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Full Length Research Paper

The effect of *Sphaceloma* sp causal agent of scab infection on grain yield of cowpea (*Vigna unguiculata*) in Northern Nigeria

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Field experiments were conducted during the 2004, 2005 and 2006 cropping seasons at the Institute for Agricultural Research farms at Samaru and Shika, Zaria (11^0 11^1N; 07^0 38^1E and 686m above sea level) to evaluate the contribution of scab infected plant parts caused by *Sphaceloma sp* to cowpea yield. Three varieties of cowpea were chosen for this study, TVx 3236, SAMPEA-6 and IT93K452-1. Data obtained from the different scab infected plant parts and grain yield were correlated and path coefficients analyses were also run to determine the direct and indirect effects as well as the percentage contributions of scab infected plant parts to grain yield. The results showed that scab infected plant parts of susceptible varieties directly or indirectly reduced grain yield of cowpea. SAMPEA-6 showed the highest percent contributions of scab infection to grain yield in all the years of investigation, followed by IT93K452-1, while TVx 3236 had the least scab infection to grain yield. Cowpea variety TVx 3236 showed no direct and indirect, percent individual and combined contributions of scab infection on the leaves in all the years of investigation. Yield reduction attributed to scab was more significant on SAMPEA-6 and IT93K452-1 and it ranges from 41.3-66.9% and 35.9%-67.1% respectively while variety TVx 3236 showed a lower yield reduction of only 13.7%-29.5%. Cowpea scab can cause yield reduction through the different plant parts up to 67% in susceptible varieties if not controlled. The use of resistance varieties or non-photosensitive medium early or medium maturing varieties would result in lower infections from scab under northern Nigerian conditions. The studies also serve as a data base of information for formulation of an integrated control strategy for the management of scab disease in Nigeria.

Keywords: Cowpea, scab disease, plant parts, grain yield, path coefficient, *Sphaceloma*.

INTRODUCTION

Cowpea (*Vigna unguiculata*) L. Walp (Fabaceae) is an annual legume, commonly referred to as southern pea, black-eyed pea, crowder pea, (Davis *et al*., 1991). The crop has a protein content of about 25%, and it is valued for its high nutritive quality and can be used at all stages of growth as vegetable. The dry matured seeds are suitable for boiling and canning. Farmers in Northern Nigeria use cowpea haulms as nutritive fodders for livestock (Davis *et al*., 1991: Singh *et al*., 1995; Henriet *et al*., 1997). Despite the importance of cowpea in the Nigerian diet and economy, it is mainly produced by small-scale farmers whose traditional methods do not produce enough cowpea for the country's need.

Diseases, parasitic weeds, insect pests, drought and low soil fertility are the major constraints to cowpea production in Nigeria. Cowpea diseases are induced by various pathogenic groups- fungi, bacteria, viruses, nematodes and parasitic flowering plants (Singh et al., 1997; Asante *et al.,* 2001; Emechebe and Lagoke, 2002; Fawole *et al*., 2005). Scab, caused by the fungus, *Sphaceloma* sp. is one of the most destructive diseases of cowpea in the Northern Guinea Savanna Zone of Nigeria. The disease affects all the above ground parts of cowpea (leaves, stems, peduncles, flower cushions and pods (Emechebe, 1980; Iceduna,

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1993; Mbong *et al*., 2010). Yield losses of up to 100% due to severe infections have been reported from Nigeria (Mbong *et al*., 2010). In previous study (Mbong *et al*., 2010) yield losses on cowpea varieties were evaluated based on the combined effect of scab and sowing dates. How much yield loss is attributed to scab infection through the different plant parts is not known. Path coefficient analysis disaggregates the causes of yield loss and quantifies the contribution of each causal agent to the overall loss. Therefore, this study was aimed at assessing the direct and indirect effects as well as percentage contributions of scab infected plant parts on the yield of some cowpea varieties in these regions.

MATERIALS AND METHODS

Fields experiments were carried out in three cropping seasons of 2004, 2005 and 2006 at the Institute for Agricultural Research at Samaru and Shika, Nigeria. Three varieties of cowpea used for this study differ in their susceptibility to scab. The field layout was factorial concept in Randomized Complete Block Design (RBCD) with three replications. Cowpea seeds were sown at the rate of two seeds per hole at 25 cm spacing. Plant stand establishment was taken 14 days after sowing (DAS). All plots were weeded thrice at 3, 6 and 9 weeks after germination. The plants were protected from insect damage by spraying biweekly with insecticide (Uppercott- Cypermethrin+ Dimethoate at 1 litre/ha) stating at 21 DAS until 75% podding. Data on scab disease on the different plant parts were recorded from the three middle ridges in each plot at intervals of one week from the first appearance of symptoms. The amount of disease was measured as the proportion of the area of a plant or plant organ that was affected.

During harvest, pods were harvested from the three varieties of cowpea, sun-dried and weighed. The pods were threshed and seed weight recorded. A simple correlation coefficient analysis between scab infected plant parts on seed yield/ha were worked out using the following formula (Dewey and Lu, 1959; Ahmed, 1997).

$$r = SPxy \Big/ \sqrt{SSx \,.SSy}$$

Where r= correlation coefficient

SPxy (Sum of product of x and y) = $\sum (x-\bar{x})(y-\bar{y})$

SSx (Sum of square of x) = $\sum (x-\bar{x})^2$

SSy (Sum of square of y) = $\sum (y-\bar{y})^2$

Similarly, the correlation coefficient between scab infected plant parts and seed yield and within the infected plant parts themselves was worked out using the same formula. These correlations were further used to develop the following simultaneous equations in order to work out the path - coefficients (P_{16}).

$r_{16} = P_1 + r_{12}P_2 + r_{13}P_3 + r_{14}P_4 + r_{15}P_5$ ---------- (1)
$r_{26} = r_{12} + P_2 + r_{23}P_3 + r_{24}P_4 + r_{25}P_5$ ---------- (2)
$r_{36} = r_{13}P_1 + r_{23}P_2 + P_3 + r_{34}P_4 + r_{35}P_5$ ---------- (3)
$r_{46} = r_{14}P_1 + r_{24}P_2 + r_{34}P_3 + P_4 + r_{45}P_5$ ---------- (4)
$r_{56} = r_{15}P_1 + r_{25}P_2 + r_{35}P_3 + r_{45}P_4 + P_5$ ---------- (5)

in the above equations, P_1, P_2, P_3, P_4 and P_5 are path-coefficients, while r_{12}-----r_{56} are the coefficients of correlations. The direct and indirect effects of individual and combined (two factors) contributions of scab infected plant parts (characters) on grain yield/ha were measured using path-coefficient analysis whereas correlation coefficient measures the mutual association between the two characters. The Individual and combined contributions were estimated using the following formula:

$I = (P_i)^2 \times 100$

$C = 2(P_i P_j r_{ij}) \times 100$

Where I =direct (individual) percentage contribution of scab infected plant parts on yield.

C= combined percent contributions of i and j, where i and j are direct and indirect contributions of scab infected plant on grain yield per hectare and rij= correlation coefficient between the two factors (i and j). The residual factor Rx that is uncounted for by the direct and combined contributions was estimated using the following formula:

Rx=1-(P1r16+P2r26+P2r36+P4r46+P5r56).

RESULTS

The direct and indirect effects of scab infected plant parts on the grain yield of TVx 3236 during the periods of experimentation were shown on Table 1. Generally, it was observed that TVx 3236 showed no direct and indirect effect of leaf scab severity via other plant parts on grain yield in all the years of study. All the direct effects of stem scab severity on grain yield of TVx3236 was negative and its indirect effect via other plant parts was also negative except its effect via peduncle in 2005 and 2006 and via flower cushion in 2006. The direct effects of peduncle scab severity on grain yield of the same variety in 2005 and 2006 were positive except in 2004 that its indirect effect via other plant parts was negative. Flower cushion scab showed a positive direct effect on grain yield in all the years but its indirect effect via other plant parts was negative except its effect via stem in 2004 and peduncle in 2006.There was no direct and indirect effect of flower cushion scab on grain yield in 2005. The direct effects of pod scab severity on grain yield were all negative but its indirect effect via flower cushion (2004), peduncle (2005), peduncle and flower cushion (2006) were positive (Table 1).

The direct and indirect effects of scab infected plant parts on grain yield of SAMPEA-6 are presented on Table 3. The direct effect of leaf scab on grain yield of this variety was positive in all the years of study but its indirect effect via other plant parts were negative in 2004. In 2005 the direct effect of stem scab on grain yield was negative except its indirect effect via leaf and

Table 1. Direct and indirect effects (contributions) of scab severity on the different plant parts on grain yield of cowpea variety TVx3236 in 2004, 2005, 2006.

Infected plant parts	Direct and Indirect effects of: Leaf scab	Stem scab	Peduncle scab	Flower cushion scab	Pod scab	Total effects
			2004			
Leaf scab	0.000a	0.000	0.000	0.000	0.000	0.000
Stem scab	0.000	-0.159a	-0.372	-0.016	-0.158	-0.705
Peduncle scab	0.000	-0.134	-0.442a	0.019	-0.229	-0.786
Flower cushion scab	0.000	0.018	-0.060	0.140a	-0.102	-0.004
Pod scab	0.000	-0.070	-0.282	0.040	-0.359a	-0.671
			2005			
Leaf scab	0.000a	0.000	0.000	0.000	0.000	0.000
Stem scab	0.000	-0.215a	0.016	0.000	-0.168	-0.367
Peduncle scab	0.000	-0.092	0.037a	0.000	-0.131	-0.186
Flower cushion scab	0.000	0.000	0.000	0.000a	0.000	0.000
Pod scab	0.000	-0.112	0.015	0.000	-0.352a	-0.449
			2006			
Leaf scab	0.000a	0.000	0.000	0.000	0.000	0.000
Stem scab	0.000	-0.407a	0.112	0.185	-0.145	-0.255
Peduncle scab	0.000	-0.197	0.231a	0.516	-0.183	0.367
Flower cushion scab	0.000	-0.123	0.195	0.611a	-0.132	0.551
ssPod scab	0.000	-0.235	0.168	0.319	-0.252a	0.000

a=direct effect

Table 2. Percentage of individual (direct) and combined contributions of scab Severity on the different plant parts on grain yield of cowpea variety TVx3236 and their residual effect 2004, 2005, 2006.

Infected plant parts	Percentage contributions in:		
	2004	2005	2006
Individual (direct) contribution			
Leaf scab	0.000	0.000	0.000
Stem scab	2.528	4.623	6.503
Peduncle scab	19.536	0.137	13.468
Flower cushions scab	1.960	0.000	30.360
Pod scab	12.888	12.390	0.000
Combined contributions			
Leaf scab and stem scab	0.000	0.000	0.000
Leaf scab and peduncle scab	0.000	0.000	0.000
Leaf scab and flower cushion scab	0.000	0.000	0.000
Leaf scab and pod scab	0.000	0.000	0.000
Stem scab and peduncle scab	11.835	-0.678	-9.028
Stem scab and pod scab	0.508	0.000	-15.020
Stem scab and flower cushion scab	5.023	7.901	-11.836
Peduncle scab and flower cushion scab	-1.671	0.000	23.853
Peduncle scab and flower cushion pod scab	-20.247	-0.063	-8.452
Flower scab and pod scab	-2.865	0.000	-16.075
Residual (Rx)	70.505	76.690	86.281
Total	100.000	100.000	100.000

Table 3. Direct and indirect effects (contributions) of scab severity on the different plant parts on grain yield of cowpea variety SAMPEA-6 in 2004, 2005, 2006.

Infected plant parts	Direct and Indirect effects of: Leaf scab	Stem scab	Peduncle scab	Flower cushion scab	Pod scab	Total effects
			2004			
Leaf scab	1.480a	-0.177	-0.834	-0.093	0.018	0.394
Stem scab	0.995	-0.264a	-0.674	-0.069	0.055	0.043
Peduncle scab	1.325	-0.191	-0.932a	-0.044	0.004	0.162
Flower cushion scab	0.477	0.063	-0.140	-0.290a	0.147	0.131
Pod scab	0.104	-0.056	-0.014	0.166	0.257a	0.125
			2005			
Leaf scab	0.547a	1.402	-1.557	-0.248	0.011	0.155
Stem scab	0.404	1.897a	-2.112	-0.287	0.000	-0.098
Peduncle scab	0.403	1.897	-2.112a	-0.285	0.000	-0.097
Flower cushion scab	0.150	0.605	-0.067	-0.900a	0.145	-0.067
Pod scab	0.021	0.000	-0.002	-0.443	0.298a	-0.130
			2006			
Leaf scab	0.009a	-0.222	0.273	0.000	0.009	0.069
Stem scab	0.005	-0.384a	0.473	-0.273	0.003	-0.181
Peduncle scab	0.004	-0.308	0.590a	-0.296	0.001	-0.009
Flower cushion scab	0.000	-0.136	0.223	-0.784a	0.009	-0.688
Pod scab	0.003	-0.042	0.035	-0.304	0.023a	-0.285

a=direct effect

pod in 2004 and via leaf in 2005 that were positive.

Stem scab had no indirect effect via pod in 2005. The direct effect of peduncle scab on grain yield in 2004 and 2005 were all positive except in 2006. Their indirect effects via stem and flower cushion (2004 and 2006) were negative but positive via the other plant parts. No indirect effect of peduncle via pods was observed in 2005. The direct effect of flower cushion scab on yield was negative in all the years and its indirect effect on other plant parts was positive except its effect via peduncle (2005 and 2006) and stem in 2006. Pod scab showed a positive direct and indirect effect on grain yield but its indirect effect via stem was negative in all the years with no indirect effect observed in 2005.

Table 5 represent the direct and indirect effect of scab infected plant parts on grain yield of IT93K452-1. The direct effect of leaf scab via the other plant parts on grain yield was positive in all the years except in 2006. Likewise, its indirect effect was all negative except for peduncle scab and pod scab (2004) and peduncle scab and flower cushion scab in 2006. The direct effect of stem scab on grain yield was negative except in 2006 and its indirect effect via the other plant parts in 2004 was positive but negative via flower cushion. In 2005 and 2006 the indirect effect of stem scab via the other plant parts were negative except its effect via leaf scab. The direct effect of peduncle scab on grain yield was negative in all the years except in 2004 and its indirect effect was positive via leaf scab and pod scab in 2004, leaf scab (2005) and leaf and stem scab in 2006. There was no indirect effect of peduncle scab via flower cushion and pod in 2006. The direct effect of flower cushion scab on grain yield was negative in all the years accept in 2006. Its indirect effect via the other plant parts in 2004 was positive except its effect via stem scab. In 2005 and 2006 all the indirect effect of flower cushion scab on grain yield via the other plant parts were negative except via leaf scab in 2005. There was no indirect effect of flower cushion scab and pod scab via peduncle in 2006 but the direct effect of pod scab on grain yield was negative except in 2004. Likewise, the indirect effect of pod scab via other plant parts in 2004 and 2005 were negative except leaf scab, and stem scab (2004). Pod scab also showed a negative indirect effect on grain yield via leaf scab.

When the percentage of individual contribution of scab infected plant parts on the grain yield of the three varieties of cowpea was considered, it was observed that SAMPEA-6 had the highest scab severity on all the plant parts compared to IT93K452-1 and TVx 3236 with cowpea variety TVx 3236 having the least scab infection (Table 2, 4 and 6). No scab was recorded on the leaves of TVx 3236 in all the years of studies. Of all the plant parts that contributed individually or directly to scab infection on grain yield, leaf scab, stem scab, peduncle scab, flower cushion scab and pod scab were all high on SAMPEA-6 but moderate on IT93K452-1 with TVx 3236 having a lower scab infection for the same plant parts. When the percentage of combined contributions of scab severity on the different plant parts of the three varieties of cowpea were considered, the effect of scab severity on grain yield of SAMPEA-6

Table 4. Percentage of individual (direct) and combined contributions of scabs everity on the different plant parts on grain yield of cowpea variety SAMPEA-6 and their residual effect in 2004, 2005, 2006.

Infected plant parts	Percentage contributions in:		
	2004	2005	2006
Individual (direct) contribution			
Leaf scab	219.040	29.921	0.008
Stem scab	6.970	359.861	14.746
Peduncle scab	86.862	446.054	34.810
Flower cushions scab	8.410	81.000	61.466
Pod scab	6.605	8.644	0.053
Combined contribution			
Leaf scab and stem scab	-52.573	153.366	-0.399
Leaf scab and peduncle scab	-246.905	-170.286	0.492
Leaf scab and flower cushion scab	-27.640	-27.077	0.000
Leaf scab and pod scab	5.325	1.254	0.016
Stem scab and peduncle scab	35.579	-801.293	-36.340
Stem scab and pod scab	3.629	-108.926	21.315
Stem scab and flower cushion scab	-2.904	0.000	-0.194
Peduncle scab and flower cushion scab	8.108	120.511	-34.970
Peduncle scab and flower cushion pod scab	-0.719	-0.124	0.160
Flower scab and pod scab	-8.526	-26.037	-1.399
Residual (Rx)	58.679	33.132	40.236
Total	100.000	100.000	100.000

Table 5. Direct and indirect effects (contributions) of scab severity on the different plant parts on grain yield of cowpea variety IT93K4524 in 2004, 2005, 2006

	Direct and Indirect effects of:					
Infected plant parts	**Leaf scab**	**Stem scab**	**Peduncle scab**	**Flower cushion scab**	**Pod scab**	**Total effects**
			2004			
Leaf scab	0.078a	-0.410	0.091	-0.460	0.191	-0.510
Stem scab	0.047	-0.677a	0.098	-0.330	0.369	-0.493
Peduncle scab	0.040	-0.370	0.180a	-0.368	0.256	-0.262
Flower cushion scab	0.059	-0.368	0.109	-0.608a	0.333	-0.475
Pod scab	0.027	-0.454	0.084	-0.368	0.551a	-0.160
			2005			
Leaf scab	0.560a	-0.473	-0.064	-0.272	-0.129	-0.378
Stem scab	0.459	-0.577a	-0.053	-0.269	-0.134	-0.574
Peduncle scab	0.289	-0.246	-0.124a	-0.178	-0.172	-0.431
Flower cushion scab	0.314	-0.320	-0.046	-0.485a	-0.149	-0.686
Pod scab	0.283	-0.305	-0.084	-0.285	-0.254a	-0.645
			2006			
Leaf scab	-0.160a	-0.005	0.034	0.099	-0.092	-0.124
Stem scab	0.001	0.797a	-0.257	-0.041	-0.443	0.057
Peduncle scab	0.011	0.411	-0.498a	0.000	0.000	-0.076
Flower cushion scab	-0.045	-0.092	0.000	0.356a	-0.549	-0.330
Pod scab	-0.016	0.371	0.000	0.205	-0.952a	-0.392

a=direct effect

Table 6. Percentage of individual (direct) and combined contributions of scab severity on the different plant parts on grain yields of cowpea variety IT93K452-1 and their residual effect in 2004, 2005, 2006

Infected plant parts	Percentage contributions in:		
	2004	2005	2006
Individual (direct) contribution			
Leaf scab	0.608	31.360	2.560
Stem scab	45.833	33.293	63.520
Peduncle scab	3.240	1.538	24.800
Flower cushions scab	36.966	23.523	12.674
Pod scab	30.360	6.452	90.630
Combined contributions			
Leaf scab and stem scab	-6.390	-52.922	0.153
Leaf scab and peduncle scab	1.426	-7.166	-0.084
Leaf scab and flower cushion scab	-7.171	-30.419	-0.317
Leaf scab and pod scab	2.974	-14.395	2.955
Stem scab and peduncle scab	-13.307	6.096	-40.961
Stem scab and pod scab	44.701	31.063	-6.526
Stem scab and flower cushion scab	-49.986	15.506	-70.563
Peduncle scab and flower cushion scab	-13.264	4.426	0.000
Peduncle scab and flower cushion pod scab	9.224	4.258	0.000
Flower scab and pod scab	-40.536	14.487	-39.110
Residual (Rx)	55.322	32.905	64.130
Total	100.000	100.000	1000.000

was higher, followed by IT93K452-1 and TVx 3236 recorded the lower severity. TVx 3236 showed no percentage of combined contributions on leaf scab and the other plant parts in all the years. When the three years were averaged for both percentage of individual and percentage of combined contributions of scab severity on the different plant parts on grain yield, it was observed that from the residual effects, scab severity on grain yield reduction of TVx3236 was 29.5% (2004), 23.3% (2005) and 13.7% (2006) (Table 2). For SAMPEA-6 it was 41.3% (2004), 66.9% (2005) and 59.8% (2006) (Table 4) and for IT93K452-1 it was 44.7% (2004), 67.1% (2005), and 35.9% (2006) (Table 6). Cowpea scab can cause yield reduction through the different plant parts up to 67% in susceptible varieties if not controlled. Hence the potential yield reduction from an epidemic of the disease cannot be overlooked.

DISCUSSION

The path coefficients analyses in this study were partitioned in to direct, indirect and total effects of scab infected plant parts on grain yield (kg/ha) of the three varieties of cowpea investigated in all the three years of studied. Any positive or negative effects observed on the different scab infected plant parts directly or indirectly and in their total contributions on grain yield of the three varieties of cowpea would certainly have an influence on the yield. This confirms previous report by Babaji *et al*. (2006), that any factor that positively or negatively affect grain yield would certainly have an influence on yield.

Of all the plant parts that contributed individually or directly to scab infection on grain yield of the three varieties of cowpea studied, peduncle scab and pod scab (TVx3236), leaf scab, stem scab, peduncle scab, flower cushion scab and pod scab (SAMPEA-6), stem scab, flower cushion scab and pod scab (IT93K452-1) showed a high positive direct effects on grain yield suggesting that these parameters contribute to scab infection on the yield of the three varieties of cowpea. In all the parameters that contributed to scab infection on grain yield of the three varieties cowpea, pod scab was the major contributor that reduces grain yield of cowpea. This report confirms previous work done by Mbong *et al*. (2010) who worked on cowpea and Tumwegamire *et al*. (1998) who worked on pigeon peas. From the residual effects, both percentages of individual and combined contributions of scab infected plant parts on grain yield of the three varieties of cowpea were determined. The residual effects obtained in the individual years showed that scab infection on grain yield of SAMPEA-6 ranged from 41-67%, IT93K452-1 ranged from 36-67% and TVx3236 ranged from 14-29%. These results indicated that the variations observed on grain yield were directly and indirectly influenced by scab infection on the different plant parts. Also the variations in the residual effects of scab infection across years on the three varieties of cowpea could also be attributed to other factors in the field. The three varieties of cowpea differed in their reaction to scab infection, with SAMPEA-6 having higher individual and combined contributions of scab infection on grain yield of cowpea, followed by IT93K452-1 and TVx3236 showed the least infection on grain yield confirming their different levels of susceptibilities. The damaged caused by scab infection was responsible for yield reduction of the three varieties of cowpea especially with SAMPEA-6 and IT93K452-1.

Yield losses of 60-71% due to scab infection on cowpea were reported in Nigeria (Emechebe, 1980; Mungo *et al*., 1995) who also worked on cowpea. From the results of this study, scab infection on the different plant parts cannot be completely eliminated because these parameters both directly and indirectly contributed to yield reduction of the of the three varieties of cowpea but the use of resistance varieties will help in disease management and improved yield.

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