

Calcium Nitrate Fertilization Effect on Anthracnose Caused by *Colletotrichum Gloeosporioides* Penz., Tuber Rot By *Rhizopus Stolonifer* Ehrenb. and Yield in *Dioscorea Alata* Variety Atoroku After Fallow

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ABSTRACT

Calcium nitrate soil amendment fertilization effects on anthracnose disease caused by *Colletotrichum gloeosporioides*, tuber rot by *Rhizopus stolonifer* and yield were determined in *Dioscorea alata* variety Atoroku (a local variety from South West Nigeria). The field design was RCBD (randomized complete block design) with 3 treatments and 3 replicates. The 3 treatments were calcium at 0, 2 and 4 kg ha⁻¹ from calcium nitrate (analar grade) applied at 3 MAP (months after planting). N in the experimental site was below the critical determined for optimum yam production in South West Nigeria, but Ca, Mg and K were above the critical. At 4 MAP, shoot number (mean, 3.68) was comparable/similar across treatments, but shoot length (3.43 m) was higher in the 2 kg ha⁻¹ treatment than others. At 5 MAP the control and 2 kg ha⁻¹ calcium fertilized plants had higher shoot number, a mean of 5, than the 4 kg ha⁻¹ calcium fertilized plants, whereas shoot length had become similar in the treatments. Tubers were inoculated and incubated for two weeks with *Rhizopus stolonifer*, an economic yam storage pathogen in Nigeria, after the 5MAP and 6MAP harvests. There were no significant differences in weight loss or infection in the incubated tubers at 5MAP. Weight loss of 11.01% in the 2 kg ha⁻¹ incubated calcium-fertilized tubers were significantly higher than in the control (3.20%) and the 4 kg ha⁻¹ treatment (1.90%) at 6MAP. However infection was significantly lower in the 2 kg ha⁻¹ (0.78%) and 4 kg ha⁻¹ (0.86%) calcium-fertilized tubers than the control (2.25%) at 6MAP. Calcium nitrate at 2 kg ha⁻¹ and 4 kg ha⁻¹ soil amendment may be used in smallholder farmers plots to reduce infection in *D. alata* variety Atoroku tubers if the six months after planting is desired for income as is the practice for white guinea yam 6MAP milk harvest in Nigeria. Anthracnose severity scored at 8MAP was moderately susceptible in the 4 kg ha⁻¹ treatment (3.17), control (2.83) and the 2 kg ha⁻¹ treatment (2.75) and were not significantly different from one another. Reduction of anthracnose may be further determined with one or two foliar sprays in addition to the 3MAP calcium nitrate soil amendment, as well as leaf calcium analysis to ascertain the optimum concentration commensurate to anthracnose resistance. Shoot number per plant at 8MAP was in the range 2.07 to 2.54 with no significant differences among the three treatments. Tuber number per plant was also not significantly different and was 3.55, 4.27 and 3.18 in the 0, 2 and 4 kg ha⁻¹ treatments. Plant weight above the mound of 4.78 kg and tuber weight of 5.35 kg in the 4 kg ha⁻¹ treatment at 8MAP harvest was significantly higher than the

control (3.25 kg and 3.55 kg respectively), and the 2 kg ha⁻¹ treatment (3.05 kg and 3.25 kg respectively), whereas both were similar in the control and the 2 kg ha⁻¹ treatment. The 8MAP yield of 3.55 kg, 3.25 kg and 5.35 kg in the 0, 2 and 4 kg ha⁻¹ treatment is the equivalent of 35.5, 32.5 and 53.5 tons ha⁻¹ and are higher than the expected 15 to 25 tons ha⁻¹ with 400 kg (8 bags) NPK 15-15-15 (ICS-Nigeria) and also in the range of the estimated potential of 30 to 75 tons ha⁻¹ (Zinsou, 1997; Diby *et al.*, 2004). Calcium nitrate soil amendment at 4 kg ha⁻¹ is recommended for increase in yield in *Dioscorea alata* variety Atoroku after fallow in South West Nigeria or areas of similar soils.

Introduction

Anthrachnose disease caused by *Colletotrichum gloeosporioides* Penz is still a major constraint to yam production everywhere yams are grown, as well as storage rots mainly caused by fungi which reduce all-year-round availability of the staple by 30% to 50% annually, depending on storage conditions. The latter also depends on the farmers' wealth and sufficiency. Smallholder farmers' who are responsible for higher production across all the agro-ecologies where yams are grown in Nigeria, the world's largest producer, wish to make supply exceed demand and not the reverse (as it is currently), so that greater wealth for their high labour will be cushioned by export. As at 2014, export was only 0.03% (Verter *et al.*, 2015). This study investigated the effect of two main nutrient elements namely calcium and nitrogen supplied from calcium nitrate fertilizer, in the economic field disease anthracnose, tuber rot by *Rhizopus stolonifer* which is about the second most important yam tuber rot (storage/market) pathogen (Dania *et al.*, 2012) and yield in an indigenous water yam variety Atoroku from within Ogun state in South West Nigeria. The experimental site at the Teaching and Research Farms of DUFARMS (Directorate of University Farms), Federal University of Agriculture, Abeokuta Ogun State, South West Nigeria had been left fallow for more than four years before this study. The choice of calcium is based on its role in improvement of plant cell structural integrity against pathogenic degradation (Marshner, 1995, Dordas, 2008). Calcium carbonate fertilization had increased resistance to tuber rot by *A. niger* and *B. theobromae* in long-term storage of 2 improved yam varieties *D. rotundata* TDr 131 and *D. alata* TDa 92-2 (Otusanya *et al.*, 2016). In the latter report, NPK was used with CaCO₃ to enhance yield, but with no positive significant effects. Ca (NO₃)₂ was chosen in this study as it is more readily taken up in the soil than CaCO₃ (Lombin, 1990) and there was no need for a separate source of Nitrogen. Nitrogen is one of the two (the second being potassium, K) major nutrients required for optimum yield in yams (Diby *et al.*, 2011).

MATERIALS AND METHODS

Sourcing of Tubers

Tubers of *D. alata* var. Atoroku were sourced from yam farmers' plots within Ogun State in South West Nigeria.

Field Plot, Soil Sampling and Analysis

The field plot used is located at the Teaching and Research Farms of DUFARMS (Directorate of University Farms), Federal University of Agriculture Abeokuta, Nigeria. Clearing of the plot was done with hoes and machetes with minimal burning of bush. The 31 m by 13 m area, had three replicates and each replicate was 13 m by 9 m. Soil samples were collected per replicate before mound making. Fifteen (15) core soil samples were collected per replicate in a zig-zag pattern

with a slanting soil auger at 20 cm depth to lift surface and lower soil (Page *et al.*, 1982). Air drying of soil, sieving and bulking according to replicates, as well as soil analysis was according to standard methods (Page *et al.*, 1982).

Field Plot Design

The field design was RCBD (randomized complete block design), with three replicates and three treatments. In each replicate there were 6 rows of 5 mounds each. Mounds were 1 m by 1 m and 80 cm high. Three rows were treatment rows to which fertilizer treatments of 0, 2 and 4 kg ha⁻¹ calcium from calcium nitrate was applied. Three rows were border plant rows planted to the same variety but without any fertilizer application. Border plant rows were each 1 metre distance from the fertilizer treatment rows. Inter-row, intra-row and inter-replicate spacing were 1 m, 0.5 m and 1 m respectively. Thus there were a total of 30 mounds in each replicate and a total of 90 mounds in the plot. A clean border of 1 m on all of the four sides of the plot was maintained.

Planting, Staking and Fertilization

Seed yam tubers of average size 0.5 kg were planted per mound, at the onset of the rains (early March, 2015). Two metre (2m) length bamboo stakes were established per mound. Soil amendment of treatment rows with 0 kg ha⁻¹ (control), 2 kg ha⁻¹ and 4 kg ha⁻¹ calcium from Ca (NO₃)₂ (Analar grade) was at 3 MAP (Months After Planting). A 20 cm groove was made at 25 cm radius around the yam plant in each mound. Fertilizer was sprinkled at the early morning hours (7.00 am) evenly in the groove. The groove was then covered well with soil (Obigbesan and Agboola, 1978).

Emergence and Shoot Growth Assessment

Number of emerged plants were assessed at 3 MAP and 4 MAP. Number of shoots per plant and shoot length of a labelled vine per plant were determined at 3 MAP, 4 MAP and 5 MAP.

Tuber Sampling and Infection Experiment at 5 MAP and at 6 MAP

Tubers were sampled per treatment along a diagonal transect (for randomization) of the field plot at 5 MAP and at 6 MAP. They were transferred to the Crop Protection Laboratory, cleaned free of soil, surface-sterilized and then inoculated with a 7-day old pure culture of *Rhizopus stolonifer* (Otusanya *et al.*, 2016). Incubation period was 2 weeks. Weight loss (Y) in the tubers was calculated with the formula $\left(\frac{A-B}{A}\right) 100$. Infection was calculated with the formula $\left(\frac{C}{A}\right) 100$, where A is tuber weight before inoculation, B is tuber weight after incubation period and C is corrected weight of infected tissue $C = \frac{(100X)}{(100-Y)}$ where X is weight of infected tissue and Y is % weight loss (Otusanya, 1994).

Assessment of Anthracnose Severity at 8 MAP

Severity of Anthracnose was determined at 8 MAP using the Anthracnose Severity Scale in Figures 1, 2, and 3 (Otusanya *et al.*, 2017).

Plant Weight and Yield at 8 MAP

The above-ground plant weight in treatment and border plants were determined at 8 MAP. This was done by severing the shoots above each mound and cutting them into smaller portions in a pre-weighed raffia basket. The above-ground plant weight was measured with a top loading

field balance. Tubers per plant (in each mound) were counted after soil on the mound was moved carefully away from the tubers within with a smooth wooden club, to avoid bruising. Tubers were cleared carefully of soil with a soft cloth and weighed per plant with a top loading field balance.

Data Analysis

Data were subjected to analysis of variance with SAS 2000 version 9.1.3. Means were separated using Least Significant Difference.

RESULTS

Soil properties of the experimental plot

Soil properties of the field plot are as shown in Table 1. The values in cmol kg^{-1} of 31.50 ± 0.04 , 2.08 ± 0.01 and 0.70 ± 0.004 , for calcium (Ca), magnesium (Mg) and potassium (K) respectively are above the critical determined for optimum yam production for the 3 elements/minerals in South West Nigeria (Ibedu *et al.*, 1988). Nitrogen (N) of the value $0.75 \pm 0.003\%$ was below the critical determined for optimum yam production in South West Nigeria (Ibedu *et al.*, 1988).

Emergence and Shoot Growth

There have been two reports only (Otusanya 2018 and Otusanya 2018) of Calcium nitrate soil amendment fertilization in *Dioscorea* species, thus it became necessary to assess the fertilizer effect in some agronomic characters. Emergence was 60%, 50% and 30% in the 0, 2 and 4 kg ha^{-1} calcium-fertilized plants at 3 MAP respectively (Table 2). At 4 MAP, emergence had increased by 33.33%, 37.50% and 57.14% respectively in the 0, 2 and 4 kg ha^{-1} treatments, with no significant differences between them (Table 2). Shoot number per plant at 3 MAP was 2.25, 2.25 and 2.50 in the 0, 2 and 4 kg ha^{-1} calcium-fertilized plants respectively (Table 3). At 4 MAP increase in shoot number was 47.67%, 35.71% and 23.08% in the 0, 2 and 4 kg ha^{-1} calcium-fertilized plants, with no significant differences between them (Table 3). At 5 MAP, shoot number percent increase in the 0, 2 and 4 kg ha^{-1} calcium-fertilized plants was 108.89%, 78.87% and 8% respectively (Table 3), indicating significantly higher shoot number in the control plants and the 2 kg ha^{-1} treatment plants over the 4 kg ha^{-1} calcium-fertilized plants. The control and 2 kg ha^{-1} treatments were comparable/similar in shoot number (Table 3). Percent increase in shoot length at 4 MAP of 37.67% in the 2 kg ha^{-1} calcium-fertilized plants was significantly higher than the control (15.60%) and the 4 kg ha^{-1} treatment (13.63%) (Table 4). The control and 4 kg ha^{-1} treatments were not significantly different in shoot length at 4 MAP. At 5 MAP, % increase in shoot length of 76.98%, 129.91% and 63.76% in the 0, 2 and 4 kg ha^{-1} treatments were not significantly different from one another (Table 4).

Infection and Weight Loss in Tubers Inoculated with *Rhizopus stolonifer* for 2 weeks

Weight loss of 27.83%, 23.11% and 35.24% in the 0, 2 and 4 kg ha^{-1} calcium-fertilized tubers inoculated with *R. stolonifer* were not significantly different from one another at 5 MAP (Table 5). Infection of 1.94% (control), 1.52 (2 kg ha^{-1}) and 2.31% (4 kg ha^{-1}) at 5 MAP were also not significantly different from one another (Table 5). However at 6 MAP, infection of 2.25% in the inoculated control was significantly higher than in the 2 kg ha^{-1} treatment (0.78%) and the 4 kg ha^{-1} treatment (0.86%) (Table 5). The latter two treatments were not significantly different from one another. Also infection in the 2 kg ha^{-1} and 4 kg ha^{-1} treatments at 6 MAP were only 51.32% and 37.23% respectively of that at 5 MAP. Weight loss of 3.20%, 11.10% and 1.90% in the 0, 2 and 4 kg ha^{-1} treatments at 6MAP were not significantly different from one another.

Mean weight loss at 6MAP in the inoculated calcium-fertilized tubers (2 and 4 kg ha⁻¹) of 6.5% was only 22% of mean weight loss of 29.2% of the same tubers a month earlier at 5MAP. Mean infection of 0.82% in the inoculated calcium-fertilized (2 and 4 kg ha⁻¹) tubers at 6MAP was also only 42.70% of the mean of 1.92% in the inoculated tubers a month earlier at 5MAP.

Severity of Anthracnose at 8 MAP

Anthracnose severity score of 2.83, 2.75 and 3.17 were recorded in the 0, 2 and 4 kg ha⁻¹ treatment plots at 8 MAP (Table 6). These scores fall into the category of moderately susceptible (Figs 1, 2 and 3, Otusanya *et al.*, 2017). They were not significantly different from one another.

Plant Weight and Yield at 8 MAP Per Plant

Plant weight above the mound at 8 MAP harvest was 4.78 kg in the 4 kg ha⁻¹ treatment plants, significantly higher than the control (3.25 kg) and the 2 kg ha⁻¹ treatment (3.05 kg) (Table 7). Mean plant weight in border plants was 1.52 kg. Mean plant weight in control plants (without fertilizer), was 213% higher than those of border row plants (also without fertilizer) which were one metre (1 m) distance from the treatment rows. Shoot number per plant was in the range 2.07 (2 kg ha⁻¹) to 2.54 (4 kg ha⁻¹) with no significant differences in the 3 treatments. Tuber number per plant was 3.55, 4.27 and 3.18 in the 0, 2 and 4 kg ha⁻¹ treatments with no significant differences among them. Tuber weight per plant was 5.35 kg in the 4 kg ha⁻¹ treatment, significantly higher than the 2 kg ha⁻¹ treatment (3.25 kg) and the control (3.55 kg), (Table 7). The latter two treatments were comparable. Tuber weight per plant equivalent in tons per hectare are 35.5, 32.5 and 53.5 tons ha⁻¹ in the 0, 2 and 4 kg ha⁻¹ treatments respectively and mean of 40.5 tons ha⁻¹. Mean of tuber weight per plant in the border plants was 1.15 kg or 11.5 tons per hectare. Tuber weight 3.55 kg of control plants is 308% higher than the mean of 1.15 kg of the border row plants.

DISCUSSION

Calcium nitrate soil amendment effects on anthracnose disease and tuber rot in *Dioscorea* species has been determined only in *Dioscorea alata* varieties Alakisa (Otusanya, 2018) and Agbodo (Otusanya, 2018). Thus emergence was determined one day before the 3 MAP fertilization and 4 weeks after at 4 MAP. Shoot number per plant and shoot length were also determined at 3 MAP (one day before fertilization and at one and two months after fertilization i.e. 4 MAP and 5 MAP (the phase of rapid/maximum leaf and vine growth – Onwueme and Sinha, 1991). Border plants one metre away from the control as well as the 2 kg ha⁻¹ and 4 kg ha⁻¹ calcium fertilized plants, were established for comparison of yield. Plant weight (above the mound) was determined one month before physiological maturity (8 MAP), as vines would be dry and leaves senescent at 9 MAP. Ca, Mg and K in the experimental soil site were above the critical determined for optimum yam production in South West Nigeria, but N was below the critical (Ibedu *et al.*, 1988).

There were no differences in emergence and shoot number after the 3 MAP soil amendment with Ca (NO₃)₂, but the control and 2 kg ha⁻¹ calcium-fertilized plants had produced more shoots than the higher calcium-fertilized treatment (4 kg ha⁻¹) at 5 months after planting. Shoot length was higher in the 2 kg ha⁻¹ treatment than the control and 4 kg ha⁻¹ treatment at 4 MAP, but at 5 MAP shoot length was comparable/similar across treatments. Four weeks to physiological maturity (8 MAP) mean shoot number and tuber number per plant (2.37 and 3.67 respectively) were comparable in all treatments, but the higher calcium-fertilized plants (4 kg

ha⁻¹) had higher above-mound plant weight and higher tuber weight than the other treatments. Mean tuber weight of 4.05 kg per plant was the equivalent of 40.5 tons ha⁻¹ at 8 MAP. The control and 2 kg ha⁻¹ calcium-fertilized treatments had comparable/similar yield at the 8 months after planting harvest. The expected yield in water yam (*D. alata*) with 400 kg (8 bags) of NPK 15-15-15 per hectare (60 kg N, 60 kg P₂O₅ and 45 kg K₂O₅/ha) in the forest zone of Nigeria is 16 to 25 tons ha⁻¹ (ICS-Nigeria). The yield in this study in the 0, 2 and 4 kg ha⁻¹ calcium nitrate fertilized plants is the equivalent of 35.5, 32.5 and 53.5 tons ha⁻¹ respectively, higher than the expected with 400 kg NPK (ICS-Nigeria) and in the range of the estimated potential of 30 tons ha⁻¹ to 75 tons ha⁻¹ (Zinsou, 1997; Diby *et al.*, 2004). At harvest the 91% to 94% of Nitrogen and potassium are accumulated in yam tubers and the tubers act as a sink for the two nutrients (Diby *et al.*, 2011). Nitrogen was below the critical in the experimental site in this study, whereas potassium was above, thus nitrogen supplied from calcium nitrate fertilizer is likely to have contributed well to the yield obtained. Therefore calcium nitrate fertilizer at 2 and 4 kg ha⁻¹ soil amendment may be recommended for increase in yield after fallow, for smallholder farmers in Nigeria, and elsewhere with similar soil conditions.

An interesting feature was that control plants (without fertilizer), had mean plant weight above the mound and mean tuber weight 213% and 308% higher than border row plants (also without fertilizer) planted one metre (1m) away from the treatment rows. This may have implications as to the spread of the roots of *Dioscorea alata* variety Atoroku probably consolidating the preference for the 25 cm radius groove around the roots (inside the mound) placement of the fertilizer in this study (as recommended by Obigbesan and Agboola, 1978) rather than side dressing.

Further research is necessary to investigate changes in culinary characteristics of calcium-nitrate fertilized *Dioscorea alata*, variety Atoroku as a reduction of the slimy characteristic of the inner flesh which is a desirable feature for special local dishes such as “Ikokore” (for which the species is appreciated) was observed in this study. Acceptability/Unacceptability of the reduction in the slimy inner flesh hinges on uses to which the water yam is put in the world’s largest producer or consumer of the tubers, because the less slimy flesh renders water yam eatable after boiling as the white guinea yam, suitable for the poor man especially as demand for this staple exceeds supply currently.

Tubers incubated with *R. stolonifer* at 5 MAP had weight loss and infection in the range 23.11% to 35.24% and 1.52% to 2.31% respectively with no significant differences in the two factors. Weight loss at 6MAP of 3.20%, 11.10% and 1.90% in the 0, 2 and 4 kg ha⁻¹ treatments were not significantly different from one another. However infection in the 2 kg ha⁻¹ and 4 kg ha⁻¹ calcium-fertilized tubers, which were 0.78% and 0.86% respectively were significantly higher than the control (2.25%) at 6MAP. Calcium nitrate fertilizer at 2 and 4 kg ha⁻¹ is recommended to reduce rot by *R. stolonifer* in tubers of variety Atoroku, if smallholder farmers desire to harvest them for sale at six months after planting as is normal in the white guinea yam in Nigeria.

Anthracoze severity was moderately susceptible in the three treatments in this study and there were no significant differences in the treatments. One or two calcium nitrate foliar sprays at strategic points in the growth cycle (such as phase of rapid leaf growth – Appendix 1) to support the calcium-nitrate soil amendment needs to be investigated for reduction of

anthracnose severity. Also as calcium plays the role of improving the structural integrity of cells (Marshner, 1995), analysis of calcium in the leaves should also determine optimum levels for anthracnose disease reduction in *Dioscorea alata* variety Atoroku.

Table 1: Soil properties of the field plot

pH	6.61 ± 0.16
Ca (cmol kg ⁻¹)	31.50 ± 0.40
Mg (cmol kg ⁻¹)	2.08 ± 0.01
K (cmol kg ⁻¹)	0.70 ± 0.004
N (%)	0.75 ± 0.003

Table 2: Emergence (%) in calcium-fertilized *Dioscorea alata* variety Atoroku

Treatment Kg ha ⁻¹ Calcium	Emergence at 3 MAP	Emergence at 4 MAP	% increase at 4 MAP
0	60	90	33.33
2	50	80	37.50
4	30	70	57.14
LSD (P = 0.05)			66.71

Table 3: Shoot number assessment in Calcium-fertilized *Dioscorea alata* var. Atoroku

Treatment Kg ha ⁻¹ Calcium	SN - 3 MAP	SN - 4 MAP	% Increase at 4 MAP	SN - 5 MAP	% Increase at 5 MAP
0	2.25	4.30	47.67	4.70	108.89
2	2.25	3.50	35.71	5.08	78.87
4	2.50	3.25	23.08	2.70	8.00
LSD (P = 0.05)			25.77		58.61

SN = Shoot number

MAP = Months after planting

Table 4: Shoot length (metre) in Calcium-fertilized *Dioscorea alata* var. Atoroku

TRT Kg ha ⁻¹ Calcium	SL - 3 MAP (m)	SL - 4 MAP (m)	% Increase at 4 MAP	SL - 5 MAP (m)	% Increase at 5 MAP
0	2.79	3.31	15.60	4.94	76.98
2	2.14	3.43	37.67	4.92	129.91
4	2.75	3.19	13.63	4.62	67.63
LSD (P = 0.05)			21.13		63.76

SL = Shoot length

MAP = Months after planting

m = meter

LSD (P = 0.05) = Least significant difference

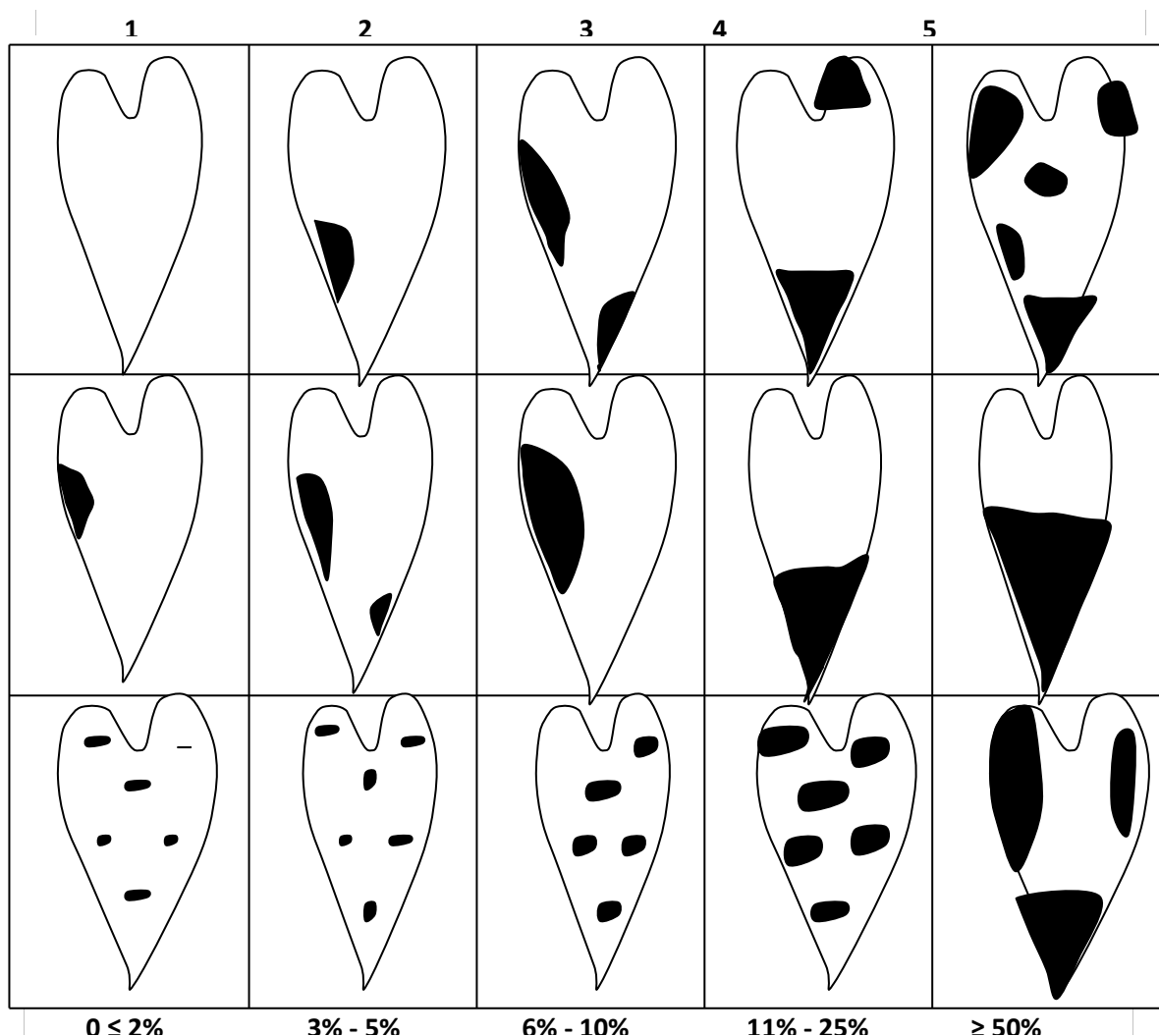
Table 5: Infection and weight loss in Calcium-fertilized *Dioscorea alata* var. Atoroku incubated with *Rhizopus stolonifer* for 2 weeks

Treatment Kg ha ⁻¹ Calcium	Tubers harvested at 5 MAP		Tubers harvested at 6 MAP	
	% Weight Loss	% Infection	% Weight Loss	% Infection
0	27.83	1.94	3.20	2.25
2	23.11	1.52	11.10	0.78
4	35.24	2.31	1.90	0.86
LSD (P = 0.05)	34.20	1.62	9.76	0.84

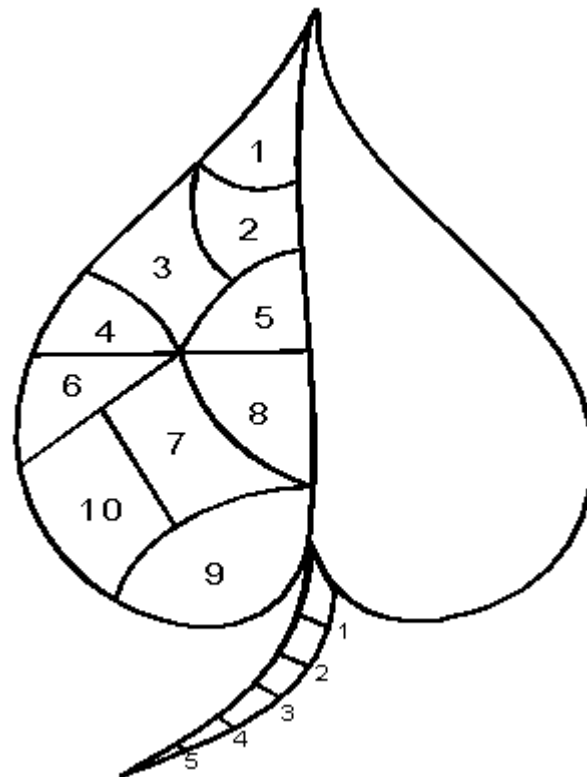
MAP = Months after planting

Table 6: Severity of Anthracnose disease caused by *Colletotrichum gloeosporioides* in calcium-fertilized *Dioscorea alata* var. Atoroku at 8 MAP.

Treatment Kg ha ⁻¹ Calcium	Anthracnose disease severity score
0	2.83
2	2.75
4	3.17
LSD (P = 0.05)	1.71



1- No symptom/ $0 \leq 2\%$ severity/resistant/highly resistant
 2 - Necrotic spots 1.00 mm – 2.00 mm/3-5% severity/moderately resistant (tolerant)
 3 - Necrotic spots 2.01 mm – 3.00 mm/6-10% severity/moderately susceptible
 4 - Necrotic spots 3.01 mm – 4.00 mm/11-25% severity/susceptible
 5 - Necrotic spots > 4.00 mm/ $\geq 50\%$ severity/very susceptible
Figure 1: Yam leaf anthracnose disease assessment diagram + lesions on petiole and stem (Otusanya et al., 2017)



Petiole $\frac{1}{5} \times 100 = 20\%$

Leaf BLADE $\frac{1}{10} = 5\%$

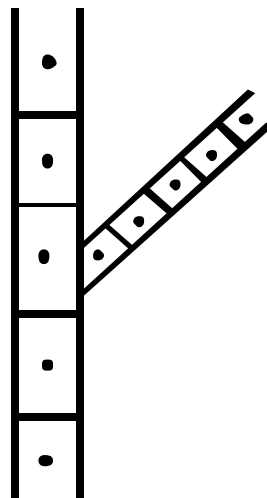
$\frac{2}{10} = 10\%$ ETC.

10 Leaves UPPER PORTION (young = tender/lighter texture)

10 Leaves MIDDLE PORTION (maturing = green/expanded/big)

10 Leaves LOWER PORTION (fully expanded + well-formed Cuticle/texture leathery)

Fig. 2: Leaf anthracnose assessment (Otusanya *et al.*, 2017)



5 Sections per vine/ petiole

TDa - 2 Vines only

TDr - 2 Vines only

Da - 2 Vines only

Estimated % area scored per Vine or Petiole

Fig. 3: Vine and Petiole anthracnose assessment (Otusanya *et al.*, 2017)

Table 7: Above-mound plant weight (AMPW), shoot number per plant and yield in calcium-fertilized *Dioscorea alata* variety Atoroku at 8 MAP

Treatment Kg Calcium	AMPW per plant (kg)	AMPW per plant in border plants	Shoot number per plant	Tuber number per plant	Tuber weight per plant (kg)	Tuber weight in tons per hectare	Tuber weight per plant in BORDER ROW PLANTS (kg)
0	3.25	1.93	2.50	3.55	3.55	35.5	0.86
2	3.05	1.74	2.07	4.27	3.25	32.5	1.54
4	4.78	0.88	2.54	3.18	5.35	53.5	1.05
LSD (P = 0.05)	0.34		1.29	2.09	0.41		
Mean	3.69	1.52	2.37	3.67	4.05	40.5	1.15

MAP = Months after planting

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APPENDIX

Appendix 1 Growth phases of the yam plant (Onwueme and Sinha, 1991)

