Screening Groundnut (*Arachis hypogeae L.*) Genotypes for Resistance to Early and Late Leaf Spot Diseases

Original research paper

ABSTRACT

Background for the study: Groundnut (*Arachis hypogaea* L.) is an important crop both in subsistence and commercial agriculture in Ghana. Early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Cercosporidium personata*) are major limiting factors to groundnut productivity in Ghana.

Aim: The objective of the study was to screen groundnut genotypes for resistance to Early and Late leaf spot diseases.

Study Design: The treatments were arranged in a randomized complete block design and replicated three (3) times.

Place and Duration of Study: The research was conducted from May to December 2013 at the Savanna Agricultural Research Institute experimental site at Nyankpala in the Northern Region. The site lies between latitude 9° 25´ 141 North and longitude 0° 58' 142 West and an altitude of 183m.

Methodology: The land was done using a tractor and field divided into plots of 2m x 5m with 1m interval between plots. Sowing was done on 3rd June 2013. One seed was planted per hole at a depth of approximately 4 cm. Early and late leaf spot ratings were recorded at 30, 60 and 90 days after planting, using a ten-point scale. At pod maturity, plants from the middle two rows of each plot were hand-harvested and weights of the above ground foliage and underground pods were oven-dried to obtain dry haulm weight and pod yield respectively. Data collected were subjected to analysis of variance using Genstat statistical package (12th edition). Means were separated using the least significant difference at 5%.

Results: The were significant differences ($P < .001$) among the groundnut genotypes in terms of severity for both early and late leaf spot diseases. F-Mix, NC 7, PC 79-79, F-Mix × SINK 24 and NKATIE-SARI had lowest score for both early and late leaf spot diseases. Among the 21 groundnut genotypes, F-Mix recorded the highest pods yield of 1100kg/ha and haulm weight of 5867kg/ha followed by NC 7 with total pods yield of 900kg/ha and haulm weight of 5373kg/ha. PC 79-79 had a total pods yield of 666.7kg/ha and haulm weight of 4867kg/ha. The pods yield of F-Mix × SINK 24 was 533.3kg/ha and haulm weight of 4600kg/ha. NKATIE-SARI recorded pods yield of 500kg/ha and haulm weight of 4633kg/ha.

Conclusions: From the study, the genotypes F-Mix, NC 7, PC 79-79, F-Mix × SINK 24 and NKATIE-SARI were found to be resistance to both early and late leaf spot disease whereas Chinese, Doumbala, GM 120, GM 324 and ICGV 86015 were susceptible to both diseases.

Key words: Groundnut, disease severity, leaf spot, genotypes, leaf defoliation, crop rotation.

1.0 INTRODUCTION

Groundnut *(Arachis hypogeae L.)* is an important economic food and cash crop grown globally. The crop contributes to the world diet and is used for food for people from both developed and developing countries.

Groundnut also has other uses such as; source of cooking oil, solvents and medicine. It can also be eaten raw, slightly cooked or when it is still fresh.

Groundnut vines (hay) can also serve as fodder for livestock especially during the dry season when there is scarcity of green forage for livestock (Tsigbey *et al.,* 2004; Naab *et al.,* 2005).

According to Asiedu (1989), groundnut is a herbaceous plant of which there are two types, bunch and runner types. Apart from the runner and bunch types, many intermediate forms or hybrids exist (Irvine, 1974).

According to FAO estimate, the average world production of groundnut pods in 1990 – 2003 was between 34.4 million tons/year from 24.4 million hectares of land (Ntare, 2007). The largest producers of groundnuts are China and India followed by Sub- Saharan African countries, central and South America (Johnson and Ives, 2001). Approximately 85% of the land area under groundnut production is in the Sudan and Guinea Savanna zones. The total production in Sub-Saharan Africa was 8.2 million tons/year from 9.5 million hectares of land (Ntare 2007). Groundnut is cultivated in all agro ecological zones of Ghana. However, a large proportion (92%) of the production is in Northern-Ghana (Twemboah, 2000).

It is produced both as a commercial and a subsistence crop (Tsigbey *et al.,* 2004). Groundnut yields are however very low in Ghana averaging less than 1000kg/hectare in comparison with an average of 2500kg/hectare obtained in developed countries (Shokes and Culbreath, 1997). In Ghana, the common limiting factor to groundnut production is the prevalence of diseases, most importantly early leaf spot caused by *Cercospora arachidicola* and late leaf spot caused by Cercosporidium *personata* (Frimpong *et al.,* 2006a). Both diseases are distributed widely and occur in epidemic proportion in northern Ghana (Nutsugah *et al.,* 2007 a). The incidence of early and late leaf spot on susceptible groundnut genotypes can lead to total defoliation which can drastically reduce yield (Shew *et al.,* 1995). High defoliation can also affect hay quality of vines fed to livestock (Tsigbey *et al., 2004).*

Leaf spot disease appear as reddish brown to black necrotic spot on leaves. The necrotic spot in early leaf spot are bounded by a yellow halo which separates it from late leaf spots which have no halo. Both diseases reduce the leave area available for photosynthesis and cause premature defoliation and yield loss as much as 70% in West Africa (Shokes and Culbreath, 1997).

Annual yield losses of up to 50% attributable to the disease can occur in northern Ghana. The most common method of control is by the use of fungicides. However, in Ghana, a large number of farmers do not practice any control for these diseases in their groundnut farms largely due to inadequate resources to use the appropriate chemical control and/or difficulty in obtaining fungicides (Allen 1983; Nutsugahet *et.al,* 2007a). Moreover, these chemicals leave toxic residues in the environment (Maloy 1993; Iheijirikael *et.al,* 2006a).

Gibbons (2002), discovered that application of chemicals against leaf spot as well as against other diseases should be reduced to a minimum on health and environmental grounds. Tuormaa (2006) reported that, world health organization (WHO) report estimated that there were between 800,000 and 1,500,000 cases of unintentional pesticides poisoning in the world, resulting to about 3,000 and 28,000 deaths.

A case study finding showed highly disturbing levels of pesticides misuse and abuse leading to poisoning of families and livestock (Adolpus, 2007).

Due to the above mentioned reasons, the use of disease – resistant cultivars is the best and economically way to control diseases of food crops (Mallikarjuna *et al.,* 2004; Jyosthna et al., 2004). It is the most cost efficient of all the control measures (Driscoll, 1990).

Resistant cultivars save time, effort and money which would have been spent in controlling plant diseases. The environment also gains because there will be no application of pesticides (Maloy, 1993). Subrahmanyam et al., (1982) reported that some genotypes of groundnut are resistant to cercospora leaf spot (early and late leaf spot).

The objective of this study was to screen groundnut genotypes for resistance to early and late leaf spot diseases.

2.0 Materials and Methods

2.1 Experimental Site.

The research was conducted from May to December 2013 at the Savanna Agricultural Research Institute experimental site at Nyankpala in the Northern Region. The site lies between latitude 9° 25´ 141 North and longitude 0° 58' 142 West and an altitude of 183m.

2.2. Field Experiment and Design.

The land was ploughed and harrowed using a tractor and divided into plots of 2m x 5m with 1m interval between plots. The treatment were arranged in a randomized complete block design and replicated three (3) times. Sowing was done manually on 3rd June 2013. One seed was planted per hole at a depth of approximately 4 cm. A plot consisted of six rows with spacing of 0.5 m between rows and 0.2 m between plants in a row. Weed control was done using hoe to remove weeds and hand pulling of weeds where necessary.

2.2.1. Source of Groundnut genotypes.

Twenty-one (21) groundnut genotypes obtained from CSIR-Savanna Agricultural Research Institute and its collaborators from Burkina Faso were used for the study. The groundnut genotypes used and their source are listed in table 1 below.

Table 1.0 groundnut genotypes and their sources.

Number	Genotype	Sources
1	NC 7	Tamale-Ghana
2	NKATIE-SARI	Tamale-Ghana
3	ICGV 86015	Tamale-Ghana
4	FDRS × F-MIX	Tamale-Ghana
5	ICGV 92096	Tamale-Ghana
6	F-MIX × SINK 24	Tamale-Ghana
7	CHINESE	Tamale-Ghana

8	F-MIX	Tamale-Ghana
9	DOUMBALA	Burkina Faso
10	TS-32-1	Burkina Faso
11	PC 79-79	Burkina Faso
12	GM 204 (123)	Burkina Faso
13	ICGV 86124	Tamale-Ghana
14	ICGV 97188	Tamale-Ghana
15	ICGV 96814	Tamale-Ghana
16	ICGV 86015	Tamale-Ghana
17	GM 656	Burkina Faso
18	GM 155	Burkina Faso
19	GM120	Burkina Faso
20	GM 663	Burkina Faso
21	GM 324	Burkina Faso

2.3. Data Collection and Analysis

Data was collected on leaf spot disease severity, number of pods per 5 plants, haulm weight, pod yield and maturity rating. Data on leaf spot severity were taken at 30, 60 and 90 days after planting using the Florida scale of (1-10) based on visual observations where 1 = no disease, 2 = very few lesions on leaves in lower canopy, 3 = few lesions on leaves in lower and upper canopy, 4 = some lesions on leaves in lower and upper canopy with ≤10% defoliation, 5 = lesions noticeable in upper canopy and ≤ 25% defoliation, 6 = lesion numerous with ≤50% defoliation, 7 = lesions very numerous with ≤75% defoliation, 8 = numerous lesions on few remaining leaves with ≤90 defoliation, 9 = remaining leaves covered with lesions with ≤95% defoliation, and 10 = plants defoliated or dead (Maninder *et al.,2011*). Ten plants were sampled per plot. Data also was taken on incidence of rossete as additional data.

At pod maturity, plants from the middle two rows of each plot were hand-harvested and weights of the above ground foliage and underground pods were oven-dried to obtain dry haulm weight and pod yield respectively. Data collected were subjected to analysis of variance and the mean difference separated using the least significant difference test at LSD of p≤ 0.05 using Genstat statistical package (4th edition).

3.0 RESULTS

3.1 Disease score of early and late leaf Spot

Table 2 Effect of groundnut genotype on severity score for early and late leaf spot diseases.

TREATMENTS	DISEASE SCORE

	EARLY LEAF SPOT	LATE LEAF SPOT
CHINESE	5.133 a-d	6.933 a
DOUMBALA	4.533 d-f	6.200 bc
F-MIX	4.200 f	5.200 de
F-MIX × SINK 24	4.600 c-f	5.333 de
FDRS × F-MIX-39	4.867 a-e	5.933 bc
GM 120	5.267 ab	6.467 ab
GM 155	5.200 abc	6.200 bc
GM 204 (123)	5.267 ab	6.267 bc
GM324	5.333 a	6.333 b
ICGV 86015	5.000 a-e	6.267 bc
ICGV 86024	5.267 ab	6.267 bc
ICGV 92096	4.867 a-e	6.133 bc
ICGV 96814	4.400 ef	6.067 bc
ICGV 97188	5.133 a-d	6.133 bc
ICGV 86124	5.133 a-d	6.133 bc
TS-32-1	5.133 a-d	6.133 bc
NC 7	4.133 f	5.333 de
NKATIE-SARI	4.667 b-f	5.067 e
PC 79-79	4.600 c-f	5.733 cd
GM 656	5.067 a-d	6.067 bc
GM 663	5.000 a-e	6.000 bc
P value	<.001	<.001
CV%	2.6	0.5
SED	0.3039	0.2786

123 Genotypes with different letters in a coloumn are significantly different (protected LSD test, P<0.05)

The results indicated that there was significant difference ($P < .001$) among the groundnut genotypes in the severity of both early and late leaf spot diseases (Table 1). The genotypes NC7, F-MIX, ICGV 96814, PC 79-79, NKATIE-SARI, F-MIX × SINK-24 and FDRS-F-MIX-39, had lower disease severity scores for early leaf spot and so have some level of resistance to early leaf spot while the genotypes CHINESE, ICGV 86015, ICGV 86124, ICGV 97188, TS-32-1, GM 656, GM 155, GM 120, GM 204 (123) and GM 324 had higher disease severity score for early leaf spot and so were susceptible to early leaf spot disease. Chinese and Doumbala were used as susceptible checks while Nkatie-SARI was the resistant check.

For late leaf spot, the genotypes NKATIE-SARI, F-MIX, F-MIX × SINK 24, NC7 and PC 79-79 recorded the lowest disease severity scores while the genotypes GM 656, ICGV 96814, TS-32-1, ICGV 92096, ICGV 97188, ICGV 86124, ICGV 86015, GM 663, GM 155, ICGV 86024, GM 204 (123), GM 120, GM 324, DOUMBALA and CHINESE had the highest disease severity score and so exhibit some level of susceptibility to late leaf spots.

3.2 Total number of pod/plant, number of matured pod/plant and dry pod weight.

Table 3 shows the effect of groundnut genotypes on total number of pods/plant; number of matured pods/plant and dry pod weight

TREATMENTS	Total number of pods/plant	Number of matured pods/plant	Dry pod weight (kg/Ha)
CHINESE	5.67 j	3.67 i	500.0 b-f
DOUMBALA	10.67 gh	7.667 fgh	866.7 a-d
F-MIX	19.67 a	17.00 a	1100.0 a
F-MIX × SINK 24	17.00 ab	14.33 abc	533.3 b-f
FDRS-F-MIX-39	15.33 bcd	12.67 bcd	566.7 b-f
GM 120	7.67 ij	4.00 i	300.0 efg
GM 155	14.33 b-e	10.33 def	533.3 b-f
GM 204 (123)	11.67 e-h	9.00 efg	400.00 efg
ICGV 86024	11.67 e-h	7.67 fgh	600.0 b-f
GM 656	11.33 fgh	8.00 efg	233.3 fg
GM 663	10.33 hi	7.67 fgh	366.7 efg
GM 324	7.6 ij	4.33 hi	366.7 efg
ICGV 86015	13.67 c-f	10.33 def	700.0 a-e
ICGV 86124	13.33 d-g	11.33 bcd	933.3 ab

ICGV 97188	13.33 d-g	10.00 d-g	500.0 b-f
ICGV IS 96814	10.33 hi	6.67 ghi	566.7 b-f
ICGV IS 92096	12.00 e-h	9.00 efg	466.7 c-f
TS-32-1	16.33 bc	10.67 def	433.3 d-g
NC 7	17.00 ab	14.67 abc	900.0 abc
NKATIE-SARI	17.00 ab	15.00 ab	500.0 b-f
PC 79-79	16.33 bc	13.33 a-d	666.7 a-f
P value	<.001	<.001	0.004
CV%	5	4.4	12.6
SED	1.462	1.745	217.9

Genotypes with different letters in a row are significantly different (Protected LSD test, P< 0.005).

The genotypes F-MIX, NC 7, NKATIE-SARI, F-MIX × SINK 24, PC 79-79, TS-32-1, FDRS-F-MIX-39 and GM 155 recorded the highest total number of pods/ plant whereas CHINESE, GM 120, GM 324, GM 663, DOUMBALA, GM 656 and GM 204 (123) had the lowest total number of pods/plant.

Also, F- MIX, NKATIE-SARI, NC 7, F-MIX × SINK 24, PC 79-79 and FDRS-F-MIX-39 had the highest number of matured pods while Chinese, GM 120, GM 324, ICGV 96814, Doumbala and GM 663 recorded the lowest number of matured pods.

The genotypes F-Mix, NC 7, ICGV 86124, ICGV 86015, and PC 79-79 recorded the highest dry pod weight while Chinese, GM 656, GM 120, and GM 324 which recorded the lowest dry pod weight (kg/ha).

3.3 Dry haulm weight (kg/ha)

The results indicated that there were significant differences (P< 0.005) dry haulm weight among the groundnut genotypes (Fig 1).

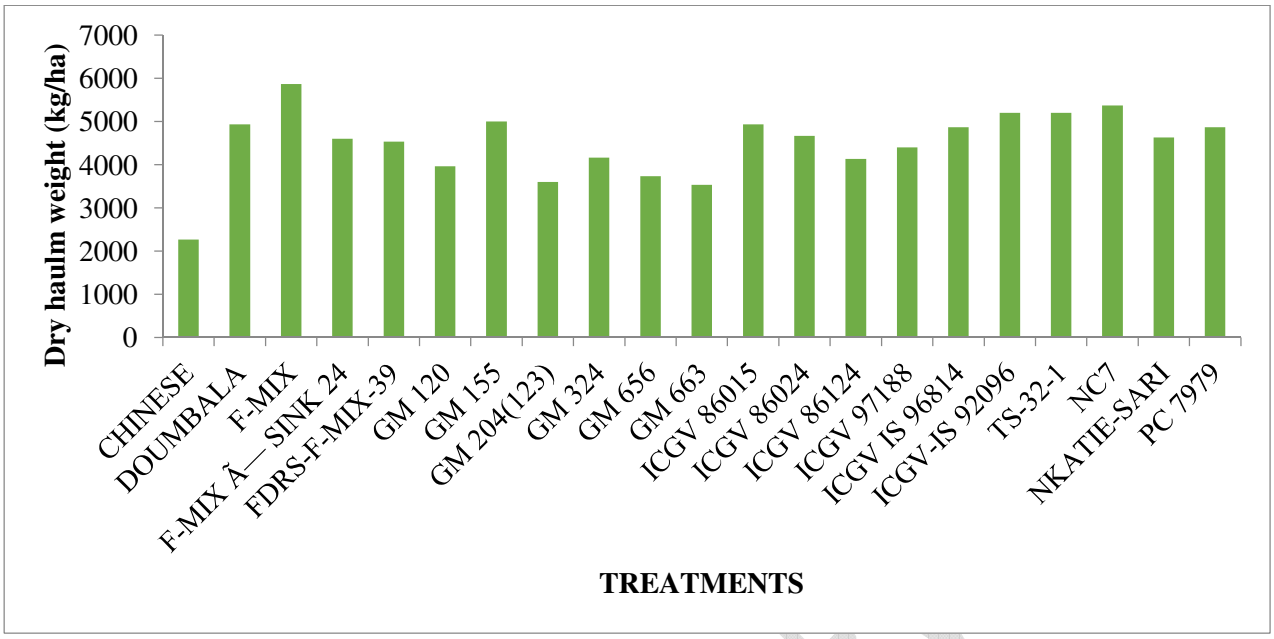

Fig 1 Effect of groundnut genotypes on dry haulm weight (kg/ha)

For dry haulm weight (kg/ha) as expected, the genotypes F-mix, NC 7, TS-32-1, ICGV 86015 and ICGV IS 92096 recorded the highest dry haulm weight (kg/ha) while Chinese, GM 204 (123) and GM 663 recorded the lowest dry pod weight.

3.4 Number of Rossete plants/10 m²

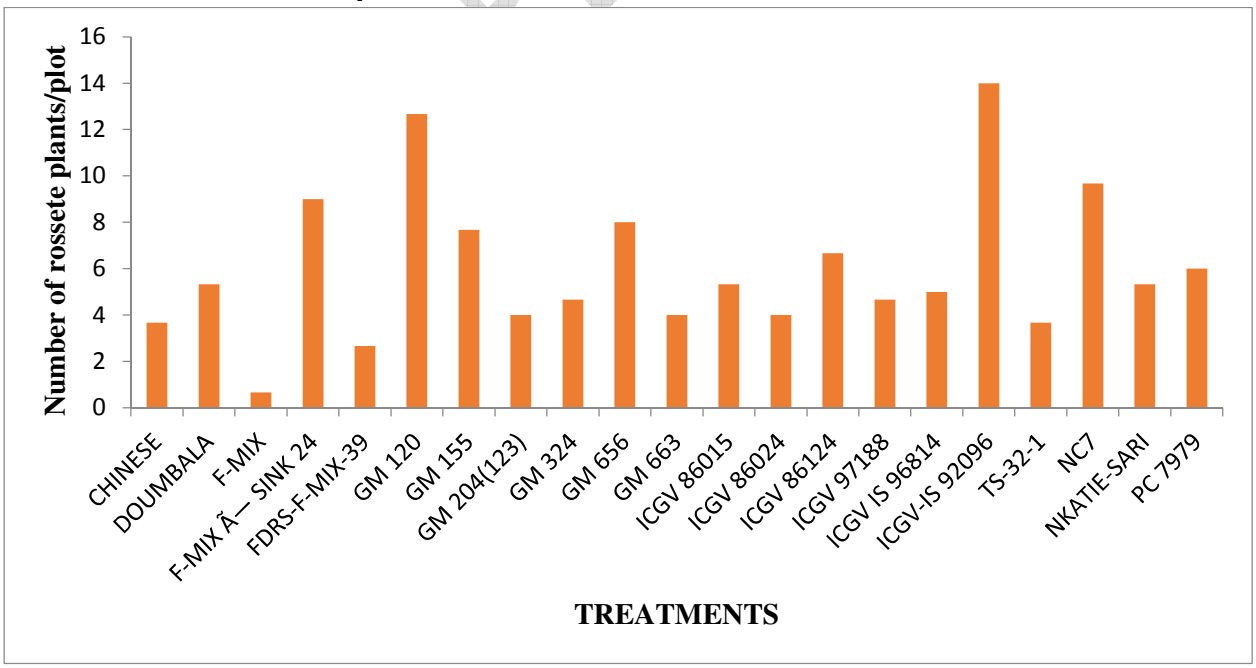

Fig 2 incidence of Rossete on the groundnut genotypes

The results show no significant difference (P> 0.05) among the groundnut genotypes on the number of rossete plants/ 10 m² (Fig 2).

4.0 DISCUSSION

4.1 Severity of Early and Late leaf spot disease score.

Early and late leaf spot diseases are the most widespread foliar diseases of groundnut (*Arachis hypogaea* L.) (Smith et al., 1992), accounting for pod yield losses of up to 50% in severe epidemics (Maninder *et al.,2011*). Management strategies for leaf spot epidemics rely on reducing initial inocula via crop rotation or on reducing the rate of disease spread via resistant cultivars and fungicide applications (Shokes and Culbreath, 1997). Crop rotation for 2 to 3 years is recommended, because this may delay the development of a leaf spot epidemic by 2 to 3 weeks (Maninder *et al.,2011*). However, because of the rapid rate of increase of leaf spot diseases, crop rotation alone is insufficient for control, hence the need for the identification of groundnut genotypes resistant to leaf spot diseases.

NKATIE-SARI was released as a groundnut cultivar relatively resistant to both early and late leaf spots compared to the susceptible cultivar Chinese and Doumbala by CSIR- Savanna Agricultural Research Institute. The present study demonstrated that the groundnut genotypes FDRS-F-MIX-39 and GM 663 were as resistant to early and late leaf spots as NKATESARI. However, F-mix, ICGV-IS 92096, ICGV-IS 96814, F-mix × Sink 24, and PC 79-79 appeared to be more resistant to early and late leaf spot than NKATIE-SARI. They could possess genes that enable them to survive or they could be escapes. These genotypes could be further evaluated using molecular genetics to identify loci responsible for resistance to the leaf spot disease for crop imrpovement

The genotypes GM 120, GM 324 and TS 32-1 were highly susceptible to both early and late leaf spots diseases.

4.2 Total number of pods/plant

As expected, the relatively resistant genotypes F-Mix, F-Mix × SINK 24, FDRS-F-Mix-39, NC 7, NKATIE-SARI and PC 79-79 had the highest total number of pods/plant. The genotypes Chinese, GM 120 and GM 324 recorded the lowest total number of pods/plant due to their susceptibility to *Cercospora* leaf spot disease. Bdliya (2007) observed that *Cercospora* leaf spot is disastrous to groundnut especially towards pod formation stage of the crop causing low seed and haulm yield. The diseases cause premature leaves defoliation and a reduction in the photosynthetic area of the leaf surface which resulted in the low yield in the susceptible genotypes (Shokes and Culbreath 1997).

4.3 Number of matured pods/plant

The genotypes F-Mix, NKATIE-SARI, NC 7 and F-Mix × SINK 24 that showed some level of resistance to leaf spots also had improved number of matured pods, apparently due to high production of photosynthate.

4.4. Dry pod weight

They improved sink source relationship due to leaf retention in the relatively resistant genotypes also resulted in increased dry pod weight.

4.5. Dry haulm weight (kg/ha)

The genotypes F-Mix, NC 7, TS-32-1, ICGV 86015 and ICGV 92096 recorded the highest dry haulm weight because they exhibited some level of resistance to both early and late leaf spot disease as compared to Chinese, GM 204 (123) and GM 663 which recorded the least dry haulm weight (kg/ha) probably because of loss of leaves to early and late leaf spot disease. This agrees with Bdliya (2007) who observed that *Cercospora* leaf spot is disastrous to groundnut especially towards pod formation stage of the crop causing low seed and haulm yield.

5.0 CONCLUSION AND RECOMMENDATION

From the study, the genotypes F-Mix, NC 7, PC 79-79, F-Mix × SINK 24 and NKATIE-SARI were found to be resistance to both early and late leaf spot disease whereas Chinese, Doumbala, GM 120, GM 324 and ICGV 86015 were very susceptible to both diseases.

The study also revealed that the genotypes F-Mix, NC 7, PC 79-79, F-Mix × SINK 24 and NKATIE-SARI recorded the highest total number of pods/plant as well as the highest number of matured pods/plant. For dry pod weight, the genotypes F-Mix, ICGV 86124 and ICGV 86015 had the highest dry pod weight. During the study there was high number of rossete plants observed, however there was no significant difference among the genotypes.

The recommendation was that, farmers should use F-Mix, NC 7, F-Mix × SINK 24 and Nkatie-SARI among others that exhibited some level of resistance to both early and late leaf spot diseases and were also high yielding. This will save them the cost of fungicide spray against the diseases and also improve their income from the increased yields. Also the susceptible genotypes especially Chinese that are widely cultivated should be improved upon through further crosses with the resistant genotypes to enhance their resistance to the leaf spot pathogen.

REFFERENCES

Abbiw, D. K. (1990). Useful plants of Ghana. Intermediate Technology Publication Ltd. pp. 337.

Abdou, Y. A. M., Gregory, W. C. and Cooper, W. E. (1974). Sources and nature of resistance to *Cercospora arachidicola* Hori and *Cercospora personatum* (Berk. and Curt.) Deighton in *Arachis* species. *Peanut Sci.* **1**:6-11.

Adolpus, M. (2007). Ghana's Agriculture @ 50: Agrochemicals- Our Wealth, Health, and Environment. Ghana Science Association Biennial Conference. GNA. http://www.ghana.gov.gh 26/09/2007.

Agrios, G. N. (1997). Plant Pathology. Academic Press London. pp. 635

Al-hassan, R. And Poulton, C. (2009). Agriculture and Social Protection in Ghana. www.future-agriculture.org 10/03/09.

Allen, D. J. (1983). The pathology of tropical food legumes: Disease resistance in crop improvement. John Wiley and Sons London. pp.413

Asibuo, Y. J., Akromah, R., Safo-Kantanka, O., Adu-Dapaah, K.H., Ohemeng-Dapaah, S. and Agyemang, A. (2008). Chemical composition of groundnut, *Arachis hypogaea* (L) landraces. *African Journal of Biotechnology* Volume **7** (13), 2203-2208.

Asiedu, J. J. (1989). Processing Tropical Crops. A Technological Approch. Macmillan Education Limited Hong kong. pp. 226.

Atuahene-Amankwa, G., Hossain, M. A. and Assibi, M. A. (1988). Groundnut production and improvement in Ghana. *Summary proceedings of the first ICRISAT regional groundnut meeting for West Africa,* 13-16 September 1988, Niamey, Niger.

Baily, J. E. (2002). Peanut Disease Management. In: 2002 Peanut Information. North Carolina Cooperative Extention, Raleigh. pp. 63-81

Barnett, H. L. and Hunter, B. B. (1972). Illustrated Genera of Imperfect Fungi. Burgess Publishing Company, Minnesota. pp. 124.51

Bdliya, B. S. (2007). Groundnut Haulm Quality as Affected by *Cercospora* Leaf Spot Severity. *Journal of Plant Protection Research*. Volume (**47)**: 3-10.

Brandenburg, R. (2003) Improving Production Efficiency through Standardized, Integrated, and Enhanced Research and Technology. Peanut CRSP Project Details. Projdetailselect1_cfm.htm 15/02/2007

Brenneman, T. B. and Culbreath, A. K. (2005). The integrated pest management system. http://nespal.cpes.peachnet.edu/pa. 07/06/05

Brenneman, T. B., Sumner, D. R., Baird, R. E., Sutton, G. W. and Minton, N. A. (1995). Suppression of foliar and soil borne peanut diseases in bahiagrass rotations. *Phytopathology* **85**:948-952.

Cook, M. (1981). Susceptibility of peanut leaves to *Cercosporidium personatum. Phytopathology* **71**(8):787-791.

CSIR. (2007). Groundnut Production Guide. MOFA Food Crops Development Project. pp.5

Dixon, G. R. (1984). Plant pathogens and their control in horticulture. Macmillan publisher's Ltd. pp. 253.

Driscoll, C. J. (1990). Plant sciences, production, genetics and breeding. Ellis Horwood Ltd. pp.228

Duffie, L. E. (2003). Effects of Intercropping Corn and Peanut on Peanut Leaf Spot Management and the Spatial and Temporal Epidemiology of *Cercospora arachidicola*. MSc. Thesis. Graduate Faculty, North Carolina State University. pp.105

Elston, J., Harkness, C. and Macdonald, D. (1976). The effect of *Cercospora* leaf spot disease on the growth of groundnuts (*Arachis hypogaea*) in Nigeria. *Ann. App. Biolo*. **83**: 39-51.

FAO. (2002). Food and Agricultural Organization Crop Production Statistics. Rome, Italy.52

FAO. (2006). http//apps.fao.org/page/collection?subset=agriculture

FAO (FAOSTAT). (1997) Groundnut (*Arachis hypogaea* L.). Consultative Group on International Agriculture.

Feakin, S. D. (1973). Air-borne fungal disease. Pest control in groundnuts. PANS Manual number 2. pp.197

Frimpong, A., Padi, F. K. and Kombiok, J. (2006a). Registration of foliar disease resistant and high-yielding groundnut varieties ICGV 92099 and ICGV 90084. *International Arachis Newsletter*. no.**26.**

Frimpong, A., Padi, F. K., Kombiok, J., Salifu, A. B. and Marfo, K. O. (2006b). Registration of 'Edorpo-Munikpa'Peanut. *Crop Science Society of America. Crop Sci* **46**: 1396-1397.

Garcia, V. V., Rubio, S. M., Arenas, R. C. and Valmonte, R. D. (1990). Peanut consumption pattern in the Philippines. Los Bonos, Laguna: PCARRD, UPLD, P-CRSP. Book series No. 91. pp. 85

Gibbons, R. 2002. Pests and diseases. Groundnut. Macmillan Education Limited. London. pp. 72-93.

Gibbons, R. W. (1966). *Mycosphaerella* leaf spots of groundnuts. *FAO Plant Protection Bulletin* **14**:25-30.

Hagan, A. K. (1998). Foliar disease of peanuts. Alabama Cooperative Extension System. http://www.aces.edu/pubs/docs/A/ANR-0369.pdf. 07/06/05

Hagan, A. K., Weeks, J. R. and Hartzog, D. (2005). Peanut. Insect, disease, nematodes and weed control recommendations. http://www.aces.edu/pubs/docs/A/ANR-0369.pdf. 20/06/05

Hemmingway, J. S. (1955). The prevalence of two species of *Cercospora* on groundnuts, *Trans. Br. Mycol. Soc.*, 38: 243-246

Hemmingway, J. S. (1957). The resistance of groundnuts to *Cercospora* leaf spots. *Empire J. of Experimental Agriculture* **25**:60-68.

Herrera, W., Samson, B. and Harwood, R. (1975). The effects of row arrangement and plant density on the productivity of corn-rice and corn-peanut intercrop. *Phil. J. Crop Sci* **1**: 125-128.

Horne, C. W., Lee jnr, T. A. and Philley, G. L. (1976). A System for improving the control of foliage diseases on peanuts through weather monitoring. Texas Agricultural Extension Service, college station, Texas.

Horsfall, J. G. and Cowling, E. B. (1977). Plant disease. An advance treatise Vol. 1. Academic Press, Inc. London. pp. 465.

Ihejirika, G. O., Nwufo, M. I., Duruigbo, C. I., Onwerenadu, E. U., Obilo, O.P., Onuoha, E. R. and Ogbede, K. O. (2006a). Effects of plant extract and plant density on the severity of leafspot disease of groundnut (*Cercospora arachidicola* Hori) in Imo State. *Journal of Plant Sciences* **1** (4): 374-377.

Ihejirika, G. O., Nwufo, M. I., Oputa, E., Obilo, O. P., Ogbede, K. O. and Onyia, V. N. (2006b). Effects of NPK Fertilizer Rates and Plant Population on Foliar Diseases, Insect Damage and Yield of Groundnuts. *Journal of Plant Sciences* **1** (4): 362-367.

Irvine, F. R. (1974). West African Crops, Oxford University Press, London. p. 56

Izge, A. U., Mohammed, Z. H. and Goni, A. (2007). Levels of variability in groundnut (Arachis hypogaea L.) to *Cercospora* leaf spot disease-implication for selection. *African Journal of Agricultural Research.* Volume **2**. No. 4. pp.182-186.

Jackson, I. F. (2006). Crop varieties officially released in Ghana in 2005. *West Africa Seed and Planting material.* No 16. p15

Johnson, A. and Ives, C. L. (2001). An Inventory of Agricultural Biotechnology for the Eastern and Central Africa Region. Agricultural biotechnology support project. Institute of international agriculture. pp. 50-51

Johnson, C. S., Beute, M. K. and Ricker, M. D. (1986). Relationship between components of resistance and disease progress of early leaf spot on virginia-type peanut. *Phytopathology* **76**:495-499.

Jolly, C. M., Awuah, R. T., Fialor, S. C.,Agyemang, K. O., Kagochi, J. M. and Binns, A. D. (2008). Groundnut Consumption Frequency in Ghana. (Abstr). *International Journal of Cosumer Studies*. 32 (6): 675-686.

Jyosthna, M. K., Eswara Reddy, N. P., Chalam, T.V. and Reddy, G. L. K. (2004). Morphological and Biochemical Characterization of *Phaeoisariopsis personata* Resistant and Susceptible Cultivars of Groundnut (*Arachis hypogaea*). *Plant Pathology Bulletin* **13**: 243-250.

Kapooria, R. G. and Zulu, J. N. (1982). The effect of carbendazole on Cercospora leaf spots of groundnut and its yield under field conditions. *Ghana Journal of Science*. **22-28** (1&2), 59-63.

Karunakaran, P. and Raj, J. S. (1980). Role of ascorbic acid on “tikka” disease of peanut. (Abstr.). *Agric. Res. Journal. of Karala* **18**:116-117.

Kenny, A. and Finn, K. (2004). Groundnut (Arachis hypogaea), women and development: impact on nutrition and women’s roles in Western Africa. Women, Groundnut (peanuts), and Development in West Africa. pp. 7 -15

Kishore, G. K., Pande, S. and Podile, A. R. (2005). Management of late leaf spot of groundnut (*Arachis hypogaea*) with chlorothalonil-tolerant isolates of *Pseudomonas aeruginosa. Plant pathology* **54**: 401-408.

Knudsen, G. R., Spurr, H. W. and Johnson, C. J. (1987). A computer simulation model for *Cercospora* leaf spot of peanut. *Phytopathology* **77**:1118-1121.55

Kokalis-Burelle, N., Beckman, P. A. and Rodriguez-Kábana, R. (1992). Potential for biological control of early leaf spot of peanut using *Bacillus cereus* and chitin as foliar amendments (Abstr.). *Biological Control* **2**:321-328.

Kwarteng, J. A and Towler, M. J. (1994). Agriculture for West African Schools and Colleges. The Macmillan press Limited. pp.321.

Lucas, G. B., Campbell, C. L., and Lucas, L. T. (1992). Introduction to Plant Diseases: Identification and Management. Chapman and Hall. N.Y. pp.364.

Mallikarjuna, N., Pande, S., Jadhav, D. R., Sastri, D. C. and Rao, J. N. (2004). Introgression of disease resistance genes from *Arachis kempff-mercadoi* into cultivated groundnut. Plant Breeding 123: 573-576.

Maloy, O. C. (1993). Plant Disease Control: Principles and Practice. John Wiley and Sons Inc. pp.346.

Marfo K. O. (1997). The performance and association among some important groundnut yield traits in Northern Ghana. Pages 133-140 In: Improvement of cropping system in the savanna zone: the challenges ahead, Mercer-Quarshie, H., Marfo K.O., Langyintuo A.S. and Owusu R. K. (eds.), *Proceedings of the third conference on improving farming systems in the savanna zone of Ghana.* 11-14 March 1993, Nyankpala Agricultural Experiment Station. Nyankpala, Tamale, Ghana. The Crop Research Institute (CRI)/ Nyankpala Agricultural Experiment Station (NAES) and Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) joint project.

McDonald, D., Subrahmanyam, P., Gibbons, W. R. and Smith, D. H. (1985). Early and Late leaf spots of groundnut. *Information Bulletin* no. 21. International Crops Research Institute for the Semi-Arid Tropics. pp. 15-16.

Meddleton, K. J., Pande, S. and Sharma, S. B. (1994). Disease of foliage caused by fungi. The groundnut crop- A scientific basis for improvement. (J. Smartt, ed.) pp. (56) :336-355.

Mehan, V. K. and Hong, N. H. (1991). Disease constraints to groundnut production in Vietnam- Research and management strategies. *International Arachis Newsletter* No. **14**. p.8.

Melouk, H. A. and Shokes, F. M. (1995). Peanut Health Management. *American Phythopathology Soc., St. Paul.* pp. 117.

Mensah, J. K. and Obadoni, B. (2007). Effects of sodium azide on yield parameters of groundnut (*Arachis hypogaea* L.). *African Journal of Biotechnology*. (6**)**: 668-671.

Mercado, F. E. (1976). Prospects for intercropping in sugarcane. *2nd PHILSUTECH Annual convention,* Iloilo city, Phillipines. (8): 18-21,

Millar, D. And Yeboah, R. W. N. (2006) Enhancing rural economies: women in groundnut marketing in the Bolgatanga area. *Ghana Journal of Development Studies*. **3**(1):119-136.

Mims, C. W., Luttrell, E. C. and Alderman, S. C. (1989). Ultrastructure of the haustorium of the peanut late leaf spot fungus *Cercosporidium personatum*. *Canadain. Journal of. Botany*. **67**:1198-1202.

Ministry of Food and Agriculture (MOFA) (2007). "Rural Livelihood in Ghana", Policy Planning,Monitoring and Evaluation Directorate, Ministry of Food and Agriculture, Accra.

Mohaptra, N. K. (1982). Post- infection changes in sugar content of groundnut leaves infected with *Cercospora personata*. *Geobios* 9(5/6):246-248.

Monfort, W. S., Culbreath, A. K. and Brnneman, T. B. (2001). Integration of strip-tillage, resistant cultivars, and reduced fungicide inputs for management of peanut leaf spot. Proc. Amer. Peanut Res. And ED. Soc. 33:68

Naab, J. B., Tsigbey, F. K., Prasad, P. V. V., Boote, K. J., Baily, J. E. and Brandenburg, R. L. (2005). Effect of sowing date and fungicide application on yield of early and late (57): 15-25

maturing peanut cultivars grown under rainfed conditions in Ghana. *Crop Protection*. **24**: 325-332.

Ntare, B. R. (2007). *Arachis hypogaea* L. In:van der Vossen, H.A.M.& Mkamilo, G.S. (eds.), PROTA14: Vegetable oils/Oleagineux.[CD-ROM] .PROTA, Wageningen, Netherlands.

374 Nutsugah, S. K., Abdulai M., Oti-Boateng, C., Brandenburg, R. L. and Jordan, D. L. (2007a).
375 Management of Leaf Spot Diseases of Peanut with Fungicides and Local Detergents in Ghana. *Plant*
376 *Pathology Journal* **6**(3): 248-253.

377 Nutsugah, S. K., Oti-Boateng, C., Tsigbey, F. K. and Brandenburg, R. L. (2007b). Assessment of yield
378 losses due to early and late leaf spots of groundnut (*Arachis hypogaea* L.) *Ghana Journal of Agriculture*
379 *Science*. (40**):** 21-26.

380 Owens, B. (1999). Virginia-Carolina Peanut Promotions: A short peanut history.
381 http://aboutpeanuts.com/every.html#anchor241393. 24/06/99.

382 Pande, S. and Rao, J. N. (2002). Effect of Plant Densities on the Severity of Late Leaf Spot and Rust of
383 Groundnut. *Plant Pathology Journal* (18**)**. 5-15

384 Paner, J. V. E. (1975). Multiple cropping means money. Agriz How to Series No. 5, p14.

385 Parry, D. W. (1990). Plant pathology in agriculture. Cambridge University Press. pp. 385.

386 Pattee, H. and Young, C. T. (1982). Peanut science and technology. Yoakum, Texas 77995, USA.

387 Porter D. M. (1997). *The peanut plant*. In: Compendium of peanut diseases. 2nd Edition, APS Press,
388 USA. pp. 1-2

389 Porter, D. M. 1970. Effectiveness of Benomyl in controlling *Cercospora* leaf spot of peanuts. *Pl. Dis. Rep.*
390 **54**: 955-958.

391 Porter, D. M., Smith, H. D. and Rodriguez-Kabana, R. (1984). Compendium of Peanut Diseases. *The*
392 *American Phytopathological Society*. (7): 7-21

393

394 Pretorius, A. E. (2006). Evaluation of groundnut (*Arachis hypogaea* L.) germplasm for resistance to leaf
395 diseases and related cytoplasmic factors, testa colour and cup leaf. MSc. Thesis. Department of Plant
396 Sciences. Faculty of Natural and Agricultural Sciences. University of Free State, Bloemfontain, South
397 Africa. pp. 116.

398 Rao, M. R. and Mathuva, M. N. (2000). Legumes for improving maize yields and income in semi-arid
399 Kenya. *Agric. Ecosyst. Environ*. **78**: 123-137.

400 Rao, P. V. S., McDonald, D. and Reddy, K. R. (1993a). Perpetuation of peanut leaf spots pathogens.
401 48:77-2-82.

402 Rao, P. V. S., Renard, J. L., Waliyar, F., McDonald, D. and Schilling, R. (1993b). Variation in symptoms of
403 *Cercospora arachidicola* isolates on some groundnut genotypes. (5): 243-250.

404 Rao, V. R. and Murty, U. R. (1994). Botany-morphology and anatomy. The Groundnut Crop- A scientific
405 basis for improvement. (J. Smartt, ed.) p. 69.

406 Reddy C.R.D. Srinivas T. and Reddy P. N. (1997). Evaluation of advanced groundnut lines for resistance
407 to early late leaf spots*. International Arachis Newsletter.* no. 17

408 Sanders, T. H., Caballero, B., Trugo, L. and Finglas, L. (2003). Groundnut oil. Encyclopedia of food
409 science and nutrition. (59): 2967-2974,

Singh M.P., J. E. Erickson, K. J. Boote, B. L. Tillman., J.W. Jones., and A. C.H. van Bruggen (2011) Late Leaf Spot Effects on Growth, Photosynthesis, and Yield in Peanut Cultivars of Differing Resistance. Agronomy journal. 103 (1): 85-91

Shew, B. B., Beute, M. K. and Stalker, H. T. (1995). Towards sustainable peanut production: Progression in breeding for resistance to foliar and soilborne pathogens of peanut. *Plant Dis.* **79**: 1259-1261.

Shilling, R. 2002. Groundnut. Macmillan Education Limited. London. pp.146.

Shokes, F. M. and Culbreath, A. K. (1997). Early and late leaf spots. In: Compendium of peanut diseases, second edition. N. Kokalis-Burelle, D.M. Porter, R. Rodriguez-kabana, D.H. Smith, and P. Subrahmanyam, (eds). *American Phytopathology Soc., St. Paul.* pp. 17-20

Shokes, F. M., Gorbet, D. W. and Sanden, G. E. (1982). Effect of planting date and date of spray initiation on control of peanut leaf spot in Florida. *Plant Dis*. **66**:574-575.

Smith, D. H. and Littrel, R. H. (1980). Management of peanut foliar diseases with fungicides. *Plant Dis* **64**: 356-361.

Stalker, H. T. and Simpson, C. E. (1995). Germplasm resources in *Arachis*. In: Advances in Peanut Science, H.E. Pattee and H.T. Stalker. (eds.) Am. Peanut Res. Educ. Soc. Inc, Stillwater. pp. 14-53.

Stitcher, L., Mauch-Mani, B. and Metraux, J. P. (1997). Systemic acquired resistance. *Annual Rev.Phytopathology* **35**: 235-270.

Subrahmanyam, P. and Hildebrand, G. L. (1997). Responses of peanut genotypes to fungicidal control of early leaf spot in Malawi. *Peanut Sci*. **24**:73-77.

Subrahmanyam, P., Bosc, J. P., Hassane, H., Smith, D. H., Mounkaila, A., Ndunguru, B. J. and Sankara, P. H. (1992). Groundnut diseases in Niger and Burkina Faso. Oleagineux **47**(3):119-129.

Subrahmanyam, P., McDonald, D., Gibbons, R. W., Nigam, J. N. and Nevill, D. J. (1982). Resistance to rust and leafspot disease in some genotypes of *Arachis hypogeae*. *Peanut Sci.,* **9**: 6-10.60

Subrahmanyam, P., Reddy, P. M and Mcdonald, D. (1990). Parasitism of rust, early and late leaf spot pathogens of peanut by *Verticillium lecanii. Peanut Sci*. **17**:1-3

Tovigan, S. V., Vodouhe, S. D. and Dinhan, B. (2001). Cotton pesticide cause more deaths in Benin. *Pesticide News*. **52**: 12-14.

Trawalley, K. (1998). Evaluation of Aqueous Neem (*Azadirachta indica*) kernel extract and Thiophanate-methyl for the control of early and late leaf spot of Groundnuts (*Arachis hypogaea L*). MSc. Thesis. Department Crop Science. College of Agriculture and Renewable Natural Resources. Kwame Nkrumah University of Science and Technology, Ghana. (13):37- 47

Tsigbey, F. K. (1996). Integrated disease management in groundnuts: effects of neem seed extract, Bavistin and Topsin-M on foliar diseases of groundnut. Pages 126-130 In: Savanna Agricultural Research Institute. Annual Report (K. O. Marfo and R. K. Owusu eds.) Nyankpala, Tamale, Ghana. pp. 126-130.

Tsigbey, F. K., Brandenburg, R. L. and Clottey, V. A. (2004). Peanut production methods in Northern Ghana and some disease perspectives. World Geography of the Peanut. pp. 1-10

Tuormaa, T. E. (2006). The Adverse Effects of Agrochemicals on Reproductive Health. Foresight Association for the Promotion of Pre-Conceptual Care. Registered no.279160.

Tweneboah, C. K. (2000). Modern Agriculture in the Tropics. Co-Wood publishers. pp.405.

Twumasi, J. K. (1993). Field performance of some selected fungicides in the control of *Cercospora* leaf spot disease of groundnut (*Arachis hypogaea* L.) in Ghana. *Ghana Journal of Agriculture Science (24*) **27**: 105-111

Van Wyk, P. S. and Cilliers, A. J. (2000). Groundnut diseases and pests. ARC Grain Crops Institute, Potchefstroom, SA.