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Evaluation of resistance in selected cocoa genotypes to the brown cocoa mirid, *Sahlbergella singularis* Haglund in Nigeria

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ABSTRACT

The use of host-plant resistance is the most economic and ecologically sound option for the control of the most important insect pest of cocoa, *Sahlbergella singularis* leaving no deleterious side effects on the produce and the environment. 44 genotypes comprising 24 hybrids and 20 clones were assessed for antixenosis whereas 25 and 28 genotypes were tested for antibiosis and tolerance, respectively. The brown cocoa mirids showed significant non-preference for genotypes T65/7xT57/22, T65/7xT9/15, P7xPa150, T53/5xN38, T53/5xT12/11, T65/35xT30/13, F3 Amazon, T86/2xT16/17, T65/7xT53/8, T86/2xT65/35, T82/27xT16/17, T9/15, T12/5, T30/13, C77, T53/8, T53/5, EET59, Pa150, UF 676, Amaz15-15, BE 10, SPEC54 and Pa107. Mirid survival (antibiosis) was lowest in EET59 (28.7%) while it ranged from 52.2 to 67.8% in genotypes BE10, Amaz15-15, SPEC54, UF 676, P7xPa150, and Pa107. The indigenous clone N38 had the highest number of lesions of 12.2 in the field while EET59, IFC-5, Playa Alta, BE10, Amaz15-15 and SPEC54 had mirid lesions of 2.7, 3.3, 5.2, 5.3, 5.5 and 5.5; respectively. However, in terms of recovery from mirid damage and dieback progression which were important parameters assessed in tolerance, Clones ICS1, EET59, BE 10, Amaz15-15, SPEC54 and Pa 102 showed highest rate of recovery from mirid damage and lowest dieback progression. Clones UF 676, C77, Pa150 and F3 Amazon also showed moderate recovery from mirid damage with mean scores of 1.2, 2.3, 1.6, 1.4, 1.7, 1.4 and 1.5, respectively. UF 676, C77, Pa150 and F3 Amazon performed moderately well in terms of tolerance. Some of these genotypes such as BE10, Amaz15-15, SPEC54, UF 676, P7xPa150, and Pa107 were very consistent in all mechanisms of resistance tested and therefore adjudged as resistant cocoa genotypes.

1. Introduction

Cultivation of cocoa (*Theobroma cacao* Linnaeus) dates back to 1874 when a local Chief (Squiss Ibaningo) established a plantation at Bonny in the Eastern region of Nigeria. In 1887, the government sent seedlings from the old botanical garden at Ebute-meta (Lagos) up country (Ibadan) for trials. This explains why cacao cultivation gained its first impetus around Ibadan and the western states of Nigeria (Opeke, 1992). Nigeria reported her first cocoa export in 1900 (Opeke, 1992). Nigeria's cocoa production continued to soar and by 1965, it had become the second largest producer in the world with an annual output of about 270,000 tonnes. However, decline in production is traceable to the incidences of pests and diseases.

The brown cocoa mirid, *Sahlbergella singularis* Haglund (Hemiptera: Miridae) is the most harmful insect pest of the cocoa tree in Nigeria (Opeke, 1992). Mirid feeds by inserting its mouthparts into the plant and sucking the juices and at the same time, salivary secretions are injected into the tissue which results in plasmolysis of the cells.

This cellular lysis results in necrosis, followed by the appearance of depressed oily spots known as lesions on the cocoa pods and chupons (Mariau, 1999). Lesions are circular on pods but oval and of somewhat greater size on stems (Wood and Lass, 1989). Canker sores develop quickly from lesions due to invasion by cryptogamous parasites causing weakness. The combination of tissue necrosis and cryptogamic attack results in wilting of the plant, leading to very low productivity (Mariau, 1999). The brown cocoa mirid, *S. singularis* is the prevalent insect pest in the cocoa belt of Nigeria and yield loss of about 30–70% has been attributed to mirid infestation and damage (Idowu, 1989, Ojelade et al., 2005). Yield loss could be as high as 75% in cocoa farms attacked by the mirids

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and which are left unattended for a period of three years and above (Padi, 1997).

Part of the objectives of the cocoa improvement program at the Cocoa Research Institute of Nigeria is breeding for higher yield, good quality and resistance to pests and diseases. Hitherto, screening for mirid resistance had been at the lowest ebb until recently when dieback incidence started assuming significant dimension in both budded and grafted cocoa, especially at the nursery stage, at the Cocoa Research Institute of Nigeria, Ibadan (Aikpokpodion Pers. Comms., 2004).

The control of this obnoxious insect pest has been limited to the use of insecticides. However, concerns over chemical residues in the cocoa bean coupled with the recent ban on the use of certain available pesticides among other factors, dictate that alternative control measures which are safe and ecologically friendly be investigated. The use of resistant varieties as an option for the control of economically important insect pest species will be cheap and affordable to the poor resource farmers as well as being ecologically sound. The Federal Government of Nigeria through the National Cocoa Development Committee in conjunction with other stakeholders such as CRIN is establishing Cocoa seed gardens in the cocoa growing communities in Nigeria. This will facilitate accessibility and easy adoption of resistant and improved cocoa cultivars by the farmers. It is against this background that three mechanisms of resistance viz: antixenosis, antibiosis and tolerance were tested on selected cocoa genotypes for resistance to the brown cocoa mirid, *S. singularis* in Ibadan, Nigeria.

Table 1
List and key of cocoa genotypes (Hybrids and Clones) evaluated for resistance to *S. singularis*.

S/N	Hybrids	S/N	International clones	S/N	Local clones
1.	T65/7xT57/22	1.	EET59	1.	T9/15
2.	T12/11xN38	2.	VEN-C4	2.	T65/7
3.	T65/7xT9/15	3.	Pa150	3.	T12/11
4.	Pa150xT60/887	4.	UF 676	4.	T16/17
5.	P7xT60/887	5.	Amaz15-15	5.	T12/5
6.	P7xPa150	6.	BE 10	6.	T30/13
7.	T65/7xT22/28	7.	SPEC54	7.	C77
8.	T53/5xN38	8.	T85/799	8.	T53/8
9.	T65/7xN38	9.	Mocorongo	9.	T53/5
10.	T53/5xT12/11	10.	Pa 102	10.	N38
11.	T65/35xT30/13				
12.	T86/2xT9/15				
13.	T9/15xT57/22				
14.	F3 Amazon				
15.	T86/2xT22/28				
16.	T82/27xT12/11				
17.	T86/2xT16/17				
18.	T65/7xT53/8				
19.	T65/7xT101/15				
20.	T86/2xT53/8				
21.	T86/2xT65/35				
22.	T101/15xN38				
23.	T82/27xT16/17				
24.	T86/2xT57/22				

N38 was used as control and is the same as genotypes 25, 26 and 27 used in this study.

2. Materials and methods

2.1. Study site

The study was carried out at the Cocoa Research Institute of Nigeria (CRIN) Headquarters in Ibadan, Nigeria. Ibadan has an annual average rainfall of 2000 mm with a bimodal pattern. It is located in the tropical rain forest ecosystem with mean solar radiation of 18mj/m^2/day. It lies between the latitude 7° 30′ N and longitude 3° 54′ E at an altitude of 200 m above sea level. The International Clonal Trial Plot was established in year 2001 on a land area of 1 hectare. A total of 10 clonal materials were observed with each of three stands replicated in three blocks ($10 \times 3 \times 3$), giving a total of 90 plants. The experimental design was Randomized Complete Block. The Local Clonal Trial Plot contained 10 clonal materials established in year 2000 on a land area of 0.6 hectare. Three stands of each line were tagged and selected per block and the land was divided into three blocks ($10 \times 3 \times 3$), giving a total of 90 plants. The Hybrid Trial Plot contained 24 hybrids established in year 2000 on a land area of 2 hectares planted at a spacing of 3.0 m $\times$ 3.0 m. Each hybrid was planted in 4 blocks of 10 plant variety per block. Three stands of the same line were randomly selected and tagged per block ($24 \times 3 \times 4$), giving a total of 288 plants. Laboratory experiments were conducted at the Entomology Division Laboratory of CRIN under ambient conditions of 27 ± 2 °C temperature and 80 ± 5% relative humidity.

2.2. Antixenosis

This study was carried out to assess the ability of selected cocoa genotypes to attract or repel mirid attack in the laboratory. The list of genotypes tested for antixenosis is presented in Table 1.

2.2.1. Laboratory microtest for antixenosis

Day old adult mirids were collected carefully very early in the day using a haemolysis tube and a camel hairbrush from the culture. After collection, the insects were allowed to rest and left unfed overnight to encourage their feeding on the plant materials to be provided during the experiment the following day.

Green twigs of expanded young flushes (about two weeks old) were used for the test. These twigs were cut into 50 mm lengths. Twigs of the same diameter were used and laid out in triangles that can fit into one Petri dish (Plate 1). The twigs were stapled together and each side of the triangle consisted of a different cocoa genotype. Each genotype was replicated 20 times in a Completely Randomized Design. Five replicates of each of the series were carried out on the same day and repeated four times until all the 20 replicates were tested. The Petri dishes were checked 24 h later for mirid feeding punctures, which were easily recognized through the dark patches left at the feeding sites on the cut twigs from the different genotypes. An analysis of variance was carried out to classify the genotypes in increasing or decreasing order of attractiveness.

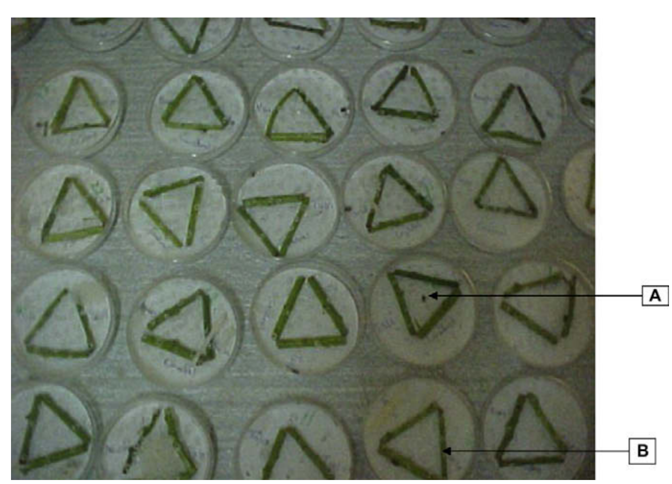

Plate. 1. Laboratory microtest for antixenosis of cocoa genotype. A=mirid position at introduction, B=cocoa genotype twig.

2.3. Antibiosis

This study assessed mirid survival and development on selected cocoa genotypes in the field.

2.3.1. Evaluation of selected cocoa genotypes for antibiosis to S. singularis *in the field*

The objective of this study was to assess the survival and development of cocoa mirids on selected cocoa genotypes in the field. The materials evaluated were 25 cocoa genotypes which included six local clones, seven international clones and twelve hybrids. A no choice test was used to assess the survival of mirids on these genotypes in a randomized complete block design. Second-instar nymphs were collected from the stock culture of mirids reared in the entomology laboratory. A muslin/mesh sleeve cage measuring 170 cm by 30 cm was used to confine two second-instar nymphs on a mature green pod in the field. Both ends of the cage were securely tied to prevent the insects from escaping. Grease was applied at both ends of the branch holding the pod to prevent ants from attacking the mirids in the sleeve cage. There were five replicates per genotype giving a total of ten mirids being assessed per genotype. The mortality of the nymphs was recorded every two days to assess mirid survival on the different genotypes.

2.4. Tolerance

This study assessed the ability of selected cocoa genotypes to withstand or recover from mirid damage.

2.4.1. Evaluation of selected cocoa genotypes for tolerance to S. singularis *in the field*

The study was conducted on 25 genotypes with the objective of identifying cocoa genotypes capable of withstanding or recovering from mirid damage. The experiment was based on the assessment of the level of dieback of twigs and recovery from damage in response to mirid feeding punctures. The design was a randomized complete block. A sleeve cage (170 cm height $\times$ 30 cm diameter) made with muslin cloth was used to confine one day old adult mirid which must have been starved overnight on a single twig for 48 h. Five sleeves were placed on one tree and this constituted one replicate. This experimental set-up was repeated on a plant per block (three blocks in all), giving a total of 15 mirids per genotype. The insects were then removed after 48 h but the sleeves were left on the field to prevent damage to the twigs by other insect pests. The physiological reaction of the shoot was observed weekly for three months. Each genotype was also wounded mechanically with the aid of a pin (10 punctures per plant twig on each internode, $n = 10$) to serve as control. The following data were recorded:

(i) The physiological reaction of the twigs once a week during the first month and monthly thereafter for three months. A 5-point scale was used with 0 = completely healthy twigs to 4 = dead twigs.
(ii) The length of progression of dieback of twigs of each genotype was measured with the aid of a measuring tape.

All data obtained were subjected to analysis of variance and means separated using the Tukeys' Honestly Significant difference at 5% probability.

3. Results

3.1. Antixenosis

Fig. 1 shows the result of antixenosis on twenty-four hybrid genotypes while the hybrid tagged 25 served as control (N38). Hybrids with mean feeding points of less than two were adjudged to be least attractive to the brown cocoa mirid. These hybrids were 1, 3, 6, 8, 10, 11, 14, 17, 18, 21 and 23 which corresponds to T65/7xT57/22, T65/7xT9/15, P7xPa150, T53/5xN38, T53/5xT12/11, T65/35xT30/13, F3 Amazon, T86/2xT16/17, T65/7xT53/8, T86/2xT65/35 and T82/27xT16/17, respectively. Antixenosis results showed hybrid 17 (T86/2xT16/17) to be the least attractive with a mean feeding point of 0.36 ± 0.36 whereas the most attractive genotype was hybrid 24 (T86/2xT57/22) with a mean feeding point of 4.79 ± 1.41.

The result of antixenosis on local clones is presented in Fig. 2. Among the ten selected genotypes tested, clone 1 (T9/15) had no mirid bite on any of its twig 24 h after mirid introduction on twigs. Genotypes 5, 6, 7, 8 and 9 which correspond to T12/5, T30/13, C77, T53/8 and T53/5, respectively were equally least attractive to mirid with mean feeding points of 0.67 ± 0.58, 1.17 ± 0.66, 1.25 ± 1.08, 0.08 ± 0.10 and 0.92 ± 0.75, respectively. Genotype 26 was the N38 control that gave a mean feeding point of 2.3.

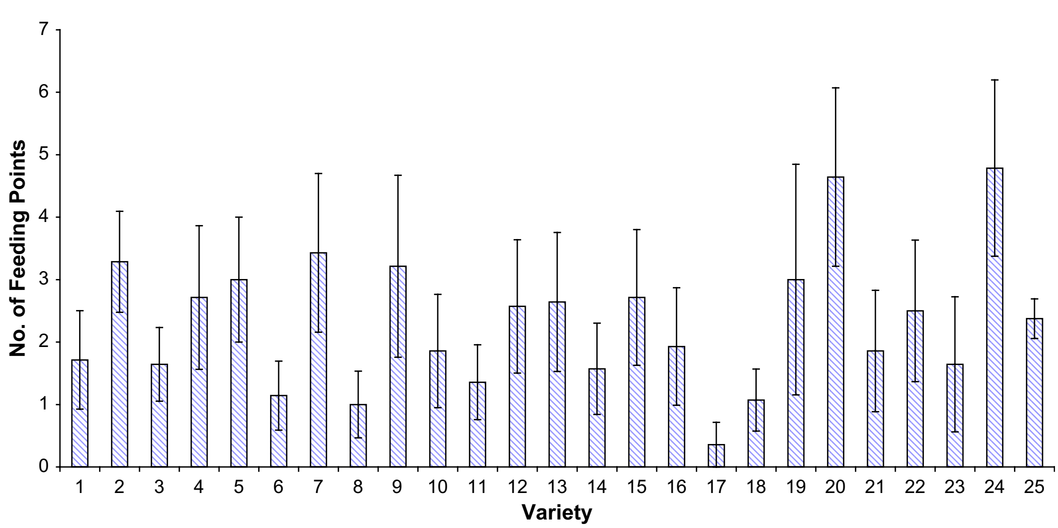

Fig. 1. Antixenosis test on cocoa hybrid twigs.

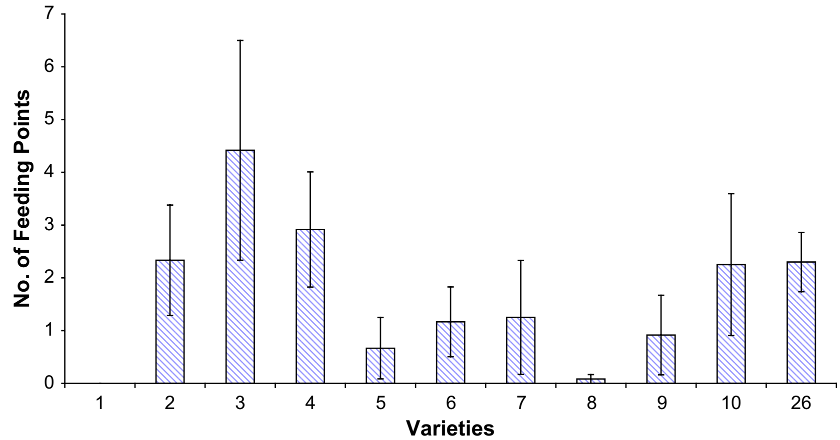

Fig. 2. Antixenosis tests on local clone twigs.

Fig. 3 shows the result of antixenosis on ten selected international clones in the laboratory. Clones tagged 1, 3, 4, 5, 6, 7 and 10 corresponding to genotypes EET59, Pa150, UF 676, Amaz15-15, BE 10, SPEC54 and Pa 102 were least attractive to mirids in the laboratory with a range of feeding points of 0.17–1.08. SPEC54 had the least mean of 0.17 ± 0.11 whereas Mocorongo (tagged 9) was the most attractive genotype with mean feeding points of 3.67 ± 1.35.

The results of antixenosis on the genotypes coupled with the result of earlier field screening of the 44 genotypes assessed informed the choice of genotypes selected for antibiosis and tolerance tests.

3.2. Antibiosis

25 genotypes were tested in all (Table 2) with outstanding results from the international clones. EET59 was the best genotype in terms of antibiosis with only 28.7% of mirid survival from second instar to adult. There were significant differences among the genotypes with respect to mirid survival on cocoa twigs using the Tukey's Studentized Range Test (HSD) at $P = 0.05$. BE 10, Amaz15-15, SPEC54, UF 676, P7xPa150, and Pa 102 gave survival means of 52.2%, 54.5%, 54.5%, 56.8%, 61.2% and 67.8%, respectively showing varying degrees of antibiosis. On the contrary, N38, T65/7xT53/8 and T9/15 supported mirid growth and development to adult stage by 100%.

3.3. Tolerance

There was a relatively large overlapping groups of significance using the Tukey's Studentized Range Test (HSD) at $P = 0.05$. 28 genotypes were assessed for their ability to withstand attack by the brown cocoa mirid, *S. singularis*. Three additional genotypes later assessed for tolerance were IFC-5, Playa Alta and ICS1. Table 3 shows the parameters tested in terms of tolerance which includes recovery ability of twigs and progression of dieback on twigs. In this study, tolerance to cocoa mirid was based on assessment of the reaction of the cocoa plant to attacks. 48 h after the introduction of mirids to selected cocoa twigs, twigs from genotypes EET59, IFC-5, Playa Alta, BE 10, Amaz15-15 and SPEC54 had mirid lesions of 2.7, 3.3, 5.2, 5.3, 5.5 and 5.5, respectively. The indigenous clone N38 had the highest number of lesions of 12.2. The scoring from healthy to dead twig showed that ICS1, EET59, BE 10, Amaz15-15, SPEC54 and Pa 102 did excellently well with mean scores of 1.2, 2.3, 1.6, 1.4, 1.7, 1.4 and 1.5, respectively. Twigs from genotypes N38, T30/13, T53/8 and T65/7xT9/15 could barely hardly recover from mirid attacks (Table 3).

Dieback progression from pin punctures and mirid stylets showed that Pa 102, SPEC54, Amaz15-15 had very low dieback progression. For instance, Pa 102 had mean lengths of dieback of 1.2 mm from pin punctures and 3.2 mm from mirid attack (Table 3) and is therefore adjudged the best genotype to slow down dieback.

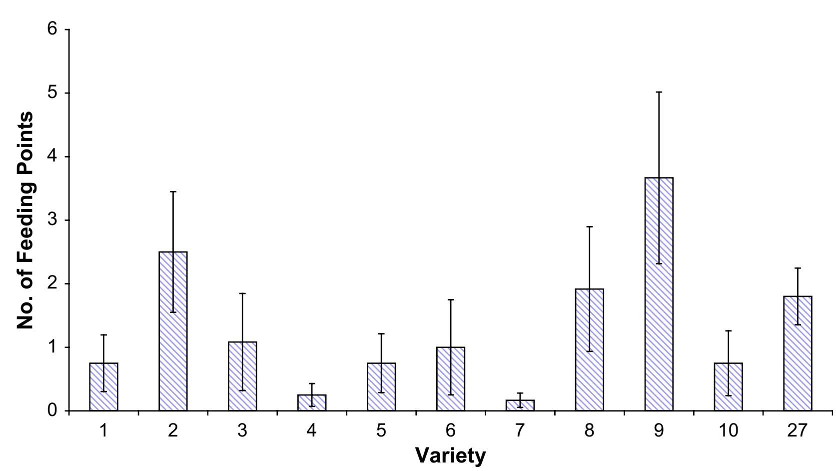

Fig. 3. Antixenosis test on international cocoa twigs.

Table 2
Survival of mirid nymphs on cocoa twigs of selected cocoa genotypes.

Assertions	Survival rate	Mean grouping
N38	100	a
T65/7xT53/8	100	a
T9/15	100	a
T53/5xN38	98.90	a
T30/13	98.90	a
T65/35xT30/15	98.90	a
T12/5	97.80	a
T53/8	97.80	a
T82/27xT16/17	97.80	a
T86/2xT65/35	96.70	a
T86/2xT16/17	95.60	a
T65/7xT9/15	94.50	a
T53/5xT12/11	94.30	a
F3 Amazon	92.30	a
T65/7xT57/22	92.30	a
C77	92.30	a
T82/27xT12/11	91.20	a
Pa150	78.90	ab
Pa102	67.80	bc
P7xPa150	61.20	bc
UF676	56.80	c
SPEC54	54.50	c
Amaz15	54.50	c
BE10	52.20	c
EET59	28.70	d

Means followed by the same letter in the same column are not significantly different ($P > 0.05$).
Tukey's Studentized Range (HSD) Test.

Genotype T65/7xT53/8 had the worst result in terms of tolerance with mean lengths of 9.6 mm and 8.1 mm from mirid attack and pin punctures, respectively. UF 676 which performed very well in terms of antixenosis and antibiosis showed a relatively moderate result in terms of tolerance. This was equally true for genotypes C77, 150 and F3 Amazon.

Table 3
Mirid feeding lesions, recovery from fresh mirid feeding lesions and progression of dieback from mirid lesions and from mechanical wounding.

Lines	Feeding lesions	Recovery rate	Dieback progression (mm)	
			Mirid	Pin
N38	12.2a	3.6a	8.4abcd	7.3abc
T65/7xT53/8	9.9abcd	2.8abcd	9.6a	8.1a
T9/15	10.3abc	3.1abc	9.0ab	7.3abc
T53/5xN38	10.2abc	3.2abc	7.8abcde	7.7ab
T30/13	10.7abc	3.4ab	6.7bcdef	6.0abcde
T65/35xT30/15	9.9abcd	2.9abc	7.8abcde	6.9abcd
T12/5	10.5abc	2.5abcdef	8.6abcd	7.3abc
T53/8	11.0ab	3.5a	8.7abc	7.3abc
T82/27xT16/17	10.5abc	3.2abc	9.0ab	8.0a
T86/2xT65/35	10.0abc	3.2abc	8.8ab	7.5ab
T86/2xT16/17	10.1abc	3.0abc	9.1ab	8.2a
T65/7xT9/15	9.6abcd	3.4ab	8.8ab	7.8ab
T53/5xT12/11	9.8abcd	2.5abcdef	8.0abcde	7.1abcd
F3 Amazon	9.8abcd	2.6abcde	5.9defgh	5.4bcdef
T65/7xT57/22	10.0abc	3.0abc	8.9ab	8.1a
C77	9.6abcd	2.6abcde	4.4fghi	3.6efgh
T82/27xT12/11	9.0bcd	3.0abc	7.4abcde	6.9abcd
Pa150	8.0bcde	2.2cdefg	6.0cdefg	3.7efg
Pa102	6.8de	1.5efg	3.2hi	1.2h
P7xPa150	7.8cde	2.3bcdefg	5.6efgh	4.1ef
UF676	5.8ef	2.3bcdefg	4.3fghi	3.7efg
SPEC54	5.5ef	1.4fg	2.8i	3.0fgh
Amaz15	5.5ef	1.7defg	2.8i	1.6gh
BE10	5.3ef	1.4fg	3.4ghi	4.7def
EET59	2.7f	1.4fg	5.6efgh	5.0cdef
IFC-5	3.3f	1.6efg	3.7ghi	4.1ef
PLAYA	5.2ef	2.3bcdefg	4.4fghi	3.9efg
ICS1	6.8de	1.2g	5.6efgh	4.8def

Means followed by the same letter in the same column are not significantly different ($P > 0.05$).
Tukey's Studentized Range (HSD) Test.

4. Discussion

The use of resistant varieties is one of the most effective tools for reducing insect damage and the three well known mechanisms of plant defense to insect damage have been tested. Similar work carried out by N'Guessan et al. (2004) in Cote d'Ivoire showed genotypes T79/501, UPA134, ICS60, UPA409, PA150, IMC57, IFC14, N38, R15, IFC6, IFC15, IFC5 as well as international clones such as Playa Alta 2, Pa107, and EET59 among others as being antixenotic. The results obtained in terms of antixenosis in this present study is partly in consonance with those obtained by N'Guessan et al. (2004) in which EET59, Pa150, UF 676, Amaz15-15, BE 10, SPEC54 and Pa 102 (international clones) and some hybrid crosses showed lower number of lesions. However, not all the genotypes tested in Cote d'Ivoire were assessed in this study in Nigeria. The result of antixenosis also agrees with Sounigo et al. (1993) who found T79/501 and Pa150 based on cumulative damage observed in the field.

Genotypes BE10, Amaz15-15, SPEC54, UF 676, P7xPa150, and Pa 102 which did very well in antixenosis were also found to have low survival of mirid nymphs. Although the causes of antibiosis have not been investigated in this study, previous works on other crops have attributed antibiosis to either presence of toxins or growth inhibitors in the plant (Smith, 1989).

The ability of the cocoa twigs to recover from mirid attack was an important parameter measured for tolerance. Genotypes ICS1, EET59, BE 10, Amaz15-15, SPEC54 and Pa 102 had good recovery rates and at the same time, had low levels of dieback. Also some genotypes with high mirid lesions, low dieback and good rate of recovery such as UF 676, C77, 150 and F3 Amazon were described as tolerant. The implication of this is that they will be able to maintain more flower cushions and yield better in the field than genotypes with low tolerance. The result of this study is in consonance with that of Babin et al. (2004) who found out that UF 676 and IMC 60 showed the best ability to contain the degree of damage, while PLAYA ALTA 2, ICS 1 and UF 676 were the best clones in terms of ability to recover from mirid damage in Cameroon.

There is no doubt this work has brought out some cocoa genotypes showing consistency in all mechanisms of resistance tested. Host-plant resistance is the inherited ability of a plant species to ward off or resist attack by pests or to be able to tolerate damage caused by pests. Resistant varieties are one of the important components of pest management and can easily be combined with other control methods. In the field, however, crop resistance to insect pests and diseases can eventually break down. Therefore, cocoa plant resistance breeding programmes should be continuous in order to select new varieties to replace older ones.

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References

Babin, R., Sounigo, O., Dibog, L., Nyassé, S., 2004. Ingenic Newsletter (9), 45–50.
Idowu, O.L., 1989. Control of economic insect pests of cocoa. In: Progress in Tree Crop Research, second ed. CRIN, Ibadan, Nigeria, pp. 152–165.
Mariau, D. (Ed.), 1999. Integrated Pest Management of Tropical Perennial Crops. Science Publishers, Inc., USA, p. 167.
N'Guessan, K.F., N'Goran, J.A.K., Eskes, A.B., 2004. Mirid resistance studies in Cote d'Ivoire: assessment of antixenosis, antibiosis and tolerance. In: Eskes, A.B.,

Efron, Y. (Eds.), Global Aproaches to Cocoa Germplasm Utilization and Conservation, pp. 177–186.
Ojelade, K.T.M., Anikwe, J.C., Idowu, O.L., 2005. Comparative evaluation of miricidal efficacy of some insecticides for the control of the brown cocoa mirid *Sahlbergella singularis i*n Nigeria. Journal of Applied Tropical Agriculture 10, 46–53.
Opeke, L.K. (Ed.), 1992. Tropical Tree Crops. Spectrum Books LTD, Ibadan. Nigeria, pp. 95–96.
Padi, B., 1997. Prospects for the control of cocoa capsids – alternatives to chemical control. In: Proc 1st Int. Cocoa Pests and Diseases Seminar, 6–10 November 1995, Accra, Ghana, pp. 28–36.
Smith, C.M., 1989. Plant Resistance to Insects, a Fundamental Approach. John Wiley and Sons, New York, Chichester, Brisbane, Toronto, Singapore. 286pp.
Sounigo, O., N'Goran, J., Coulibaly, N., Clément, D., Lachenaud, P., 1993. Evaluation de clones de cacaoyers pour la productivité, la résistance aux mirides et la résistance a la pourriture des cabosses. In: Proceedings of the 11th International Cocoa Conference, 18–24 July, 1993. Yamoussoukro, Cote d'Ivoire. Cocoa Producers' Alliance, Lagos, Nigeria, pp. 375–381.
Wood, G.A.R., Lass, R.A. (Eds.), 1989. Cocoa: Tropical Agricultural Series. John Wiley and Sons. Inc., New York, pp. 265–383.