the upper surface remains smooth. Over time, the spots coalesce leading to defoliation which further translates into reduced yield. Conidiophores of ELS are usually dark at the base, unbranched, and septate; leading to curved, subhyaline, septate conidia (15-45 × 3-6 µm); whereas conidia of LLS (20-70 × 4-9 µm) are unconstructed, straight with a rounded apex, and are produced on smooth, brown conidiophores (Shokes and Culbreath, 1997). The initial inoculum source in most cases is conidia in crop residue that is spread through wind and water splash. Studies have shown that high ascorbic acid and riboflavin are physiological characteristics of susceptible and resistant plants, respectively.

Leaf rust disease

The groundnut rust occur in form of uredinia, that has many pedicillate uredospores (Tashildar *et al.,* 2012); and there is no alternate host for the disease, thus the aecial stage of its lifecycle is obscure. The pathogen does not have a sexual stage, and this contributes to it not having races or variants (Ghewande, 2009). However, recent studies have reported the presence of teliospores of *P. arachidis* in nature which is a form of sexual spores and therefore further studies are needed to confirm this phenomenon which would be crucial in generation of variants/different strains of rust (Mondal and Badigannavar, 2015). Uredospores are the key source of inoculum which is airborne and often found on the pod or seed surface (Park and Wellings, 2012). Under field conditions, leaves are infested by uredospores to form uredosori, which culminates in production of numerous uredospores after bursting following maturation; and these are responsible for further cycles of infection in the field. The development of white flecks on the abaxial surface followed by yellow ones on the upper leaf surface are the very first signs of the disease. At the same time, orange to red or brown-colored pustules (uredinia) form on the lower surface of the leaves. These uredinia are raised with a diameter ranging between 0.2 mm to 0.3 mm with a circular to elliptical shape. This is followed by bursting of the uredinia after two days of appearance thereby exposing the circular or oval dark orange uredospores, which become cinnamon brown once mature (Leal-Bertioli *et al.,* 2009). Over time there is necrosis in the area with pustules and these may coalesce leading to defoliation.

Environmental conditions for optimal disease development. The optimal environmental temperatures for maximum infection efficiency, infectious period and sporulation intensity for early leaf spot range from16°C to 24°C. In Late leaf spot the optimal temperatures range from 20°C to 26 °C. However, the two pathogens require extended periods of relative humidity greater than 90% (Shokes and Culbreath, 1997). The most favorable weather conditions for development of the disease is prevalence of warm temperatures (>22 °C) coupled with high humidity conditions (>78 %).

Management of foliar diseases in groundnut. The control of the three foliar fungal diseases includes cultural, chemical and the use of resistant varieties. The cultural control options focus on reducing the inoculum source and preventing the spread of the diseases to areas where they are not present to contain the disease. Crop rotations involving non-host crops are effective in controlling the three fungal diseases (Cantonwine *et al.*, 2006; Wright *et al.,* 2009; Mondal *et al.,* 2014). The inoculum level can also be reduced through field hygiene including uprooting of volunteer plants and adapting fallow system to break the cycle of the pathogen development. When groundnuts are planted earlier, they have less exposure time to hot and humid conditions which provide optimal pathogen development conditions. In addition, pathogen inoculums levels are usually low during the early period of the season. A correct planting density of 50 cm x 30 cm or 50 cm x 40 cm can control

the leaf spot diseases. Enough spacing will help in aeration of the crop, ensure the fungicides reach all parts of the plant and ensure spore transmission from plant to plant is reduced.
Chemical control of the foliar fungal diseases by application of fungicides have been reported to be successful in managing the disease (Woodward and Black, 2007); and where the three fungal diseases are prevalent it is cost effective to use multi-purpose fungicides that control all at once. Mohammed (2004) reported that the use of systemic fungicides could contribute to increment in yield and haulm quality. Further, failure to use fungicides has been reported to cause significant pod yield reduction by 50% or more in diseased plants (Zhang *et al.,* 2001). In order to avoid development of fungicide-specific, resistant strains it is imperative for the growers to use numerous fungicides with different modes of action and active ingredients in a single growing season. Despite the use of chemicals being effective in containing fungal diseases, the constrained small-scale farmers are not able to afford them and this calls for an integrated pest disease management strategy that is economically and environmentally sound.

Breeding for resistance within the host would be a desirable alternative for foliar fungal disease management to substantially reduce the cost involved in chemical control and get rid of upsurge of resistance by pathogens. Over years, the groundnut improvement regional program at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), have developed groundnut genotypes that are resistant to leaf spots and rust, and more work is in progress to test for multiple resistance. The breeding efforts have confirmed that that the wild species that are relatives to cultivated groundnut have high levels of resistance to these fungal diseases (Singh, 2004). In earlier breeding efforts, the adoption of many disease resistant cultivars by most growers has not been a success due to a number of reasons such as poor germination rate and percentage, delayed maturity and undesired seed sizes which translate to gapping and shelling difficulties (Morton, 2007). All these problems could be largely attributed to the narrow genetic diversity for leaf spot resistance. However, the recent breeding efforts have addressed most of these challenges to deliver resilient varieties with high rate of adoption.

Genetics of resistance to foliar fungal diseases. Numerous genetic studies have shown that the resistance to the three foliar diseases is under the control of more than one recessive gene, thus it is polygenic (Dwivedi *et al.,* 2002). The two leaf spot diseases occur together in most cases and one disease may be more predominant in a given environment sometimes. So far, no reports and or evidence for complete or single gene resistance for the two pathogens, and only partial resistance influenced by more than one component of resistance to reduce the rate of disease development have been reported (Janila *et al.*, 2013). The major components associated with resistance include latent period, lesion size and spore production (Chiyembekeza *et al.,* 1993). The expression of these components varies across regions due to the genotype by environment interaction and the pathogen abundance. Studies based on analysis from segregating populations developed by crossing resistant and susceptible parents have shown that resistance to fungal foliar diseases is controlled by additive and or combination of additive x dominance gene effects (Ghewande, 2009). Other studies have singled out early leaf spot resistance to be under control of non-additive gene action.

Progress in use of modern approaches in breeding for resistance. Research efforts by ICRISAT have been made to deliver groundnut varieties that are high yielding coupled with resistance to foliar diseases in groundnut. As a result, major quantitative trait loci (QTL) for rust resistance

(QTLrust01) were identified in earlier efforts to integrate molecular markers in the global breeding program. Using the marker assisted backcrossing approach, these QTLs were introgressed into popular groundnut varieties to introduce the rust resistance background, and a number of selected superior lines are being advanced into finished product and now under valuation for adaptability and QTL stability across Africa. In addition, using marker assisted back crossing approach, rust resistance was successfully combined with early maturity, a key trait for drought tolerance (Varshney *et al.,* 2014)

Conclusion

Foliar fungal diseases limits groundnut production and productivity globally, thus the need to deploy improved resilient varieties. The development of such varieties require good understanding of the genetic basis of resistance, key genes controlling resistance and high throughput phenotyping and genotyping techniques. Owing to advancements in technology, continued research by ICRISAT and other international organizations on the same have led to identification of several molecular markers for use in marker assisted selection. Genetic control of fungal diseases in groundnut is still not clearly understood and refined, therefore, genetic studies with a focus on multiple resistance is crucial.

Future perspective. Owing to advancements in breeding for resistance, further studies need to be conducted to elucidate the total number of genes responsible for conferring resistance. Further, owing to the low narrow sense heritability of the resistance components based on numerous inheritance studies, it is crucial to use more stable progenies beyond F_2 for selection as a breeding strategy. According to Janila *et al.* (2013), the heritability of disease score component is high coupled with ease of measurement, therefore, this should be adapted in breeding as a selection criteria.

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