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Groundnut rosette disease symptoms types distribution and management of the disease in Uganda

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Groundnut rosette disease (GRD), caused by a complex of three agents: groundnut rosette assistor luteovirus, groundnut rosette umbravirus, and the associated satellite RNA, is a major groundnut disease in Uganda. Two main symptom types, chlorotic rosette and green rosette occur. A nationwide survey covering 23 districts was done in 2012 and 2013 to ascertain the predominant GRD symptom types, GRD incidences and severity, farmers' knowledge and their GRD coping mechanisms, the current groundnut seed system and farming practices. Data were analysed using SPSS and Chi-square tests of association. Mean GRD severity scores were geo-referenced and plotted on the Uganda map. Most respondent (52%) were females. Other than Northern Uganda, most regions grow groundnut landraces. Major seed sources were home saved and marketed. Thirty six percent of farmers grew groundnuts after cereals as recommended. All the farmers sampled knew about and had seen both rosette symptoms types, which were more visible during the second rains. A whole 42% of the farmers have no coping mechanism against GRD. The current knowledge of GRD did not have a significant effect on its management, seed source, varieties grown or gender of the farmers. The green rosette type predominates, making Uganda a green rosette belt.

Key words: *Arachis hypogaea* L., groundnut rosette virus, green rosette, yellow rosette.

INTRODUCTION

Groundnut (peanut, *Arachis hypogaea* L.) is the second most important legume, after common beans, grown by smallholder farmers in Uganda (Okello et al., 2010, 2013). The crop also represents a significant source of income that contributes to food security and alleviates poverty. Groundnut seeds contain 40 - 50% high quality edible oil, 20 - 50% easily digestible protein and 10 - 20% carbohydrate depending on the variety. Groundnut is also a nutritional source of vitamin E, niacin, falacin, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium (Savage and Keenan, 1994).

Groundnut rosette disease (GRD), which is endemic to sub-Saharan Africa (SSA) and its off-shore islands, is widespread and one of the most destructive disease

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Table 1. Regions/districts surveyed.

Region	Districts	Freq	%
North	Arua, Lira, Nwoya, Nebbi, Oyam, Pader	40	34
Central	Lyantonde, Mukono	8	7
East	Bugiri, Bukedea, Busia, Iganga, Jinja, Kaberamaido,Mbale, Soroti, Tororo, Namutumba	42	36
West	Hoima, Isinygiro, Masindi, Mbarara, Rubirizi	28	24
Total		118	100

of groundnuts (Waliyar et al., 2007). GRD is the most important disease of groundnuts in Uganda (Okello et al., 2010). GRD was first documented at the beginning of the twentieth century in present-day Tanzania and South Africa (Hayes, 1932) and since then has been reported in all groundnut-growing regions of SSA and in Madagascar (Naidu et al., 1998, 1999; Storey, 1935; Storey and Bottomley, 1928). The disease is caused by a complex of three agents: groundnut rosette assistor luteovirus (GRAV), groundnut rosette umbravirus (GRV) and a satellite RNA (Sat-RNA) associated with GRV (Naidu et al., 1999). Two main symptom types of the disease occur (Hayes, 1932, Smartt, 1961; Hull and Adams, 1968) chlorotic rosette (Murat et al., 1988; Naidu et al., 1999; Storey and Bottomley, 1928) and green rosette (Murant et al., 1988). Both types of symptoms are attributed to variants of the Sat-RNA (Murant and Kumar, 1990). Chlorotic rosette has been the predominant form, while green rosette has been reported in the western and southern regions of Africa (Naidu et al., 1998). To date, there is no report on the distribution of the GRD symptom types in Uganda (Wangai et al., 1999). The aphid, *Aphis craccivora* Koch, transmits both forms of GRD in a persistent and circulative manner (Hull, 1964). Either symptom type can cause up to 100% loss in pod yield if the infection occurs before flowering (Naidu et al., 1999; Okello et al., 2010).

In recent years, efforts to control GRD have focused on improving cropping practices to delay the onset and spread of both the vector and the disease and on breeding for host-plant resistance. Cropping practices have led to effective management practices for controlling GRD (Naidu et al., 1998); however, the approach is seldom feasible for the subsistence farming systems of SSA (Deom et al., 1999). Efforts in breeding for host-plant resistance and evaluation of the global collection of groundnut germplasm have contributed to the identification and development of several groundnut germplasm lines with acceptable levels of field resistance to GRD (Olorunju et al., 1991; 2001; van der Merwe and Subrahmanyam, 1997; Subrahmanyam et al., 1998). Since 1995, the Uganda National Groundnut Improvement Programme has released 13 rosette resistant commercial varieties. The goal of this work was to determine the knowledge and management practices used for GRD, document the groundnut seed systems, and analyze the prevalence and distribution of GRD symptom types in widespread districts of Uganda

MATERIALS AND METHODS

All major groundnut production areas of the country, Eastern (Bugiri, Bukedea, Busia, Iganga, Jinja, Kaberamaido, Mbale, Soroti, Tororo and Namutumba), Northern (Arua, Lira, Nwoya, Nebbi, Oyam and Pader), Central (Lyantonde and Mukono) and Western Uganda (Hoima, Isingiro, Masindi, Mbarara and Rubirizi) were sampled during the survey. Farmers' groundnut fields were visited when the crop was between 50% anthesis and physiological maturity. Entire fields were scored for GRD severity based on a scale of 1-9 (NaSARRI scale); where, (1-3) = resistant; (4-6) = moderately resistant; (7-9) = susceptible. GRD symptom types (chlorotic and green) were visually scored and documented from field observation in addition to the farmers' responses. Disease identification was based on the experience of the field research team and ICRISAT disease field guides to identify GRD. Geographical position system (GPS) coordinates were recorded for each sampled field site to produce a geo-referenced map of GRD prevalence and occurrence in the Uganda. Additional, data recorded included: the previous crop in the field, the groundnut varieties grown, seed sources, stage of crop growth (age of the crop), prevalence and severity of GRD, farmer knowledge of GRD and the symptom types and GRD management schemes used by farmers.

Data analysis

Respondents' data were analyzed using SPSS (version 11). To study association between the presence of GRD in the field with farmer's knowledge, socio-economic characteristics and other farm attributes, Chi-square test for association was performed. The association between farmers' knowledge on GRD and farmers' socio-economic background was also tested using Chi-square test for association. The mean incidence scores were then geo-referenced in Arc-GIS (Version 9) software and plotted on a map of Uganda.

RESULTS

A total of 23 districts representing the major groundnut Agro-ecologies of Uganda were surveyed (Table 1). One hundred and eighteen farmers' fields were sampled countrywide and the owners were interviewed. Central Uganda had the least coverage (7%) whereas Northern (40%) and East Uganda (42%) had the highest coverage.

Table 2. Gender.

Gender of farmers	%				
	General	North	Central	East	West
Female	52	25	50	61	71
Male	48	75	50	39	29
Total	100	100	100	100	100

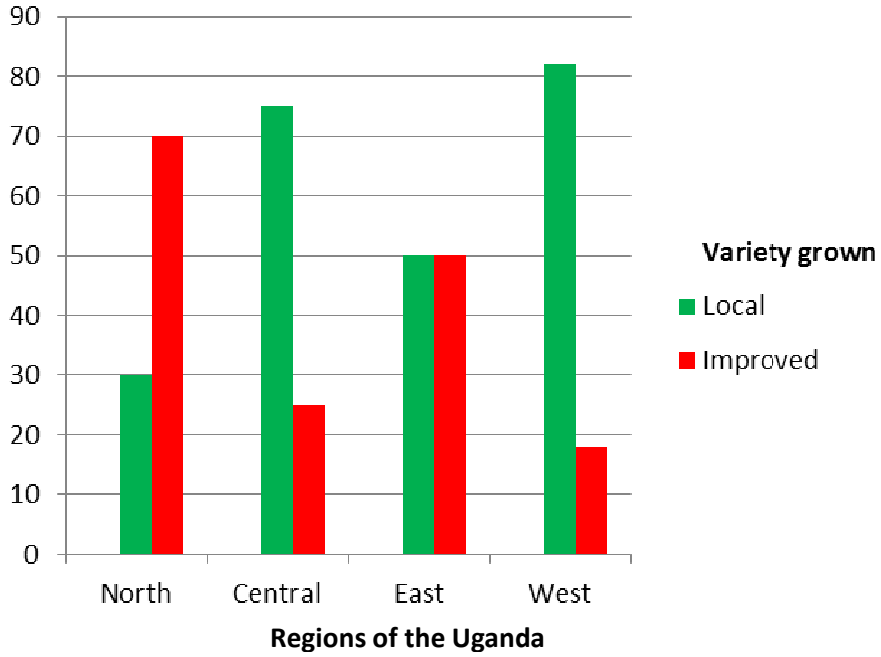

Figure 1. Varieties grown.

Gender

Fifty two percent (52%) of the farmers surveyed were females (Table 2). Eastern and Western Uganda had the highest percentage of female respondents (71 and 61%, respectively), whereas the Northern region had the highest number of male respondents (75%). Groundnuts, like most legumes in Uganda, are predominantly grown by women farmers.

Varieties grown

With the exception of Northern Uganda, most of the groundnut varieties grown in the other regions were landraces with the Western region having the highest percentage (82%) of landraces (Figure 1). The highest percentage of farmers growing improved varieties was in Northern Uganda. This is as a result of NGOs who operate in post war Northern Uganda frequently supplying seed aid instead of other types of relief aid as the communities re-settled their villages from the two decade long insurgency. The NGOs buy improved varieties and distribute to their supported farmers.

Most farmers purchased seeds from the market (36%), others used saved seeds (23%), and 20% of the farmers procured directly from NARO (Table 3). A mere 9% of seeds were procured through the National Agricultural Advisory Services (NAADS), the official government link between research and farmers. The NAADS programme has their sponsored farmers grouped and crop priorities determined. They then provide funds and link farmers to seed sources. NAADS should be in the forefront of seed supply, connecting government supported research and farmers. Development partners (NGOs) buy seeds directly from the research institutes because of the high seed quality. Overall, twenty percent (20%) of the farmers mentioned NARO as their seed source. These farmers are supported by the NGO and they procure the seeds directly from research stations with the help of their sponsors. This trend is good for the sustainability of the seed system post NGO era. Such farmers would still recognize the research station as a source of high quality seeds.

Table 3. Seed source.

Seed source	%				
	General	North	Central	East	West
Donors	1	3	0	0	0
Farmer groups	3	3	0	5	0
Markets	36	20	38	57	29
Neighbors	6	5	13	5	7
NGO	2	0	0	5	0
Research (NARO)	20	33	25	10	18
Saved seed	23	25	25	7	43
NAADS	9	13	0	12	4
Total	100	100	100	100	100

NARO (National agricultural Research Organization); NAADS (National Agricultural advisory Services) is a formal link between research and farmers.

Table 4. Growth stage.

Growth stage	%				
	General	North	Central	East	West
Past 50% anthesis	62.7	82.5	62.5	74	18
Physiological maturity	37.3	17.5	37.5	26	82
Total	100	100	100	100	100

Table 5. Previous crop.

Percentage	%				
	General	North	Central	East	West
Bananas	1	0	13	0	0
Legumes	18	10	38	19	21
Vegetables	3	2.5	0	0	7
Tubers	30	30	13	50	4
Cotton	3	5	0	0	4
Cereal	36	40	38	24	50
Simsim	4	10	0	2	0
Sunflower	1	0	0	2	0
Virgin land	5	2.5	0	2	14
Total	100	100	100	100	100

Growth stage

Overall, 37.3% of the groundnuts were at physiological maturity and 62.7% had past 50% anthesis (Table 4). This was the time to rate the GRD severity since after 50% anthesis most of the plants assimilate partitioning will be towards the fruit development, hence any stress diseases would manifest themselves. The highest percentage of plants at physiological maturity was 82%, in the West. This reflects the seasonal variability throughout Uganda and the preference to grow early maturing local Spanish and Valencia groundnut botanicals in the West.

Previous crop

A high percentage of the farmers (36%) grew groundnuts after cereals (Table 5). This is a recommended practice. The 18% of the farmers who grew groundnuts after legumes need to be further discouraged of using this practice through education. If done repeatedly over more

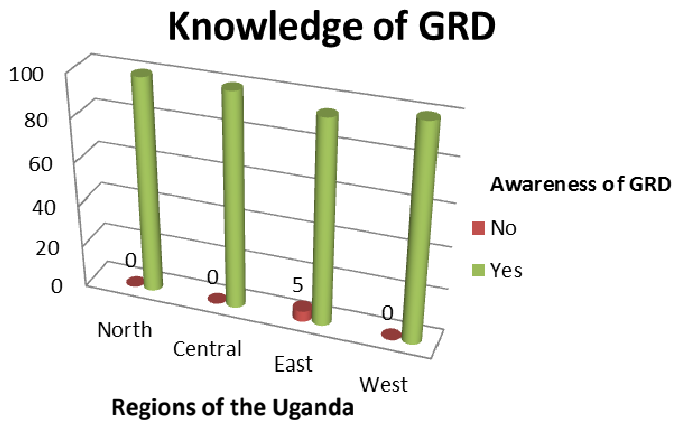

Figure 2. Knowledge of GRD.

Figure 3. See GRD in the field. The percentage is calculated based on 118 respondents (farmers).

than one season the practice leads to build up of pests and diseases that directly have impact on groundnut production.

Knowledge of GRD

Most respondents (98%) know and are aware of GRD (Figure 2). With exception of 5% of the respondents in Eastern Uganda, all the respondents routinely see GRD in the field (Figure 3). This observation however is not translated into the GRD management practice as reflected by the association result (Figure 9).

Common GRD symptoms

The green symptom type predominates (95%) in all the regions surveyed. It ranges from 100% in the Central region to 86% in the West, 97.5% in the Northern and 98% in the Eastern region. Chlorotic symptom type ranges from high (14%) in the West to not being detected in Central Uganda (Table 6). The two rosette symptom types are shown in Figure 4.

Seasonal GRD symptoms

The majority (53%) of the respondents mentioned that the GRD symptoms were more often observed in the second rains (Figure 5). Second rains in most parts of Uganda are short and are followed by mid- and end-of-season drought. GRD is more severe under such stressed environments.

Management of GRD

A large percentage of farmers (42%) do nothing when GRD appears. A large percentage of respondents in the East (17%) and West (14%) do spray their groundnut crops, which are mainly landraces (Table 7). In the East, we observed landraces lines Amasoga, Mpeke mbiri, Kabonge, Mzungu, which are very susceptible to GRD (Picture 2). This could in part explain the spraying requirements.

In the West, Redbeauty a local Valencia, which is susceptible to both GRD and late leafspots, is majorly grown. The spraying regimes are targeting those two diseases. Twenty three percent (23%) of the farmers grow GRD resistant varieties. NARO has released GRD resistant varieties, which are available on station at NaSARRI in Serere and with seed companies. With education and demonstration settings, the percentage of farmers controlling GRD through the use of resistant varieties should rise significantly (Figure 6).

Predominant GRD symptom type observed in the field by the team

The green rosette symptom type was predominantly observed in groundnut fields (93%) in all regions sampled. The highest incidence of chlorotic rosette (18%) was observed in Western Uganda (Figure 7).

GRD severity

In general, GRD severity was low (1-3), falling in the resistant category. Northern Uganda had the majority of fields with the least severity scores (65%), whereas the highest severity scores were observed in Eastern Uganda. This result correlates well with the varieties grown in the various regions of Uganda (Figure 8). Farmers in Northern Uganda with the assistance of the NGOs are growing improved varieties, which are

Table 6. Common GRD symptoms.

Rosette symptom types	%				
	General	North	Central	East	West
Green	95	97.5	100	98	86
Yellow	5	2.5	0	2	14
Total	100	100	100	100	100

Figure 4. Green rosette symptom (left) and yellow/chlorotic rosette symptom (right).

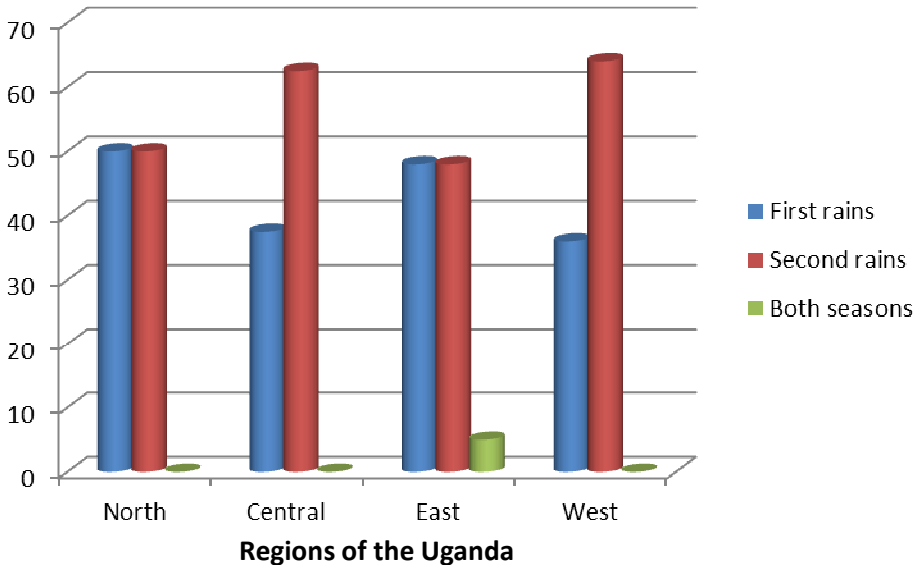

Figure 5. Season GRD is common.

resistant to GRD.

Association between the presence of rosette in the field, knowledge of rosette and other factors

Other than management of GRD, there were insignificant associations between the key factors tested and the presence/absence of GRD in the field (Table 8). This means that if one manages GRD, less or no disease will appear in the garden. Management can be through planting resistant varieties and following good agronomic practices (crop rotation, timely planting, right plant density).

The current knowledge of GRD was not significantly associated with GRD management, seed source, variety

Table 7. Management of GRD.

Crop management	%				
	General	North	Central	East	West
Crop rotation	6	10	0	5	4
Early planting	4	10	0	2	0
Intercropping	1	0	0	2	0
Nothing done	42	17.5	50	55	57
Resistant variety	23	47.5	37.5	5	11
Shifting cultivation	2	5	0	0	0
Spray	12	7.5	0	17	14
Uproot and burn	10	2.5	12.5	14	14
Total	100	100	100	100	100

Figure 6. A groundnut landrace field heavily affected by rosette virus disease in Bukedea, Eastern Uganda 2012B season.

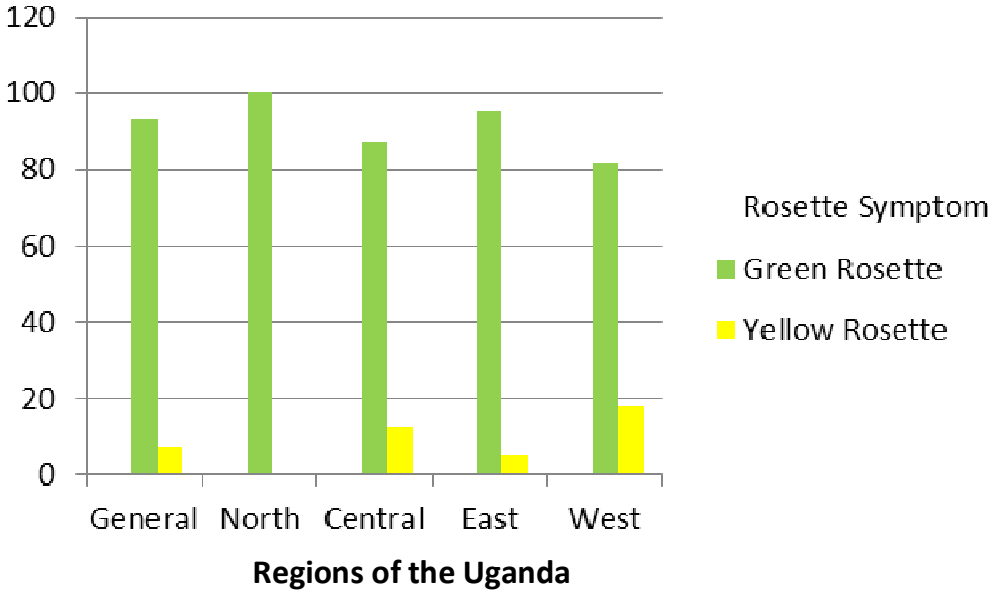

Figure 7. Predominant GRD symptom type observed in the field by the team.

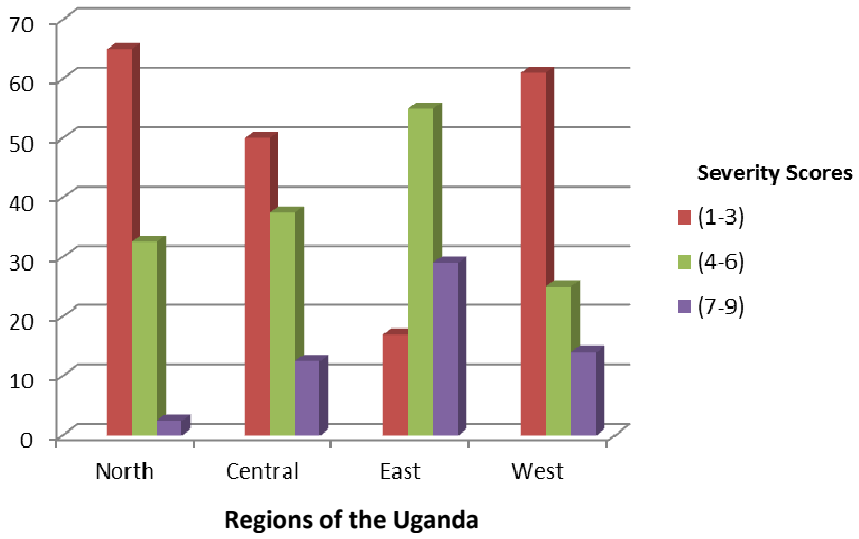

Figure 8. GRD severity. Resistant = (1-3); moderate resistant = (4-6); susceptible = (7-9).

Table 8. Analysis of association between the presence of rosette in the field, knowledge of rosette and other factors.

Row factor	Column factor	Pearson chi-square value, degree of freedom	P-value	Significant association
Presence/absence of Rosette in the field	Management of Rosette	61.73 df =10	<0.001	Yes
	Source of seed	8.08 df = 8	0.426	No
	Variety grown	2.67 df =3	0.445	No
	Previous crop in the field	15.42 df=22	0.843	No
	Gender	1.90 df =1	0.168	No
	Knowledge of Rosette disease	0.04 df =1	0.851	No
	Stage of crop growth	1.21 df =2	0.546	No
	Variety grown	2.67 df =3	0.445	No
	Season	0.05 df =2	0.975	No
	Most common rosette symptom	0.11 df =1	0.741	No
Knowledge of rosette disease	Previous crop in the field	8.40 df =22	0.996	No
	Management of Rosette disease	2.82 df =10	0.985	No
	Gender	1.90 df =1	0.168	No
	Source of seeds	4.96 df =8	0.762	No
	Variety grown	0.11 df =3	0.991	No

grown and as well as the gender of the farmer.

Farmers were able to identify GRD in the field and the predominant season, but the knowledge is not reflected in adopting recommended technologies. The underlying factors for not putting knowledge into practice need to be addressed. Probably the existing GRD management technologies are expensive (seeds, pesticides) as compared to what farmers have (landraces). The extension educators (NAADS) need to be more visible in the ground. Researchers also need to demonstrate the superiority of GRD resistant technologies in farmers' fields. The current groundnut seed trends of on-farm saved seeds contributing a large stake of the seed supply needs strengthening. Groundnuts seed banks should be set up in the communities and there should be active community based seed multiplication groups linked to

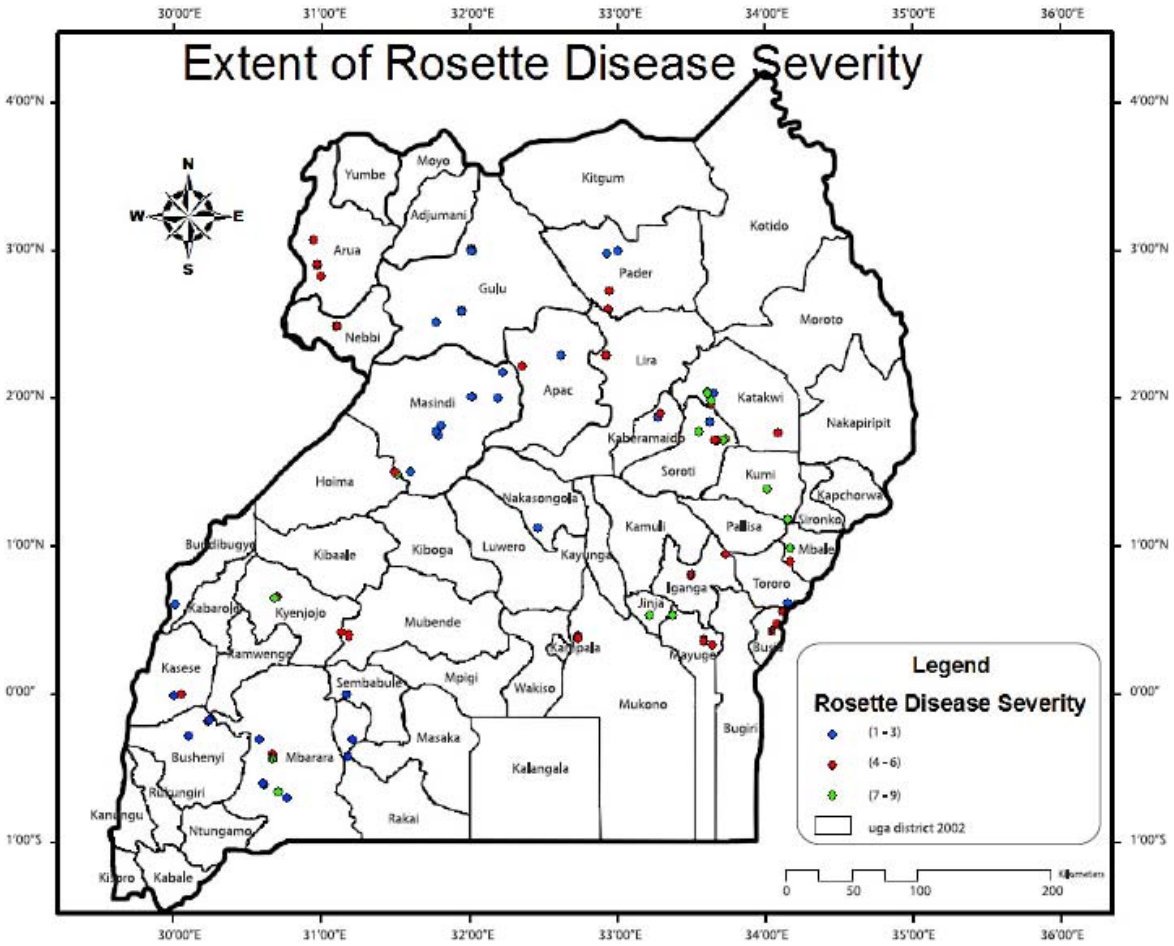

Figure 9. The GRD severity distribution.

seeds markets and research knowledge. Such a research linked seeds multiplier could then be trained and monitored routinely to produce both foundation and quality declared seeds to meet the current demand for desired GRD resistant varieties.

GRD severity distribution

Northern Uganda has the least GRD severity because they mainly grow GRD resistant varieties as a result of the humanitarian aids intervention post war. GRD severity is high in the East especially the Jinja and Pallisa Area (Figure 9). There are two hotspots at Nakabango in Jinja and Ikilki in Pallisa. In Western Uganda, GRD severity is mainly high because farmers mainly grow red landraces, which are usually susceptible to GRD

Conclusion

In Uganda, GRD resulting in green symptoms predominates. This is in contrast with Wangai et al. (1999), who reported that chlorotic GRD has been the predominant form throughout sub-Saharan Africa. This finding is of utmost importance because Uganda is a major groundnut grower in SSA and a regional ICRISAT GRD trial site. The dynamics of the GRD symptomatology and the vector behavior needs further research.

Jinja and the surrounding area recorded the highest severity. This further affirms that the region is a GRD hotspot, as previously reported by Okello et al. (2010)

Most of the groundnut farmers interviewed were females who practice the recommended crop rotations. According to Kaaya and Christie (2009), groundnut production in Uganda is mainly dominated by women. This finding further strengthens the notion of the groundnut being a woman's crop.

Northern Uganda farmers mostly grew improved varieties. This is attributed to the development partners' (NGO and humanitarian organizations) post-war initiatives, which supplied farmers with improved seeds from research and seed companies instead of food relief. This also explains the low GRD severity levels in this region since most of the improved varieties are GRD disease resistant.

Generally, home saved seeds and markets are more visible sources of seeds than seed companies and NAADS. This unfortunate seed source trend needs to be modified to enable farmers' access to the latest groundnut technologies.

Formal seed companies and local seed banks need to be established in Western and Southern Uganda where no GRD resistant varieties were reported to be used. The national research programme at NaSARRI needs to work with NAADS and NGOs in the areas and set up demonstration and participatory variety selection trial sites to aid in popularizing the new high yielding GRD and leafspot resistant varieties.

The dual occurrence of GRD and leaf spot diseases were reported nationwide. Leaf spot severities were very high in Western and Southern Uganda and farmers reported that they harvest their groundnut crops prematurely (2-3 weeks before physiological maturity and keep them for 3-4 weeks for colour development before stripping) because when left in the garden they dry off and the pegs become detached from the main plant and remain in the soil. Nationwide, farmers confuse leaf spot diseases with harvest indicators. A large percentage of the farmers sampled (42%) do nothing about GRD. Novel GRD and leaf spot disease resistant technologies are available and need to be rigorously disseminated through education, demonstration plots and field days.

RNA viruses exist as "quasispecies" (Roossinck, 1977) in infected plants, and thus the population complexity of GRAV, GRV and sat RNA in the field has the potential to be large. The potential permutations among variants of the three agents are able to form viable alternatives and their capacity to adapt to diverse and changing eco-niches are thus enormous. With time, this continuous "evolution" of GRD agents under strong selection pressure can lead to new disease patterns. For example, in Nigeria, a clear shift occurred from green to chlorotic rosette over a period of about 20 years (Naidu et al., 1999; Yayock et al., 1976; Misari et al., 1988). The shift could be due to changes in the genome sequences of GRD agents or to different vector biotypes and cropping patterns. Routine documentation of the predominant GRD symptom types is therefore necessary. This will enhance research efforts by NaSARRI, which are geared towards development of novel strategies to support crop protection measures currently in use for management of the GRD in Uganda. This is the first report on the GRD symptom types distribution in Uganda. Since groundnuts are important and widely grown in Sudan, DR Congo, Tanzania, Rwanda and Burundi, it would be interesting to determine the GRD symptom types distribution in those countries.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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