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Groundnut rust disease epidemiology and potential sustainable management strategies

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Abstract

Groundnut is an important food and cash crop for the majority of the world's population. However, diseases have impeded groundnut cultivation in groundnut-growing regions. Of them, groundnut rust disease caused by *Puccinia arachidis* is one among the major diseases causing more than 50% economic yield losses. For decades, chemical pesticide application has been the most effective option for controlling groundnut in Tanzania rust disease. However, hazards associated with excessive usage of chemical pesticides and development of pathogen- resistance against pesticides has prompted intensive research on disease management alternatives that are effective and eco-friendly to the environment. Thus, this review will focus on groundnut rust disease etiology, epidemiology and expounds various management options with much emphasis on the potential of the selected pesticidal plant species (*Azadirachta indica, Jatropha curcas, Parthenium hysterophorus* and *Moringa oleifera*) in combatting the disease.

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Introduction

Groundnut (*Arachis hypogaea* L.) is an important legume crop and it is among the most important oil and protein sources for smallholders in tropical and subtropical countries of the world (Pande *et al.*, 2003). It contains 48-50% of oil and 26-28% of protein and is a rich source of dietary fibres, minerals (zinc, iron, riboflavin, thiamine, phosphorus, magnesium, calcium and potassium) and vitamins (niacin, folate, thiamin, riboflavin, choline, Vitamin B_6 and E) (Pandey *et al.*, 2012; Izge *et al.*, 2007).

Despite the importance of groundnut in Tanzania, its production is still low with an average of 718kg/ha (MAFC, 2010) while expected potential yield is 1500kg/ha (Philipo and Nchimbi-Msolla, 2019; Mponda and Kafiriti, 2008). Groundnut production and economic returns are threatened yearly by destructive fungal diseases namely rust, early leaf spots and late leaf spots (USDA, 2003). When these foliar fungal diseases attack groundnut in combination they may cause about 70% yield loss. Nevertheless, in many regions of the world where groundnut is grown, groundnut rust disease caused by the basidiomycete fungus *Puccinia arachidis* Speg., which belongs to class Pucciniomycetes has been identified to cause up to 57% yield loss mainly during rainy season since the condition favour disease development (Mansoor, 2012; Patel *et al.*, 1987). Other losses associated are reductions in the amount and quality of foliage used for fodder (Subrahmanyam and McDonald, 1987). To mitigate the groundnut rust disease, so far synthetic fungicides have been recommended as the most effectual management option (Monyo *et al.,* 2009). However harmful impact of most of synthetic fungicides application on human and environment also development of pathogen resistance against pesticides has led to a growing demand of using pesticidal plants as protection materials.

Based on researches and many scientific works gives evident that pesticidal plant are biodegradable and have less risks on human and environment also are cost effective unlike widely used synthetic chemicals. Nevertheless little is still known of the available resources of pesticidal plants and their great role on crop protection. Therefore investigating efficiency of more plant species/ resources available will enhance utilization of the local resources in order to produce more bio pesticides which are highly needed. Thus, this review will expounds various management options with much emphasis on the potential of the selected pesticidal plant species (*Azadirachta indica, Jatropha curcas, Parthenium hysterophorus* and *Moringa oleifera*) in combatting groundnut rust disease.

Groundnut rust disease

The disease is caused by a pathogen *Puccinia arachidis* Speg., which is a member of the Urediniomycetes where the Uredinales, the rusts, is a single order, containing approximately 5000 host-specific, obligate parasites (Agrios, 2005; Subrahmanyam *et al.*, 1983). The diseases significantly reduces the pod and fodder yield and oil quality (Agrios, 2005; Subrahmanyam *et al.*, 1983).

Occurrence and distribution of Groundnut rust disease

The disease was first recorded in 1827 from Surinam, in 1910 and in Soviet Union and Mauritius in 1914. Thereafter, groundnut rust was considered a disease of South America prior to 1970. In the recent years, the disease has spread around the world where the groundnut is grown in Asia (Brunei, Philippines, Indonesia, Japan, Korea, Thailand, India, Taiwan, Malaysia and Taiwan), Australasia and Oceania (Australia, Fiji, Solomon Island and New Guinea) and Africa (Burkina Faso, Sudan, Benin, Malawi, Botswana, Ethiopia, Uganda, Kenya, Tanzania, Mauritius, Mozambique, Nigeria, Zambia, Senegal, Zimbabwe and Republic of South Africa) (Subrahmanyam *et al.*, 1985; Bromfield, 1971). Since this pathogen is found wherever the crop is grown, there is need to seek for sustainable management option because the pathogen tend to spread very fast causing huge crop losses.

Hosts of Puccinia arachidis

The pathogen *P. arachidis* is genus-specific, being limited to *Arachis* including *A. glabrata*, *A. burkartii,* *A. marginata, A. cardenasii, A. helodes, A. stenosperma, A. nambyquarae and A. hagenbeckii* (Hennen *et al.*, 1987). It does not have any alternate host either in legume or non-legume plants (Hennen *et al.*, 1987; Subrahmanyam and McDonald 1983). The obligate nature of the pathogen has implications in management of the disease. For instance, practicing crop rotation could be a better solution since the pathogen cannot infect any non-*Arachis* genus. However, farmers may not be able to do crop rotation by substituting with crops that are not of interest to them and therefore searching for other management options for groundnut rust disease is of paramount importance to groundnut growing farmers.

Biology and ecology of Puccinia arachidis

The *Puccinia arachidis* pathogen is known to perpetuate and spread via urediniospores (Savary *et al.*, 1985; Subrahmanyam *et al.*, 1983). The urediniospores may disperse through wind movement, rain splash, insects and sometimes by the movement of the infected crop debris, pods or seeds (Subrahmanyam and McDonald, 1983). Moreover the presence of groundnut plants or volunteer groundnut plants in one or other parts of the country enabled the survival of the pathogen from season to season on self-sown (volunteer) groundnut plants (Subrahmanyam *et al.*, 1983). Furthermore, (Sunkad and Kulkarni, 2007) reported that the urediniospores on self-sown/voluntary peanut plants play an important role in survival and viability of the pathogen from season to season. The existing survival mechanism of the groundnut rust pathogen shows challenges in breaking the disease cycle hence need to find the best management option for the disease.

Factors affecting P. arachidis survival

Temperature

Urediniospores production is highly favored at temperature ranging between 20-28°C and subsequently leads to infection and disease development (Rao *et al.*, 1994; Subrahmanyam and McDonald, 1987). The temperatures below 20°C or above 30°C are highly detrimental to urediniospore production (Rao *et al.*, 1994). Consequently it is important to seek for new management options to control the disease since the favourable weather condition for crop production also favors disease infection.

Wind

Wind as agent of urediniospore dispersal is responsible for spreading the groundnut rust disease. Normally distribution of wind speed near leaves is a bit more complex and is influenced by canopy density, height and roughness (Aylor, 1990). The urediniospore is disseminated long distance during dry windy weather by the movement of the infected crop debris or seeds surface-contaminated with uredospores moreover the infection depends on leaf wetness from rain or dew (Savary *et al.*, 1985). In view of the above, the wind factor can be controlled by planting tall trees to act as wind breakers and hence reducing the disease dispersal emanating from wind.

Moisture

Moisture in the plant environment comprises humidity, dew, rainfall or water from irrigation. This is critical factor in the spread of most plant diseases. Normally, rain is characterized by its duration and the amount of fallen rain [mm/h], with great variation in each rain event (Ivan, 2000). The distribution of rain drop diameters depends on the number of drops per unit volume and the rain intensity and different types of rain events (Ulbrich, 1983). Also according to Savary and Janeau,1986; the light rains favor disease dispersal than heavy showers because the spore content of the lesions in the canopy are strongly reduced by heavy rain as compared with light rain. Moreover, urediniospore germination depends on the presence of fluid water (Mallaiah and Savary 1986; Rao, 1982). Thus taking measure against that factor is the most economical means of preventing the disease development.

Humidity

Normally, growth rate of spores of some fungi occurs at 100% relative humidity and sometimes could not grow below 93% relative humidity (Subrahmanyam and McDonald 1983; Rao *et al.*, 1994).

High relative humidity favour urediniospore production and subsequently favour rust disease development (Savary *et al.*, 1985). Since it is difficult to manage relative humidity in the ecosystem and thus there is need to seek for different management options in controlling this important disease of groundnut.

Symptomatology of Groundnut rust disease

The disease occurs in the field under warm conditions at temperature ranging between 15-28°C and when leaves are wet due to rain or dew the uredospores germinate and produce appresoria that penetrate the leaf through the stomata (Mallaiah and Rao, 1979). Always incubation period ranges between 9 to 20 days, depending on environmental factors and host reaction and spreads quickly by repeated infection cycles of urediniospores. Normally it starts with whitish flecks on the abaxial surface of leaves (Chiteka *et al.*, 1988; Subrahmanyam *et al.*, 1985). Thereafter, pustules rupture after about 2 days of appearance to expose circular or oval urediniospores which are dark-orange at first but become cinnamon-brown with maturity. Later on, epidermis ruptures and exposes a powdery mass of urediniospores. Under wet and warm weather, the spots may be formed on all aerial plant parts from flowers to pegs in contrast with the rapid defoliation associated with leaf spots (Subrahmanyam *et al.*, 1985). When the disease progresses, it may lead to production of small and shriveled seeds which subsequently have implication on yield (Subrahmanyam and McDonald, 1983). The disease symptoms describe the detrimental effects on groundnut growth and yield attributes hence this knowledge helps to decide the proper time for starting disease management in order to combat great losses.

Common management options used to control groundnut rust disease

Cultural control and sanitary methods

This employ practices that make the environment less attractive to pathogen and less favorable for their survival, dispersal, growth and reproduction while promoting the development of a desired plant. It involves reducing inoculum, intercropping, crop rotation, plant quarantine regulations, mulching and soil amendments (Thurston, 1992; Sill, 1982). Some of effective practices reported against *P. arachidis* involves long break between successive groundnut crops aiming to disrupt viable urediniospores, removing volunteer groundnut plants and ground-keepers. Subrahmanyam and McDonald, 1983; suggested adjusting times of sowing as well as controlling weeds was effective as assisted in avoiding the environmental conditions conducive for disease build-up. Also intercropping pearl millet or sorghum with groundnut (1:3) has been reported to be useful in reducing the intensity of rust disease (Ghosh and Dayal, 1998). Other practices include strict plant quarantine regulations to avoid the movement and spread of rust on pods or seeds to disease free areas (Palti, 1981). Moreover application of high doses of phosphorous fertilizers (60-75kg phosphate/ha) has been reported to slow down the development of rust (Mayee, 1983). Although cultural control is effective in managing rust disease but those practices should be integrated with other management option to make it more effective.

Biological control

Biological control of fungal diseases of plants is eco-friendly and potential component of integrated disease management option which involves use of natural enemies including parasites, predators and competing organisms to low levels at which there is little economic damage (Pal and McSpadden, 2006). This method is highly specific to a particular pest and it provides long term solution to a pest problem and it reputed of being environmentally eco-friendly. According to Biswas *et al.*, 2010, 70% rust disease reduction was observed when treated with *Trichoderma viride* or *Trichoderma harzianum* as foliar spray. Similarly, Govindasamy and Balasubramanian, 1989; reported the significant reduction of number of uredosori/leaflet and uredospore/pustule by *Trichoderma harzianum* on detached groundnut leaves. Furthermore, according to Ghewande, 2006; maximum inhibition of *in vitro* germination of urediniospores and significant reduction in *in vivo* development of rust was exhibited by *V. lecanii* and *P. islandicum*. Furthermore, a study by Meena *et al.*, 2010; proved efficacy of a talc-based powder formulation of *Pseudomonas fluorescens* strain Pf1 in controlling groundnut late leaf spot and rust when applied as seed as well as foliar treatment.

The biological control option seems effective against groundnut rust disease nevertheless it involve research hence too expensive. It is only successful on confined places i.e. 'glasshouse pests' and pest problems located in small area/ islands moreover time and patience is needed. Basing on economic status of small holder farmers in Sub Saharan Africa, there is great need of searching of cheaper, effective and eco-friendly management option for management of groundnut rust disease.

Use of resistance varieties

Use of resistant variety is the simplest, practical, effective and economical option for rust management (Pande and Rao, 2001). It also saves time, energy and money spent on other control measures. According to (Subrahmanyam 1995; Subrahmanyam *et al.*, 1985) in recent years there have been concerted efforts by many countries to exploit genetic resistance to groundnut rust disease due to its importance. More than 13,000 accessions of groundnut germplasm were successfully screened at ICRISAT, India leading to the identification of over 160 genotypes with resistance to rust (Singh and Singh, 1997; Mehan *et al.*, 1996; Subrahmanyam *and* McDonald 1980). These resistant varieties are characterized by slow rusting type, increased incubation period, reduced infection frequency, reduced lesion diameter and low sporulation index (Mehan *et al.*, 1996; Subrahmanyam *et al.*, 1983).

Despite the fact that resistant varieties are effective in managing the rust disease, there are some challenges because in order to develop acceptable varieties it may take 10-15 years (Brown 1980) which is such a long time coming up with a single variety. Furthermore, the host-pathogen system resistance in groundnut rust is not long-lasting (Johnson, 1979). Similarly, sometimes the resistant varieties may have lower crop yield and poor quality hence not preferred by farmers. Therefore, the limitations associated with use of resistant varieties open a door to explore other management options.

Chemical control

Numerous synthetic fungicides have been reported to be effective against groundnut rust disease. For instant several dust formulations of copper and the combinations of mancozeb and zinc and several sterol-inhibiting fungicides proved to be effective against groundnut rust Subrahmanyam, 1997). Likewise, Chiteka *et al.* 1988; reported that when Tridemorph 2gm/lit of water sprayed 3-4 times at 15-20 days intervals gave good management of groundnut rust. Also according to (Culbreath *et al.*, 2002), spraying chlorothalonil 0.2%; or mancozeb 0.25% or Hexaconazole/propaconazole 30 days after germination till 15 days before harvesting at regular 10-15 day intervals reduced disease incidences. Likewise, Calixin at 0.5 ml/liter of water or Kavach at 2 g/liter of water controls groundnut rust (Culbreath *et al.*, 2002). The above mentioned synthetic fungicides respond quickly and effectively in managing the rust disease. However, due to poor socio economic conditions of small holder farmers in the developing world, they cannot afford or follow the recommendations for the application of the optimum amounts. In most cases they apply lower dosage which has implications in developing pathogen resistance to the chemicals (Monyo *et al.*, 2009). Subsequently, this calls for the affordable substitute to the chemical pesticides. The use of botanical pesticides previously called 'native pesticides' has gained reputation due to their less risks to environment, human, livestock and natural enemies.

Pesticidal plant

Currently, a lot of interest has been developed in the antimicrobial effects of pesticidal plants for plant disease management aiming to replace synthetic pesticides (Zida *et al.*, 2008). According to (Zida *et al.*, 2008; Davicino *et al.*, 2007), there are more than 250,000 higher plant species on earth that can be evaluated for their antimicrobial bioactive chemical compounds/phytochemicals. These phytochemicals occur naturally in plants and are classified into two groups' i.e. primary metabolites and secondary metabolites. The primary metabolites (ethanol, lactic acid and amino acids) are mainly for growth, development and reproduction of the organism (Sofowora, 1993). While the secondary metabolites i.e. alkaloids, steroids, saponins, tannins and phenol compounds are synthesized and deposited in specific parts or in all parts of the plant serves as physical defense systems (Ndakidemi and Dakora, 2003; Joseph and Raj, 2010).

A number of pesticidal have been screened to be effective against foliar fungal disease of groundnut such as early leaf spots, late leaf spots and rust (Harsha *et al*., 2011). According to Kishore and Pande, 2005; 38 plant extracts were screened against late leaf spot and rust disease of groundnut and found that aqueous leaf extracts (20%,w/v) of *Prosopis juliflora* and *Lycopersicon esculentum* completely inhibited the spore germination of *Phaeoisariopsis personata* and *Puccinia arachidis*. Similarly, chloroform extracts of *Hemionitis arifolia* was effective against *P. personata* and *P. arachidis* (Sahayaraj *et al*., 2009). Another study by Eriyanto and Alfi (2016), reported the efficacy of crude extract 5% of *Ageratum conyzoides* against rust disease of groundnut. Kishore and Pande (2005) confirmed a positive effect of extracts of *Datura metel* (25g/L) and *Lawsonia inermis* (50g/L) against late leaf spot lesion and rust pustules by 65-74% compared with control. Also an aqueous extracts of *Eupatorium odoratum* L. showed antifungal activity against spore germination of *Puccinia arachidis* over control. Moreover, chloroform extracts of three fern plants were effective against *Phaeoisariopsis personata* and *Puccinia arachidis* (Sahayaraj *et al*., 2009). These evidences proves the antifungal activity of plant extracts in managing rust-causing pathogen *Puccinia arachidis* and open a new prospect in plant disease management by attracting antimicrobial investigation of available plant species against groundnut rust disease. We are focusing on the potential phytochemical compounds possessed by the four selected pesticidal plant species (*Azadirachta indica*, *Moringa oleifera*, *Parthenium hysterophorus* and *Jatropha curcas*) since they have proved efficient against different fungal pathogens as described in Table 1. This call for further studies on how these selected plant species can effectively manage groundnut rust disease and improve crop production.

Table 1. Identified selected pesticidal plant species against fungal pathogens.

Plant	Plant part	Diseases/pathogen	References
Azadirachta indica	Leaf, stem bark, root, shoot,	Anthracnose pepper *Fusarium solani* *Alternaria porri Stemphylium* blight diseases Protozoa, bacteria *Aspergillus flavus, Alternaria solani* *Colletotrichum capcisi, Schizophyllum commune*	(Nduagu *et al*., 2008) (Dharam and Sharma, 1985) (Atawodi and Atawodi, 2009) (Mohammad and Forough, 2007) (Shrivastava and Kshma, 2014; Muktarul *et al*., 2009)
Parthenium hysterophorus	Shoot, leaf, root, stem	*Fusarium solani* *Alternalia alternate* *Aspergillus niger, Candidia albicans* *Fusarium oxysporum* *Aspegillus niger* *Aspegillus flavus* *Alternalia brassicae, Alternalia brassicola*	(Gupta *et al*., 1996) (Pareek *et al*., 2011) (Singh and Srivastava, 2013; Zunera *et al*., 2012;) (Harsha *et al*., 2011), (Ajay *et al*., 2013; Barsagade and Wagh 2010) (Harsha *et al*. 2011; Rukhsana *et al*., 2003)
Moringa oleifera	Leaves, seeds, stem, roots	*Rhizopus stolonifer* and *Microsporum gypseum* *Gibberella xylarioides* *G. candidum* *M. micheli* and *R. stolonifer*	(Ganie *et al*., 2015) (Nkya *et al*., 2014) (Jabeen *et al*., 2008); (Oluduro, 2012); (Bamishaiye *et al*., 2011)
Jatropha curcas	Leaves seeds, stem, roots	*Colletotrichum musae* *Colletotrichum gloeosporioidesFusarium oxysporum, Pythium aphanidermatum, Lasiodiplodia theobromae, Fusarium semitectum, Colletotrichum capsici and Colletotrichum gloeosporiodes*	(Oskoueian *et al*., 2011) (Saetae and Suntornsuk, 2010)

Phytochemical compounds found in four selected plant species (Azadirachta indica, Jatropha curcas, Parthenium hysterophorus and Moringa oleifera) for pesticidal activity.

Azadirachta indica

Azadirachta indica also known as neem, it is native to India, Pakistan and Bangladesh, currently grown in tropical and semi-tropical regions. It is a large evergreen dense tree growing some 10 to 15 meter height and width of about 2-3 meter. Products made from neem trees have been used in India for over two millennia for their medicinal properties. Neem products possess good antifungal, antibacterial, antiviral, anthelmintic, antidiabetic, sedative and contraceptive since they possess most important phytocompounds steroids, phenolic compounds, saponins, alkaloids, glycosides, terpenoids, flavonoids and tannins (Ramadass and Subramanian, 2018; Shrivastava and Kshma 2014; Mohammad and Forough, 2007). Moreover Neem have other valuable active phytocompounds such as azadirachtin, nimbolinin, nimbin, nimbidin, nimbidol, salannin and quercetin, 6-desacetylnimbinene, nimbandiol, nimbolide, ascorbic acid, n-hexacosanol and amino acid, 7-desacetyl-7-benzoylazadiradione, 7-desacetyl-7-benzoylgedunin, 17-hydroxyazadiradione and nimbiol (Hossain *et al.*, 2011; Kokate *et al.*, 2010; Muktarul *et al.*, 2009).

These important ingredients plays important role in the inhibition of growth of numerous microbes such as viruses, bacteria and pathogenic fungi through cell wall breakdown (Hossain *et al.*, 2013); Mordue and Nisbet, 2000). Therefore, it is vital to explore the potential of neem extracts in management of groundnut rust disease.

Moringa oleifera

Moringa oleifera commonly known as Moringa, drumstick tree, ben oil tree, is the only genus in the family Moringaceae. It is native to northwestern India and widely cultivated in tropical and subtropical areas. Moringa tree is a small, graceful, deciduous tree with sparse foliage, often resembling a leguminous species. The tree grows to 8m height with smooth, dark grey; slash thin, yellowish (Fuglie, 2001).

Approximately all parts of the Moringa tree are edible and consumable by humans. It is used worldwide traditionally as medicine for various health conditions since it has antifungal, antibacterial and anti-inflammatory properties (Bamishaiye *et al.*, 2011; Anyasor, *et al.,* 2011; Mahmood *et al.*, 2010; Fuglie, 2001; Sairam, 1999). The *Moringa oleifera* possess numerous bioactive components including vitamins, phenolic acids, flavonoids, saponins, alkaloids, isothiocyanates, tannins, glycosides, terpenoids and steroids Oluduro, 2012: Jabeen *et al.*, 2008). *Moringa oleifera* plant has been proved to be effective against numerous fungal pathogens this encourages scientists for further studies on its efficacy against other diseases such rust disease of groundnut.

Parthenium hysterophorus

Parthenium hysterophorus L. (Asteraceae) is an annual herbaceous plant that can reach a height of 1.5m in its native range, but sometimes can grow up to 2.5m where it is an invasive species (McConnachie *et al.*, 2011). It is commonly known as carrot weed, white top, ragweed parthenium, congress grass and star weed. It is widely distributed in semi-arid, subtropical, tropical and warmer temperate regions with a preference for warmer temperate climates (Adkins and Shabbir, 2014; Shabbir and Bajwa, 2006; EPPO, 2018).

Researchers reported *P. hysterophorus* has antiviral, antifungal, antibacterial, anti-helmintic, anti-molluscal and anti-inflammatory properties (Sesha *et al.*, 2013; Sukanya *et al.* 2009). The major components of toxic being parthenin and other phenolic acids such as caffeic acid, vanillic acid, ansic acid, p-anisic acid, chlorogenic acid and parahydroxy benzoic acid are toxic to human beings and animals (Mahadevappa, 1997; Gupta *et al.*, 1996). The phytochemical investigation of *P. hysterophorus* revealed the presence of various chemical constituents viz., alkaloids, proteins, saponins, tannins, carbohydrate, glycosides, terpenoids, steroids, volatile oils, amino acids, amino sugars, lignans, phenolic compounds, flavonoids, metallic elements, organic acids and terpenoids (Lakshmanan *et al.*, 2013; Sankar and Dipak 2014; Pareek *et al.*, 2011; Das and Das, 1995; Bakhtiar *et al.*, 2012.) Possession of various phytocompounds enable its efficacy against different plant diseases hence the study on how *P. hysterophorus* can be effective in managing groundnut rust disease is important.

Jatropha curcas

Jatropha curcas L is a drought resistant perennial plant, belonging to genus Jatropha and is a member of the Euphorbiaceae family, producing oil containing seeds (Amit *et al.*, 2010). It originates from Mexico or neighboring parts of Central America, which is the only area where it has often been collected from undisturbed vegetation (Igbinosa and Igbinosa, 2009; Henning, 2007). Jatropha plants can easily be grown on marginal soils to help repossess land, hence can be used to conserve the land (Igbinosa and Igbinosa, 2009).

All parts of Jatropha (seeds, leaves, bark, and roots) play a major role in the treatment of various disease pathogens, including bacteria and fungi (Prasad *et al.*, 2012; Duke, 1988). The phytochemical analysis of the methanol extract of the leaf, stem bark and root of *Jatropha curcas* revealed the presence of alkaloids, flavonoids, saponins, glycosides, tannins, terpenoids, resins and steroids in varying quantities (Muklesur *et al.* 2011; Oskoueian *et al.* 2011; Obasi *et al.*, 2011;) Saetae and Suntornsuk,2010. The fungicidal properties of *J. curcas* against different fungal pathogens call for further research in the utilization of this plant in managing groundnut rust disease.

Conclusion

Based on researches and evidences from other research groups, the active ingredients found on the selected pesticidal plants (*Azadirachta indica*, *Moringa oleifera*, *Jatropha curcas* and *Parthenium hysterophorus*) are biodegradable in nature and possess less risks to the environment, human, livestock and natural enemies, Thus these plants may be used as possible substitute for synthetic fungicide in the management of groundnut rust disease. Moreover these plants are cheap and readily available to small holder farmers in Tanzania Africa, who do not have ready access to chemical fungicides.

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