Trials of FHIA Bananas for Performance and for Resistance to Black Leaf Streak in Pohnpei, Federated States of Micronesia

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by

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Introduction

Next to breadfruit, banana is the most important energy food source for healthy living in the Pacific. Preparation methods vary: they can be simply be ripened and eaten, they can also be boiled, fried or broiled/grilled; they can be crushed to make an edible paste and mixed with other ingredients, usually with sugar and coconut milk; they can be cut up and mixed with vegetables to make fish or meat stew.

During the decade of the 1990's, world production of banana rose from about 60 to about 100 million tons (Valmayor, 1990 and undated INIBAP report). Only 10 to 13% of production however was exported (as dessert banana), the remaining 87% or so consumed domestically and not leaving the country where it was produced (Valmayor, 1990, and INIBAP 21Jan03 report).

About 75% of banana and plantains are grown on small, subsistence-type farms with a minimum of material inputs or technology (Umali and Lantican, eds. 1985). Banana is cultivated with a minimum of cultural practices (Gonzales et al 2003). Subsistence-type banana farms rarely use inorganic fertilizers or pesticides to control insect pests and diseases.

However, the growth of bananas in large-scale plantations favored the development and severity of diseases such as Black Leaf Streak or BLS (caused by the fungus, *Mycosphaerella fijiensis* Morelet). Besides the obvious costs in labor and materiel associated with fertilizer and pesticide applications (sometimes up to 40 times per year in commercial plantations), there are potential dangers posed to the health of individual farm workers as well as to the environment. Therefore, the use of host resistance in subsistence agriculture is a feasible and practical answer to pest control problems in the relatively fragile Pacific island ecosystems.

The Fundacion Hondurena de Investigacion Agricola (FHIA) developed a number of high-yielding banana hybrids with resistance to BLS (Gonzales et al 2003). Some hybrids also were reported to have superior values for important yield parameters.

The International Musa Testing Program (IMTP) is a collaborative effort coordinated by Bioversity International to evaluate, in various locations around the world, elite *Musa* varieties produced by breeding programs as well as promising germplasm from the International Musa Germplasm Collection in Leuven, Belgium. The objective of the program is to identify banana

and plantain hybrids, that, in addition to being resistant to the main pests and diseases that affect banana production, also meet local requirements.

We at UH-CTAHR and in Pohnpei (COM-FSM) became involved in the IMTP project via funding provided by the ADAP project (Agricultural Development in the American Pacific) starting about the year 2000. By 2001, we had two, replicated banana variety experiments, including some FHIA bananas, planted in Pohnpei and we had begun data collection.

Our objective was to examine the agronomic performance and disease resistance of several of the more important FHIA hybrids under Pohnpeian conditions, and determine taste preference of the locals for the varieties. Here, we provide a preliminary report of these trials, with a focus on the disease reactions and yield of the FHIA hybrids and the other reference clones and local varieties included in the trial.

Materials and Methods

Source of Planting Materials. In February 2000, The Regional Germplasm Center (RGC) of the Secretariat of the Pacific Community (SPC), Suva, Fiji provided tissue-cultured and certified disease-free FHIA hybrids. The varieties were: FHIA-01; FHIA-02; FHIA-03; FHIA-17; FHIA-18; and FHIA-23. Four reference clones with known reactions to BLS - Akadahn, Grande Naine, Utin Menihle, and Yangambi Km 5 - were included for comparison with the FHIA hybrids. Two of the reference clones, Grand Naine and Yangambi Km5, were provided as tissue-cultured plants from SPC via the International Network of Banana and Plantain Program (INIBAP), whereas two Pohnpeian local varieties, Akadahn and Menihle, were 12-18 cm tall sword suckers collected in Pohnpei. Salient characteristics of the planting materials, such as genome and uses, are listed in Tables 1 and 2.

***In Vitro* Propagation.** *In vitro* multiplication was conducted at the new low-cost Plant Tissue Culture Laboratory of the Cooperative Research and Extension (CRE), College of Micronesia-FSM (Federated States of Micronesia). The laboratory was finally equipped and fully supplied by mid-2000, after which multiplication of material for the trials was conducted early 2001. Plantlets were acclimatized, hardened and established in the newly built shade house covered with plastic (6 mils thick) and green shade cloth. Plantlets were grown in the shade house for 8 to 12 months until they were of transplanting size (30 cm tall with at least 5 leaves).

Field Planting - Holes one foot deep and one foot wide were dug six feet apart along rows that are distanced 7.5 feet away from each other, providing each mat an area of 45 sq. ft and a total of 968 mats per acre. Various authors suggested varying planting distances and densities. Gonzales et al (2003) used 2m by 3m distancing (6.56’ by 9.84’ = 65 sq ft per mat) that gives 670 mats per acre. Vargas and Guzman (2004) planted 1371 plants per hectare, which translates to 78 sq ft per mat and 555 mats per acre. Scully and Bevacqua in Guam (undated) suggested planting distances of 8’ by 12’ (that provides 96 sq ft per mat); 10’ by 10’ (100 sq ft); and 10’ by 12’ (120 sq ft) which give planting densities of only 453; 435; and 363 mats per acre, respectively. PCARRD (1992) recommended 3 to 4m by 5 to 7m that gave densities ranging from a low of 145 mats to a high of 270 mats per acre. Scully and Bevacqua (undated) noted that densities over 700 mats per acre produce lower bunch weights and longer fruit maturation. They further added that a properly managed plantation may produce 80 lb bunches with 8 hands per bunch.

Tissue-cultured seedlings aged 8 to 12 months and approximately 30 cm tall with at least five leaves were field planted on April 20/01 in AES Farm, CRE at COM-FSM in Palikir and May 5/01 in the State Agriculture Pilot Farm in Pohnlangas, Madolenihwm.

Experimental Design - The experiment was laid out in a Randomized Complete Block Design in the two sites, each site having four replications, ten varieties with five plants per experimental unit (Table 4, Figure 2).

Management Practices - One month after planting, one-half pound of complete (N-P2O5-K20) fertilizer with an analysis of 12-17-17 was applied to each mat (distributed in four holes dug around and about one foot away from the plant). Total fertilizers applied per acre in the first year (six applications) are 348 lbs of N; 492 lbs of P2O5; and 492 lbs of K2O. In comparison, Scully and Bevacqua's (undated) recommendation of two lbs of 10-20-20 (N-P2O5-K2O) per mat applied four times in the first year provided a total fertilizer application rate of 348-696-696 lbs per acre. The two rates may be comparable on a per area basis but considerably less P and K were applied per mat in the former. The rate was doubled during the second year and onwards. Two shovels of commercial chicken manure were likewise applied every time the inorganic fertilizers were applied (about 18 tons per acre total for the year). Scully and Bevacqua on the other hand recommended a pre-plant rate of only 5 to 10 tons per acre.

The plants received no watering but were weeded every other month (hand weeding around the plants and weed-eater in the inter-rows and pathways). The last two leaves (100% brown leaf surface) were removed every other month. No chemicals were applied.

In this trial, de-suckering and de-handing were not implemented in order to determine relative vigor of the varieties.

Data Collection and Parameters Measured. The data collected included a wide range of plant growth and disease parameters (Table 3). Measurements on growth and development include height at flowering (HF), height at harvest (HH), girth at flowering (GF), girth at harvest (GH), tallest sucker at flowering (TSF), tallest sucker at harvest (TSH), number of suckers at flowering (#SF), number of suckers at harvest (#SH), number of functional leaves at flowering (LF), number of functional leaves at harvest (LH), bunch weight (BW), weight of hand #3 or #4 (WH), number of hands per bunch (HB), number of fingers per hand HF), weight of fingers (WF), number of days to flowering, and number of days to harvesting.

Monitoring and data collection were prevented whenever typhoons visited Pohnpei. Plants were blown down and uprooted, destroying flowers and fruits of the affected plants. In particular, observations were missing for the following months: Oct and Dec in 2001; Apr and Jul in 2002; May 2003; Dec 2004; and, Dec 2005. There were other causes for missing data such as theft, and birds, rats or chicken eating the fruits.

This presentation focuses on data collected for BLS disease severity, bunch weight, taste and acceptance, and a derived variable, "plant health index", which is (number of leaves / BLS disease rating).

Disease Development and assessment. Disease development in the plots occurred naturally. The test plants were not inoculated with the pathogen.. Instead, the susceptible reference varieties, Akadahn and Utin Menihle, besides being integral parts of the study, were planted along the perimeter and middle in between the blocks in both sites to stimulate the development of the epidemics (Figure 2).

Monthly monitoring for disease incidence started November 2001 in the COM-FSM AES Farm Site in Palikir, and December 2001 in the State Agriculture Site in Pohnlangas, Madolenihwm

until February 2005. Observations started 7 months after planting (instead of 6 months due to inclement weather during the month of October 2001) as suggested by the International Musa Testing Program (IMTP**).**

At each disease assessment, each unfurled leaf on each of the test plants was rated for disease severity, defined as percentage of leaf area diseases. We used an international disease assessment scale for BLS with 6 disease categories (Figure 3). Leaves were numbered from the top of the banana plant down, starting with the first unfurled leaf as leaf #1 and proceeding down the plant until all functional leaves were rated for disease severity (i.e., percent leaf area covered with BLS lesions).

Data analysis. Data were subjected to analysis of variance using a general linear model and where appropriate, means separation procedures (Duncan's multiple range test, or least squares means where there were missing data). Data were combined for analysis between locations where appropriate.

Results and Discussion

Disease Evaluation. In the analysis of variance, there was a significant variety x location effect; therefore, the data from each site are presented separately in Tables 5 and 6. At Palikir (Site #1), disease severity ranged from 13.8% (FHIA-03) to 25.8% (Utin Menihle). The banana varieties with the lowest disease severity values were FHIA-01 and FHIA-03, whereas the local variety, Utin Menihle, and Grand Naine, had the highest disease severity values. At site #2 (Pohnlangas), disease severity ranged from 13.6% (FHIA-23) to 24.4% (Grand Naine). The bananas with lowest BLS disease values were FHIA-23 and FHIA-03, whereas the local variety, Utin Menihle, and Grand Naine, had the highest disease severity values (Table 6). In general, the FHIA hybrids had lower disease values than the reference clones, including the highly resistant variety, Yangambi Km 5.

Bunch Weight. Bunch weight is the ultimate indicator of a banana plant's productivity. FHIA-3 produced the heaviest bunch of fruits with 36.38 lbs (Table 7). It is not different from FHIA-1 with 34.01 lbs, but is significantly more than the other varieties, the heaviest of which is only 27.62 lbs. Grande Naine, Menihle, and Akadahn produced the lightest bunches with 18.27, 16.35, and 12.6 lbs, respectively.

Gonzales et al (2003) reported getting heavier bunches, harvesting 79.2 lbs from FHIA-01; 41.36 lbs from FHIA-18; 54.12 lbs from FHIA-17; and 110 lbs from FHIA-23. Their lowest yield (of 41.36 lbs by FHIA-01) is five lbs heavier than the heaviest bunch yield of 36.38 lbs (by FHIA-03) in this study. And, their heaviest yield of 110 lbs (by FHIA-23) is about five times the lowest bunch yield in this study of 23.74 lbs (by FHIA-02). The findings agree with Scully and Bevacqua (undated) that planting closer (or higher planting density) tends to reduce bunch weights.

When presented as yields per acre, FHIA-03 and FHIA-01 in Pohnpei gave almost the same yields with FHIA-17 in Colombia, averaging 17.6; 16.5; and 18.1 ST (2000 lbs/ST) respectively. FHIA-18 and FHIA-17 gave comparable yields with FHIA-18 in Colombia giving yields of 13.4 and 13.3 vs. 13.9 ST, respectively. FHIA-23 and FHIA-02 in Pohnpei gave low yields with 12.4 and 11.4 ST compared with FHIA-01 that gave 26.6 ST and FHIA-23 with 36.9 ST, respectively. The yield difference was somewhat reduced by higher planting density, but was not totally so. Some other factor such as fertilizer application rates, climatic and/or soil conditions or even interaction of the varieties with BLSD under Pohnpei conditions may have had relevance.

Yield and Yield Parameters. In general, varieties FHIA-03 and FHIA-01 performed consistently well with the former being slightly better in most yield and yield parameters including number of leaves at flower and harvest. They both had the heaviest bunch, hand, and finger weights (data not shown).

Plant Health Index. Two FHIA hybrids had significantly higher values for plant health index across both experimental locations (Table 8), FHIA-01 and FHIA-03. These two varieties consistently had the most leaves and the most disease-free leaves when compared with the other entries in the trial. In general, the FHIA hybrids had better plant health index values than non0FHIA entries in the test, with the exception of FHIA-17.

Taste and acceptability. The taste and acceptability values did not necessarily correlate with good agronomic performance and low disease values. For example, Akadahn had the highest values for taste and acceptability (Table 8), while performing poorly is disease ratings and yield. Pohnpeians also liked the taste of FHIA-17 and FHIA-23 but the performance of these bananas in our trial was relatively poor. FHIA bananas 01, 02 and 03 received relatively good rankings, and therefore should be acceptable bananas for the Pohnpeian landscape, farms and consumers. There have already been many requests for suckers of these FHIA bananas in Pohnpei.

Based on the performance of the FHIA bananas in Pohnpei, we are considering introducing several of the varieties to Hawaii.

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Table 1. Qualities of FHIA bananas included in the Pohnpei trials for agronomic performance and for resistance to black leaf streak disease.

Hybrid	Genome	Qualities*	Uses
FHIA-01 'Goldfinger'	AAAB	Highly resistant to BLS; resistant to Race 1 FW; tolerant to BN; Resistant to CR; tolerant to drought; tolerant to cold temperature; female parent is 'Dwarf Brazilian'	Pome-type, apple flavor dessert banana; also green cooking
FHIA-02 'Mona Lisa'	AAAA	Highly resistant to BLS; resistant to CR	Sweet, similar to Cavendish
FHIA-03 'Sweetheart'	AABB	Resistant to BLS; resistant to Race 1 FW; drought resistant; highly vigorous; semi-dwarf; tolerant to marginal conditions; one parent is 'Bluggoe'	Cooking banana, Also for dessert
FHIA-17	AAAA	Resistant to Race 1 FW	Dessert banana Can also be cooked
FHIA-18	AAAB	Resistant to BLS; long shelf life; few skin blemishes	Sweet acid (apple flavor) dessert banana
FHIA-23	AAAA	Tolerant to BLS; one parent is 'Highgate' (a 'Dwarf Bluefields')	Dessert

* BLS = Black Leaf Streak; BN = Burrowing Nematode; CR = Crown Rot; FW = Fusarium Wilt

Table 2. Qualities of reference banana clones and local varieties included in the Pohnpei trials for agronomic performance and for resistance to black leaf streak disease.

Variety	Genome	Qualities*	Uses
'Akadahn' (Pohnpei variety)	AAA Red/Green-red subgroup	Susceptible to BLS; drought tolerant; resistant to BN	Dessert High in carotenoids
'Grande Naine'	AAA Cavendish subgroup	Susceptible to BLS; grows well at high elevations in Hawaii	Dessert
'Utin Menihle'	AAB Silk = 'Manzano' = 'Amorosa' = "true apple" = 'Silk Fig'	Susceptible to BLS; very susceptible to FW and CW	Dessert
'Yangambi Km 5'	AAA Ibota subgroup	Highly resistant to BLS; resistant to BN and CW	Dessert or cooking

* BLS = Black Leaf Streak; BN = Burrowing Nematode; CR = Crown Rot; FW = Fusarium Wilt; CW = Corm Weevil

Table 3. Data collection for banana growth and disease parameters at the trials of FHIA bananas in Pohnpei from 2001-2005*.

1. **Black Leaf Streak disease severity** (international rating scale, visual estimates)
2. Plant Height: at flowering and at harvest (feet)
3. Plant girth: at flowering and at harvest (inches)
4. Tallest suckers: at flowering and at harvest
5. Number of suckers: at flowering and at harvest
6. Number of functional leaves: at flowering and at harvest
7. **Bunch weight** (pounds)
8. Weight of hand 3 (or hand 4 if hand 3 was damaged) (pounds)
9. Number of hands per bunch
10. Number of fingers per hand, weight of fingers (pounds)
11. Number of days to flowering
12. Number of days to harvesting
13. **Taste and acceptance** (using Hedonic scale)

* This presentation focuses on data collected for BLS disease severity, bunch weight, taste and acceptance, and a derived variable, “plant health index”, which is (number of leaves / BLS disease rating).

Table 4. Random assignment of banana varieties to the Blocks at the two experimental locations for the FHIA banana trials in Pohnpei from 2001-2005.

Site 1 (Palikir)

BLOCK	**I**	**II**	**III**	**IV**
ROW	**Variety**			
1	G Naine	FHIA-01	FHIA-03	Yangambi
2	Menihle	FHIA-18	FHIA-02	FHIA-17
3	FHIA-03	G Naine	Yangambi	Akadahn
4	FHIA-01	FHIA-02	FHIA-01	FHIA-18
5	FHIA-23	Menihle	FHIA-17	FHIA-23
6	Yangambi	FHIA-17	G Naine	Menihle
7	Akadahn	FHIA-23	Menihle	FHIA-02
8	FHIA-17	Yangambi	Akadahn	G Naine
9	FHIA-18	FHIA-03	FHIA-23	FHIA-01
10	FHIA-02	Akadahn	FHIA-18	FHIA-03

Site 2 (Pohnlangas)

BLOCK	**I**	**II**	**III**	**IV**
ROW	**Variety**			
1	Menihle	FHIA-23	FHIA-23	G Naine
2	Akadahn	FHIA-18	Yangambi	FHIA-23
3	G Naine	Akadahn	FHIA-17	Menihle
4	FHIA-17	Yangambi	FHIA-18	Akadahn
5	FHIA-02	FHIA-17	Akadahn	FHIA-18
6	FHIA-23	FHIA-01	FHIA-03	FHIA-17
7	FHIA-18	Menihle	G Naine	FHIA-01
8	FHIA-01	FHIA-03	FHIA-02	FHIA-02
9	FHIA-03	FHIA-02	FHIA-01	FHIA-03
10	Yangambi	G Naine	Menihle	Yangambi

Table 5. Comparison of banana varieties in the black leaf streak trial in Pohnpei for mean disease severity (%)* (Site 1, Palikir).

Variety	Disease Severity (%)[1]	Duncans grouping[2]
Utin Mehnile	25.77	A
Grande Naine	24.20	B
Akadahn	19.47	C
FHIA-17	17.88	D
FHIA-18	17.27	D
Yangambi Km 5	15.75	E
FHIA-23	15.16	EF
FHIA-02	14.72	EF
FHIA-01	13.99	F
FHIA-03	13.83	F

[1]Mean disease severity (percentage of leaf area diseased) for plants from 2001-2005 based on international BLS rating scale

[2]Means followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 6. Comparison of banana varieties in the black leaf streak trial in Pohnpei for mean disease severity (%)* (Site 2, Pohnlangas).

Variety	Disease Severity (%)[1]	Duncans grouping[2]
Grande Naine	24.35	A
Utin Menihle	23.88	A
Akadahn	18.94	B
FHIA-02	16.09	C
FHIA-01	16.05	C
FHIA-18	15.78	C
Yangambi Km 5	15.39	C
FHIA-17	15.18	C
FHIA-03	14.59	CD
FHIA-23	13.59	D

[1]Mean disease severity (percentage of leaf area diseased) for plants from 2001-2005 based on international BLS rating scale

[2]Means followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 7. Comparison of banana varieties in the black leaf streak trial in Pohnpei for mean bunch weight (pounds) (combined sites 1 & 2).

Variety	Bunch weight	Duncan grouping[1]
FHIA-03	36.4	A
FHIA-01	34.1	A
FHIA-18	27.6	BC
FHIA-17	27.4	BC
FHIA-23	26.7	BC
FHIA-02	23.7	CD
Yangambi Km 5	23.5	CD
Grand Naine	18.3	DE
Utin Menihle	16.3	DE
Akadahn	12.6	E

[1]Means followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 8. Comparison of banana varieties in the black leaf streak trial in Pohnpei for mean plant health index* (combined sites 1 & 2).

Variety	Plant health index*	Duncan grouping
FHIA-01	1.67	A
FHIA-03	1.58	A
FHIA-02	1.48	AB
FHIA-18	1.35	BC
FHIA-23	1.2	CD
Yangambi Km 5	1.10	D
FHIA-17	1.01	D
Akadahn	0.61	E
Grande Naine	0.54	E
Utin Menihle	0.5	E

*plant health index = (leaf number / disease severity). A high value meansthere are a relatively high number of leaves (a large numerator) with relatively low level of disease (a small denominator)

Table 9. Taste and acceptability values for FHIA bananas and reference varieties/clones included in the banana trials for resistance to BLS and for agronomic performance in Pohnpei from, 2001-2005.

Variety	**Taste***	**Acceptability***
FHIA-18	2.9	3.8
FHIA-02	3.0	3.6
FHIA-03	3.0	3.6
FHIA-23	3.0	3.7
Yangambi Km 5	3.0	4.4
Utin Menihle	3.0	4.2
FHIA-01	3.2	3.7
Grand Naine	3.2	3.1
FHIA-17	3.3	4.0
Akadahn	4.3	4.0

Legend: * = average of all replications
5 – Excellent
4 - Very Good
3 – Good
2 – Fair
1 - Poor

Figure 1. Map of Pohnpei showing the location of the two experimental sites for the trials of FHIA bananas for resistance to BLS and for agronomic performance.

Site 1: Palikir
Site 2: Pohnlangas

Figure 2. Sample field plot layout for banana trials in Pohnpei for FHIA

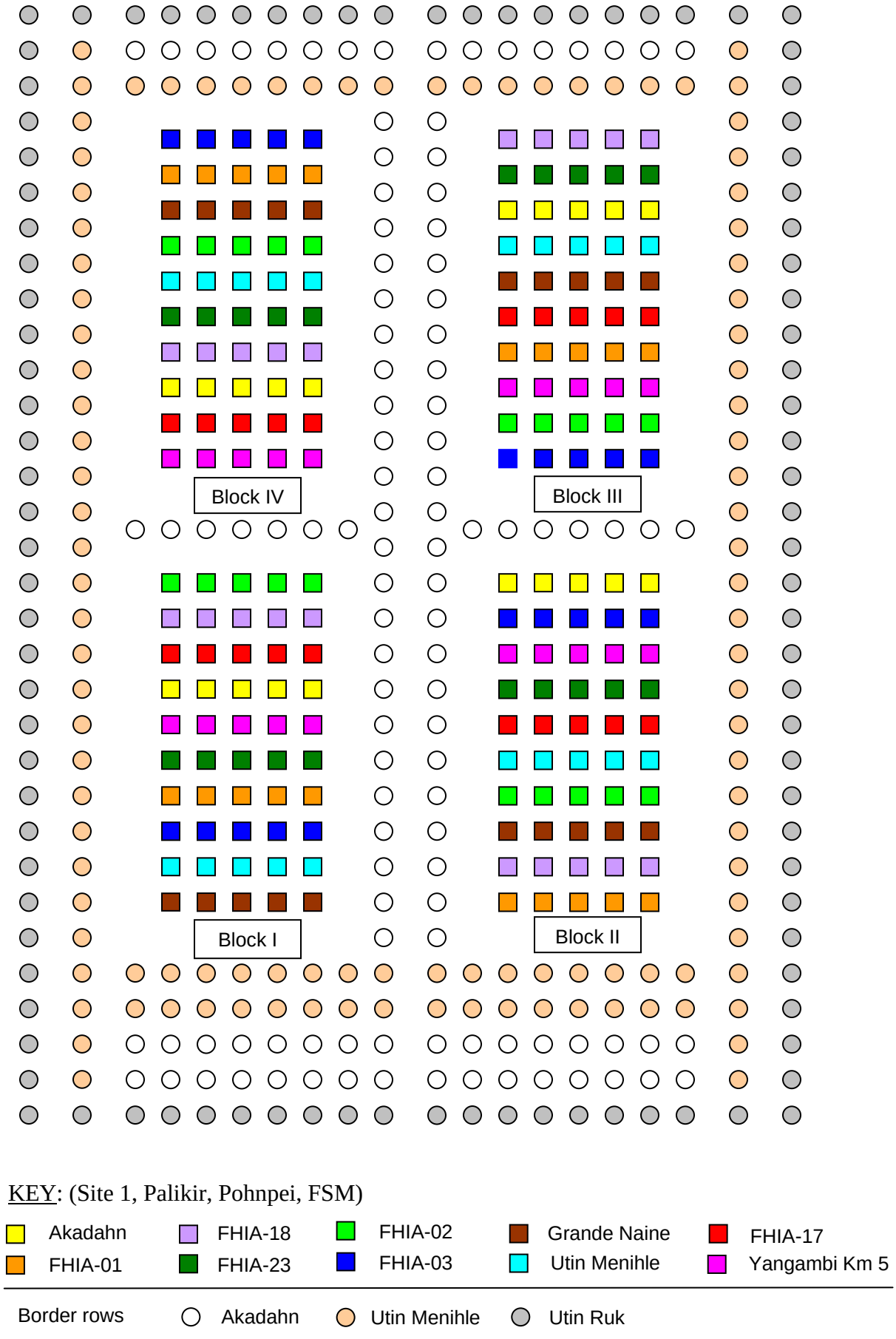
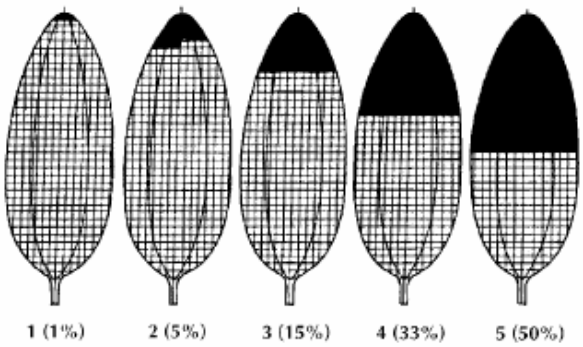


Figure 3. The international disease rating scale used to evaluate FHIA bananas and reference varieties/clones in the trials for resistance to black leaf streak disease in Pohnpei.



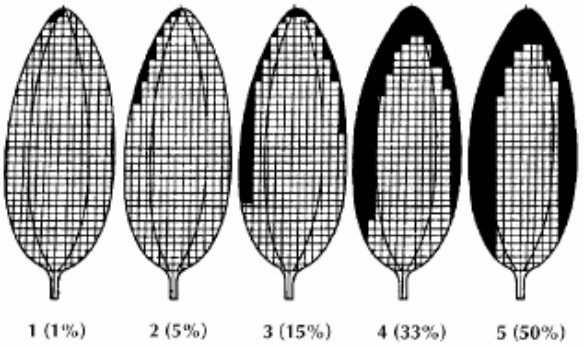


Figure 7. Sigatoka severity scoring.

The Gauhl's modification of Stover's Sigatoka severity scoring system is shown in Figure 7.

Key:

*	=	youngest completely unfurled leaf
0	=	no symptoms
1	=	less than 1% of lamina with symptoms (only streaks and/or up to 10 spots)
2	=	1 to 5% of lamina with symptoms
3	=	6 to 15% of lamina with symptoms
4	=	16 to 33% of lamina with symptoms
5	=	34 to 50% of lamina with symptoms
6	=	51 to 100% of lamina with symptoms
–	=	missing leaf or dead leaf hanging down the pseudostem (when a leaf is missing or dead and hanging down the pseudostem, it should not be included in the infection index calculations).