Response of Peanut to Fungicide and Phosphorus in On-station and On-farm Tests in Ghana

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ABSTRACT

Peanut (*Arachis hypogaea* L.) is an important component of cropping systems in West Africa. Identifying production constraints in farmers' fields and evaluating possible management strategies are of prime importance to improve peanut productivity and adoption of new technologies. The objective of our research was to study the influence of fungicides and phosphorus application on severity of leaf spot, dry matter production and pod yield of peanut crops grown in on-station and farmer participatory tests (on-farm conditions) in Northern Ghana. On-station tests to evaluate yield benefits of fungicide sprays and applications of phosphorus were conducted at Wa. On-station tests included two fungicide treatments (no-spray versus fungicide spray) at four P fertilizer levels (0, 30, 60 and 90 kg P ha^{-1}). On-farm tests were conducted in three villages Nakor, Piisi and Janguasi with participation of 6–11 farmers per village. On-farm tests included three treatments: (i) farmers' practice of no-fungicide and no-fertilizer (control), (ii) only fungicide, and (iii) combination of fungicide and phosphorus. The commonly grown Spanish type cultivar Chinese (90-d duration) was selected. Both leaf spot and lack of phosphorus nutrition were yield-limiting factors in on-farm tests. Applications of fungicide were effective in controlling leaf spot and improved peanut pod yield on average by 49% in the three tested field sites in on-farm tests and by 40% in on-station tests. Application of phosphorus to fungicide-treated plots further increased pod yield by 32% when compared to fungicide alone in on-farm tests. Combination of both fungicide and P fertilizer improved peanut pod yield by 95% (ranged from 75 to 120%), when compared to farmers' practice of no-fungicide and no-fertilizer.

Key Words: On-farm research, fungicide, phosphorus fertilizer, single super phosphate, biomass and pod yield.

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Peanut (*Arachis hypogaea* L) or groundnut is an important component of cropping systems of smallholder farmers in West Africa. Peanut seed is a primary source of protein and oil for human populations in this region. In addition, vegetative biomass (haulm) and shells are important animal feed and source of supplementary income during the dry season. The productivity of peanut in Ghana and other developing countries in West Africa is very low (~ 1000 kg pod ha^{-1}) compared to Asia (1800 kg ha^{-1}), Argentina (2500 kg ha^{-1}) and United States of America (3400 kg ha^{-1}) (FAO, 2006). Lower productivity of peanut in West Africa is attributed to biotic factors (mainly foliar diseases) and abiotic factors such as nutrient deficiencies and water stress.

Among the foliar diseases of peanut, early leaf spot caused by *Cercospora arachidicola* Hori and late leaf spot caused by *Phaeoisariopsis personata* (Berk. & Curtis) Arx = *Cercosporidium personatum* (Berk. & Curtis) Deighton are the most commonly occurring diseases. Leaf spot diseases are routinely epidemic on peanut grown in the tropical and subtropical regions of the world including Africa, South America and Southeast Asia causing yield losses to the extent of 50–75% (Waliyar, 1991; Subrahmanyam and Hilderbrand, 1997; Waliyar *et al.*, 2000). Peanut crops in West Africa are grown under rain-fed conditions and farmers in this region do not apply fungicides or fertilizers to peanut crops. Farmers usually attribute leaf defoliation to maturing of the crop, and yield loss from foliar diseases is not recognized. Fungicide use is not a common practice in developing countries of this region partly because of lack of resources and lack of awareness of the extent of economic and yield benefits from application of fungicide. Applications of fungicides have shown yield improvement in Ghana (Naab *et al.*, 2005). Studies under on-farm conditions are limited in Ghana or other parts of West Africa. Data on yield benefits under on-farm studies should be quantified to bring awareness to agricultural communities, and to improve access to capital resources to demonstrate that fungicide application can be economically viable with greater returns. Farmers should be participants in the research program to better understand the yield limiting factors in their fields and for adaptation of technologies from the on-station tests. Thus, it is important to conduct on-farm tests to identify factors responsible for lower yields and to motivate farmers to adopt new technologies to improve yields and economic returns from their small landholdings.

Nutrient management is an important component of cropping systems. Phosphorus (P) nutrition is essential for improving productivity of smallholder agriculture in sub-Saharan Africa (Snapp, 1998). On a global scale, P is probably the most deficient element for peanut production (Gascho and Davis, 1995). About 60% of African soils are moderately to severely deficient in P (Buresh *et al.*, 1997). In most of the developing countries in West Africa including Ghana, fertilizer use is minimal to nonexistent among small farmers. Peanut crops require large quantities of P, Ca and S for pod and seed development and oil quality. Single super phosphate (SSP) is the most commonly available fertilizer that contains 8% P, 21% Ca and 12% S, all of which are important nutrients for peanut. Considering the availability and high cost of gypsum and S application in West Africa, SSP would be most advantageous. It is essential to demonstrate the benefits of SSP in on-station conditions as well as on-farm conditions of small resource-poor farmers under rainfed-conditions to sustain peanut production in West Africa.

The objectives of our research were to quantify yield losses due to disease and to demonstrate the influence of fungicides and SSP fertilizer application on severity of leaf spot, dry matter production and pod yield of peanut crops grown in on-station and on-farm conditions in Northern Ghana, which is representative of the important peanut producing regions of West Africa.

Materials and Methods

On-station tests

On-station experiments were conducted at the Savanna Agricultural Research Institute farm at Wa (10°N lat., 2°92′ W long., and 184 m altitude). The soil at the experimental site was broadly classified as Ferric lixisol (FAO) or Alfisol (USDA). Soil was a sandy loam (79% sand, 11% clay) with pH of 6.2 (1:2 soil:water ratio), bulk density of 1.45 g cm^{-3}, and available P of 5.9 mg kg^{-1} and exchangeable Ca of 1.5 cmol kg^{-1}. Soil available P was estimated by Bray I method and exchangeable Ca was extracted by 1 N ammonium nitrate followed by measurement with flame photometer. Minimum and maximum air temperatures and rainfall data for the crop growing seasons during 2002 and 2003 are given in Fig. 1.

There were four P fertilizer levels [i.e. 0 (control), 30, 60 and 90 kg P ha^{-1}) supplied by application of SSP] and two fungicide treatments (no-fungicide control and fungicide sprayed), laid out in a randomized complete block design with four replications.

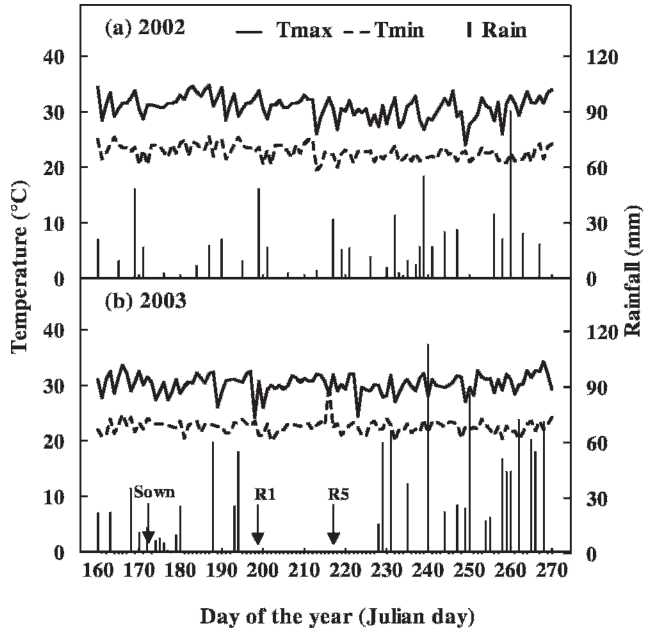

Fig. 1. Mean daily maximum (solid lines) and minimum (dashed lines) temperature and rainfall (solid bars) during the crop season at Wa on-station site during (a) 2002; and (b) 2003. Arrows indicate the sowing dates, start of flowering (R1; Boote, 1982) and beginning seed (R5) in 2003.

Crop management practices during 2002 and 2003 were similar except the selected site was different in both years. Peanut cultivar Chinese (90-d duration) was sown on 10 June 2002 and 19 June 2003 on a flatbed (flat non-bedded or non-raised) system with spacing of 50 cm between rows and 10 cm between plants. Gap filling was done 7 d after emergence to maintain uniform population. Fertilizer (SSP) was broadcast and incorporated in the soil at a depth of 15 cm using an animal drawn plough at the time of sowing.

The crop was kept weed free by manual weeding using hand hoes. Fungicide treated plots were sprayed with tebuconazole (Folicur 3.6 @ 0.22 kg a.i. ha^{-1}) four times at 14 d intervals starting from 28 d after sowing (DAS) using a back mounted 15-L knapsack sprayer. Spray volume was 150 L ha^{-1}. The crop was harvested at about 90 d after sowing.

At harvest maturity, samples from the inner 2 rows (8 m^2) were collected and all the plants were separated into component parts (leaves, stems, and pods). Haulms (leaves and stems) were oven dried for 7 d at 60°C and data on dry weights were recorded. The pods were sun-dried and shelled by hand to obtain seed yields.

On-farm tests

On-farm tests were conducted on farmers' fields in the villages of Nakor and Piisi in 2002, and Nakor, Piisi and Janguassi in 2003. In Nakor trials were conducted on six different farmers' fields (i.e. 6 replications), while in Piisi there were five fields and in Janguassi there were 11 fields. On-farm tests were laid out using a randomized complete block design with farmers' fields as replicates. The soil in farmers' fields was a sandy loam (about 77% sand and 8% clay), with soil pH ranging from 6.5 to 7.5, available P in the range of 2.7 to 6.8 mg kg^{-1} (average 5 mg kg^{-1}) and soil Ca in the range of 1.5 to 2.4 cmol kg^{-1} (average 2 cmol kg^{-1}). There were three treatments in each field: (i) farmers practice (control, no-fungicide and no-fertilizer), (ii) only fungicide, and (iii) combination of both fungicide and P fertilizer (60 kg ha^{-1}). The net plot area of each treatment was 25 m by 2 m in each field.

Crop management practices in all the farmers' fields were similar except for the treatment differences. The fields were ploughed and harrowed using animal drawn equipment. Seeds of cultivar Chinese (90-d duration) were sown soon after onset of rains, when sufficient soil moisture was achieved. In 2002, the crop was sown on 24 June in Nakor and 04 July in Piisi, while in 2003, sowings dates were between 27 and 30 June in all three villages. Seeds were sown at a row spacing of 50 cm and about 10 to 20 cm within rows on a flatbed. The plant populations across the various fields were similar.

The farmers practice (control) plots did not receive any sprays of fungicides or inorganic fertilizer. Fungicide treated plots were sprayed with tebuconazole (Folicur 3.6 @ 0.22 kg a.i. ha^{-1}) four times at 14 d intervals starting 28–30 DAS using back mounted 15-L knapsack sprayer. Spray volume was 150 L ha^{-1}. The fungicide-plus-fertilizer-treated plots received a combination of both fungicide sprays and P fertilizer as 60 kg P ha^{-1} from SSP applied at sowing. The fertilizer was broadcast and incorporated into the soil at a depth of 5 cm using hoes. The crops were kept weed-free by manual weeding using hand hoes. The crop was completely rainfed during the growing season.

At maturity (90 to 105 DAS), all plants from the inner four rows of each treatment plot (50 m^2) were harvested by digging with hoes and data on total dry weight (leaf, stem and pod), pod dry weight, and seed dry weight were recorded. Data on haulm dry matter (leaf and stem) were recorded after oven drying the samples at 60°C for 7 d, while pods were sun-dried and shelled by hand to obtain seed yield.

Leaf spot incidence and severity

There were no serious pests or diseases other than leaf spot in both on-station and on-farm trials. Incidence and severity of leaf spot disease was measured based on (a) visual disease rating on a scale of 1–10 (Chiteka *et al.*, 1997); and (b) main-stem defoliation, estimated as ratio of number of missing to total number of leaflets (Bourgeois and Boote, 1992) and expressed as percentage.

Data analyses

Data from on-station tests were analyzed as randomized complete block design in a factorial combination of two fungicide (with and without fungicide) and four P treatments with four replications. Data from on-farm tests were analyzed as randomized complete block design with 6, 5, and 11 farmers' field as replications in Nakor, Piisi, and Janguassi, respectively. PROC ANOVA techniques were used to identify significant differences between treatments using SAS (SAS, 1987).

Results

On-station tests

There was severe incidence of leaf spot disease in the non-sprayed control plots as shown by higher disease ratings and greater main-stem defoliation at harvest maturity in both years (Fig. 2). Application of fungicide was effective ($P<0.05$) in controlling severity of leaf spot and decreased defoliation by 44% in 2002 and 34% in 2003 when compared to the non-sprayed control.

There were significant effects of fungicide application on total biomass, haulm yield, pod yield and seed yield during 2002 (Table 1) and 2003 (Table 2). In both years, there were no significant interactions between fungicide and P treatments. Overall, fungicide application increased total biomass, haulm yield, pod yield and seed yield by 57, 67, 48 and 60%, respectively, during 2002. In 2003, total biomass, haulm yield, pod, and seed yield were increased by 35, 36, 33% and 28%, respectively.

In 2002, application of P fertilizer (30 kg P ha^{-1} as SSP) significantly increased total biomass and seed yield compared to no fertilizer application (Table 1). There were no significant differences for total biomass, pod yield and seed yield at P levels of 30 and 60 kg ha^{-1}. Similarly, there was no significant difference between yields at P levels of 60 and 90 kg ha^{-1}. There were no effects of different P levels on haulm yield. In 2003, there were no significant differences between the P levels and there was no interaction between fungicide and P treatments (Table 2), with an exception of total biomass which was significantly higher at P level of

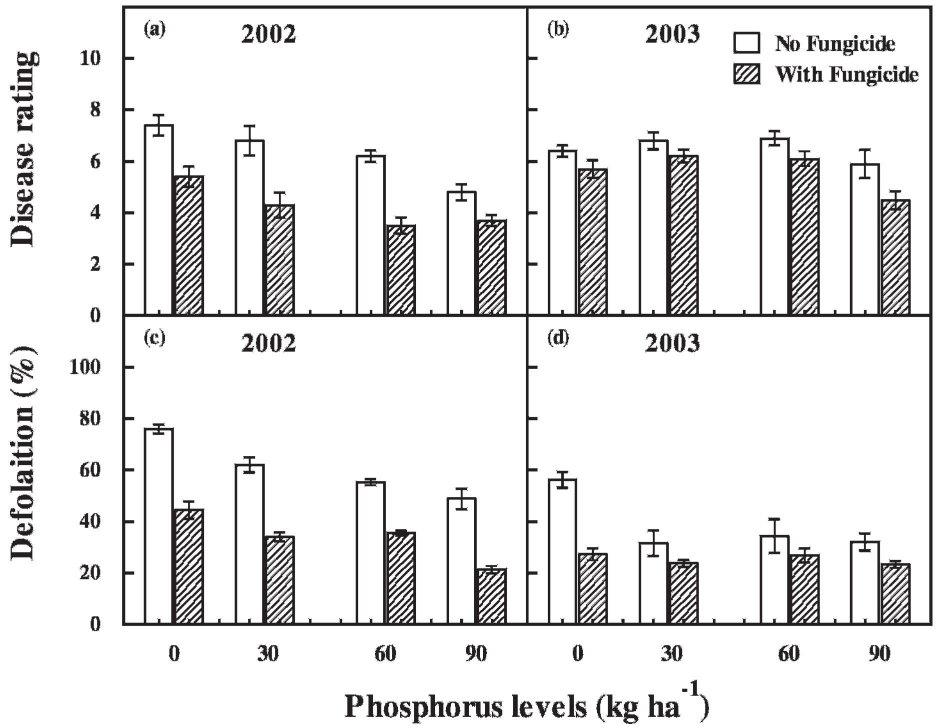

Fig. 2. Influence of fungicide application at different levels of P fertilizer on disease rating (a and b), and main-stem defoliation (c and d) of peanut crops at harvest maturity when grown in on-station tests during 2002 (a and c) and 2003 (b and d). Each datum is a mean of four replications. Vertical lines on each bar denote ±standard deviation.

90 kg ha^{-1} when compared to no fertilizer application.

On-farm tests

Disease rating and main-stem defoliation at harvest maturity were significantly ($P<0.05$) higher under no fungicide treatment across all villages (Fig. 3). There was no influence of P application on disease rating or main-stem defoliation. Application of fungicide decreased main-stem defoliation on average by 46% in 2002 and 40% in 2003.

Table 1. Influence of fungicide and P fertilizer levels on total biomass, pod yield and seed yield of peanut in on-station tests during 2002.

Treatment	Total biomass	Haulm yield	Pod yield	Seed yield
	kg ha^{-1}			
Fungicide (F)				
No Fungicide	2657	1285	1371	884
With Fungicide[a]	4164	2142	2023	1414
LSD (0.05)	442	390	293	145
P levels (kg P ha^{-1})				
0	2741	1335	1406	906
30	3293	1660	1633	1188
60	3623	1858	1766	1281
90	3982	1998	1984	1220
LSD (0.05)	479	NS	414	205
Interaction				
Fungicide × Phosphorus	NS[b]	NS	NS	NS

[a]Fungicide tebuconazole (Folicur 3.6 @ 0.22 kg ai ha^{-1}) was applied four times at 14 d intervals starting from 28 d after sowing.

[b]NS = nonsignificant

Table 2. Influence of fungicide and different P fertilizer levels on total biomass, pod yield and seed yield of peanut in on-station tests during 2003.

Treatment	Total biomass	Haulm yield	Pod yield	Seed yield
	kg ha^{-1}			
Fungicide (F)				
No Fungicide	2942	1581	1361	1058
With Fungicide[a]	3957	2143	1814	1358
LSD (0.05)	272	207	136	132
P levels (kg P ha^{-1})				
0	3212	1703	1508	1154
30	3421	1847	1565	1210
60	3485	1920	1574	1221
90	3679	1979	1701	1247
LSD (0.05)	384	NS	NS	NS
Interaction				
Fungicide × Phosphorus	NS[b]	NS	NS	NS

[a]Fungicide tebuconazole (Folicur 3.6 @ 0.22 kg ai ha^{-1}) was applied four times at 14 d intervals starting from 28 d after sowing.

[b]NS = nonsignificant

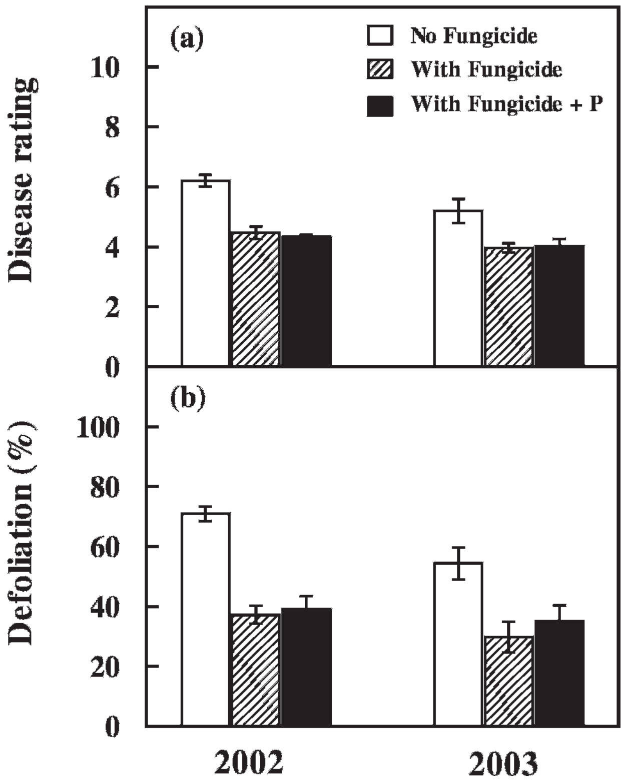

Fig. 3. Influence of fungicide and P application on (a) disease rating (1–10 scale, Chiteka *et al.*, 1997); and (b) main-stem defoliation of peanut crops at harvest maturity in on-farm tests at Nakor and Piisi during 2002 and 2003. Each datum is a mean of two villages which had 5 (Nakor) or 6 (Piisi) fields as replications. Vertical lines on the each bar denote ±standard deviation.

There were significant differences between the treatments for traits shown in Table 3 and 4. In 2002 at Nakor, application of fungicide significantly increased total biomass, haulm yield, pod and seed yield when compared to the control treatment by 79, 89, 64 and 66%, respectively; while at Piisi only total biomass was significantly increased by 30% (Table 3). During 2003, fungicide application increased pod yields by 51, 35 and 68% in Nakor, Piisi and Janguassi villages, respectively (Table 4). The corresponding increases for haulm yield in respective villages were 86, 52 and 102%.

Application of P fertilizer (SSP) in combination with fungicide significantly increased total biomass, haulm yield, pod and seed yield during both years at Nakor and Piisi when compared to fungicide alone (Tables 3 and 4). The haulm, pod and seed yields with P application were increased by about 32–35% on average across all villages over the 2-year period. Combination of both fungicide and P fertilizer application considerably increased biomass, haulm yield, pod and seed yields compared to the control (no fungicide or P). For example, during 2003, application of both fungicide and P fertilizer increased total biomass, haulm yield, pod yield and seed yield by 135, 160, 100, and 101% when averaged across all three villages (Table 4). The response to fungicide application was generally greater in Nakor and Janguassi than Piisi. The response to P application was variable, i.e. greater in Piisi compared to Nakor in 2002; whereas, in 2003, the response to P fertilizer was greater in Nakor compared to Piisi and Janguassi.

Discussion

This is the first report of research under on-farm conditions in Ghana that demonstrates that late

Table 3. Effect of fungicide and combination of fungicide plus P fertilizer on total biomass, haulm yield, pod yield and seed yield (kg ha^{-1}) of peanut crops grown under on-farm conditions in villages of Nakor and Piisi during 2002.

	Treatment				Yield improvement (%) due to[b]		
Village & Trait	No fungicide (1)	Fungicide only (2)	Fungicide + P fertilizer (3)	LSD (0.05)	Fungicide (2−1)/1	P fertilizer (3−2)/2	Fungicide + P fertilizer (3−1)/1
	kg ha^{-1}				%		
Nakor[a]							
Total biomass	2239	4013	5195	761	79	29	132
Haulm yield	1389	2620	3538	636	89	35	155
Pod yield	850	1393	1657	173	64	19	95
Seed yield	620	1030	1223	159	66	19	97
Piisi[a]							
Total biomass	1272	1656	2392	382	30	44	88
Haulm yield	700	944	1368	299	35	45	95
Pod yield	572	712	1024	168	24	44	78
Seed yield	384	500	774	131	30	55	102

[a]Data are the means of 6 farmers' fields at Nakor and 5 farmers' fields at Piisi.

[b]Yield increase due to fungicide, P fertilizer (60 kg P ha^{-1}) and combination of fungicide and P fertilizer were estimated as differences between the respective treatments and expressed as percentages.

Table 4. Effect of fungicide and combination of fungicide plus P fertilizer on total biomass, haulm yield, pod yield and seed yield (kg ha^{-1}) of peanut crops grown under on-farm conditions in villages of Nakor, Piisi and Janguassi during 2003.

	Treatment				Yield improvement (%) due to[b]		
Village & Trait	No fungicide (1)	Fungicide only (2)	Fungicide + P fertilizer (3)	LSD (0.05)	Fungicide (2−1)/1	P fertilizer (3−2)/2	Fungicide + P fertilizer (3−1)/1
	kg ha^{-1}				%		
Nakor[a]							
Total biomass	1585	2726	4496	671	72	65	184
Haulm yield	952	1769	3089	470	86	75	225
Pod yield	633	957	1407	322	51	47	122
Seed yield	420	647	1000	300	54	55	138
Piisi[a]							
Total biomass	1547	2268	3048	485	47	34	97
Haulm yield	1079	1635	2228	450	52	36	106
Pod yield	468	632	820	134	35	30	75
Seed yield	304	396	500	111	30	26	65
Janguassi[a]							
Total biomass	1221	2245	2735	548	84	22	124
Haulm yield	579	1169	1429	293	102	22	147
Pod yield	642	1076	1306	302	68	21	103
Seed yield	450	746	894	213	66	20	99

[a]Data are the means of 6 farmers' fields at Nakor, 5 farmers' fields at Piisi and 11 farmers' fields at Janguassi.
[b]Yield increase due to fungicide, P fertilizer (60 kg P ha^{-1}) and combination of fungicide and P fertilizer were estimated as differences between the respective treatments and expressed as percentages.

leaf spot disease and phosphorus nutrition are yield-limiting factors for peanut production, and shows that application of foliar sprays of fungicide (tebuconazole) and soil application of SSP improves peanut productivity. Typical symptoms of late leaf spot (necrotic lesions with yellow halo; Subrahmanyam *et al.*, 1992) were observed in unsprayed plots under both on-station and on-farm conditions, resulting in severe defoliation (Figs 2 and 3). Yield losses due to leaf spot disease are associated with loss of photosynthetic leaf area due to necrotic lesions and defoliation (Boote *et al.*, 1980; Adomou *et al.*, 2005) and decreased canopy photosynthesis (Bourgeois and Boote, 1992). Application of fungicide decreased defoliation and improved seed yields as much as 49% under on-farm conditions, when averaged across all locations over two years. This yield response is similar to that obtained from previous on-station studies in Ghana (Naab *et al.*, 2005) and other parts of Africa (Kanniyan and Haciwa, 1990; Subrahmanyam *et al.*, 1997; Waliyar *et al.*, 2000).

Our research has clearly shown that application of SSP increased biomass and seed yield of peanut on average by 35%. This response is believed due mainly to P, although the SSP also contained Ca and S. Soil analyses of the experimental sites in farmers' fields showed that soil was deficient in available P (<5 mg kg^{-1}, Bray-1 P). Phosphorus deficiency in soils is mainly because farmers in this region do not apply inorganic fertilizer to peanut crops or crops that precede peanut. Furthermore, these village regions are newly occupied and new to agricultural production and lack previous fertilization. The response of P fertilizer application in on-station tests was not as high as in farmers' fields because on-station test sites occasionally received fertilizers on previous crops. Those nutrients can slowly become available to succeeding crops. Differential P response in on-station tests for two years (2002 and 2003) could be related to soil P values or residual fertilizer applied to previous crops. Phosphorus status and crop response to P in Africa is highly variable at the micro field level as well as macro level watershed (Brouwer and Bouma, 1997). Application of 30 kg ha^{-1} of P to bean and maize crops increased yields by about 100% (Snapp, 1999). Previous studies in southern Africa demonstrated positive effects of P fertilization through rock P on groundnut and cowpea yields (50 to 120%) (Snapp, 1998). An alternative source of P is rock phosphate. Although it may be a cheaper source of P than SSP, because of its very low P concentration and bulky nature the transportation costs are usually high (Hammond *et al.*, 1986). In addition, peanuts also require large quantities of Ca for better pod growth and seed filling. Lack of Ca in the soil can lead to poor seed filling and pops, i.e. unfilled pods (Gascho and Davis, 1995). Application of Ca and S through gypsum is known to improve peanut yield and is highly recommended in peanut production (Gascho and Davis, 1995). As SSP supplies P, Ca and S, it will be more beneficial to peanut farmers.

Adoption of new technology, either fungicide or P fertilizer, has been very slow in subsistence farming systems in sub-Saharan Africa. This is due to lack of on-farm tests, low performance of some technologies under on-farm conditions, and limited awareness of the constraints of crop production by the small farmers. Access to capital has also been limiting in the past, but this situation may gradually improve with establishment of micro-credit agencies which would facilitate the benefits of the technology. Our on-farm trials in 2002 developed interest by other farmers in the region who were not among the tested farmers. In 2003, some other farmers used fungicide and P fertilizer in their farms and observed yield increases. This clearly suggests that farmers have an interest in adopting new technologies if they are certain of economic benefits. In view of the tremendous yield advantage, fungicide recommendations are being made to peanut farmers in this region. Farmers' participatory research on management of foliar diseases in peanut in India has shown similar results and proved useful (Pande *et al.*, 2001). More efforts in on-farm research are needed with participation of farmers and to better understand the needs and limitations of farmers and to develop ways for enhancing adoption of new technologies in Africa. Our research clearly demonstrates the benefits of fungicide spray to control leaf spot disease. However, it is important to choose appropriate fungicide programs for disease control. Recent studies in United States have shown a significant decline in performance of the four-spray tebuconazole program relative to a full-season chlorothalonil program for leaf spot control (Stevenson and Culbreath, 2006). They also observed a significant shift in sensitivity of both leaf spot causing pathogens (*Cercospora arachidicola* and *Cercosporidium personatum*) to discriminatory concentrations of tebuconazole (Stevenson and Culbreath, 2006). Thus, farmers and researchers need access to additional fungicides to alternate among, to prevent the development of leaf spot biotypes that may become resistant if just one compound such as tebuconazole is applied. In addition, there is also need for access to new technologies of application equipment to improve fungicide coverage.

In conclusion, late leaf spot disease and phosphorus deficiency are major yield-limiting factors under on-farm conditions in Ghana. Applications of fungicide were effective in controlling leaf spot and improved peanut pod yield on average by 48% in the three tested village sites under on-farm conditions and by about 40% under on-station conditions at two sites. Application of P fertilizer (SPP) increased pod yield by 32% when compared to application of fungicide alone. The effects of fungicide and P fertilizer were additive and combination of both fungicide and P fertilizer improved peanut pod yields by about 95% (ranged from 75 to 120%) under on-farm conditions in Ghana. This research clearly indicates that high peanut yields can be obtained under farmers' production conditions, provided sufficient care is taken with respect to application of fertilizers and fungicide.

Acknowledgements

We thank Messers George Mahama and Vincent Kulen for data collection and all the farmers who participated in this research program. This research was supported in part by the United States Agency for International Development, Peanut Collaborative Research Support Project. The statistical advice and help provided by Dr. S.S. Buah is acknowledged. This manuscript is approved for publication as Florida Agricultural Experiment Station Journal Series No. R-10222 and Kansas Agricultural Experiment Station Contribution No: 09-044-J.

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