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Evaluation of performance and resistance of banana and plantain hybrids to black leaf streak disease under organic fertilization in southern Côte d 'Ivoire

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SUMMARY
Response to black leaf streak disease and agronomic performances were compared in hybrids of bananas (FHIA 23, FHIA 25, BITA 3 and of plantain (FHIA 21 and CRBP 39). Local references were Grand Naine (banana) and Orishele (plantain). Investigation was conducted in Azaguie district (southern Côte d'Ivoire). The soil of the plots was covered with cocoa waste and no chemical was applied. Pathological parameters (youngest leaf spotted, youngest leaf necrosed, infection index) were evaluated weekly and agronomic parameters (time from planting to flowering, time from planting to harvest, bunch weight, number of hands, number and grade of fingers) were assessed. Hybrids showed higher resistance to Black leaf streak disease than local cultivars. The ranks of young leaves with necrosis were up to 7 for hybrids BITA 3 (7.10) and CRBP 39 (10.3) while youngest leaves with necrosis were rank 5 for the local cultivar. Leaves of hybrid FHIA 25 showed no symptom of black leaf streak disease throughout the growth period, which indicates that FHIA 25 is highly resistant. At the emergence of the inflorescence and at harvest time, the number of leaves on hybrid banana cultivars was higher than that on the local cultivars. Three levels of BLSD infection index were observed: weak level, CRBP 39 (10.8%); average level, FHIA 21 (33.3), BITA 3 (23.7); FHIA 23 (29) and high level Grand Nain (57.4), and Orishele (47.5). Marketable weight data were highest for the hybrids FHIA 25 (68t/ha) and FHIA 21 (45t/ha). Hybrid BITA 3 yielded an average of 34 t/ha and covered its whole cycle in 10 months. Hybrids FHIA 21 and BITA 3 can be distributed to farmers while FHIA 25 can be used as female parent in a breeding scheme.

2 INTRODUCTION

Three closely related Ascomycete species *Mycosphaerella musicola* Leach (*Pseudocercospora musae*), *M. fijiensis* Morelet (*Paracercospora fijiensis*) and *M. eumusae* (*Septoria eumusae*) are responsible respectively for Sigatoka disease, Black Leaf Spot Disease and Eumusae Leaf Spot disease in banana and plantain (Carlier *et al*., 2000; Jones, 2000; Crous & Mourichon, 2002). These fungi are present in the main banana production zones of the world; and the newly discovered *M. eumusae* might be present in Nigeria (Carlier *et al*., 2000). These fungi can have competition-substitution relationships, particularly *M. musicola* and *M. fijiensis.*

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The differences in varietal susceptibility could also account for cohabitation of those species in the same area. In Côte d'Ivoire, despite the presence of *M. fijiensis* for many years, *M. musicola* is still observed but preferentially on cultivars that are partially resistant to *M. fijiensis* such as "figue sucrée" (Traoré, 2008).

The pathogens induce senescence of the banana leaves in susceptible varieties, and therefore reduce the photosynthetic area, which leads to reduced fruit filling and premature ripening. The yield losses can reach 50 % (Mourichon & Fullerton, 1990).

The management of foliar diseases starts with the knowledge of the causal agents' biology and their interactions with the environment. Banana monoculture has for long been characterized by systematic application of chemical pesticides, especially of a wide range of fungicides. Nevertheless, these high input strategies of disease control are inaccessible to smallholder farmers with limited resources and whose farming systems are inappropriate for intensive fungicide applications (Craenen & Ortiz, 2002; Traoré & Kobenan, 2006). The cost of chemical pesticides and their adverse impact on the environment are very high.

The use of resistant plants is a suitable option for banana production as it reduces chemical use, and hence input costs, as well as environmental pollution.

International efforts coordinated by the International Network for Improvement of Banana and Plantain (INIBAP) began a multi locational testing of hybrids bred at FHIA, CARBAP and IITA. Côte d'Ivoire was selected to participate in the third phase of this program through CNRA. This paper presents the results of this study.

3 MATERIAL AND METHODS

3.1 Trial site: The trial started in 2003 in Azaguié district (5° 36' 03'' N; 4° 01' 50'' W, 80 m above sea level). The previous cultural practice at the trial site was organic banana production with numerous hybrids. The soil is a sandy ferralitic type and the area receives two rain seasons (April -June and September -November) with dry seasons in between. The annual rainfall is about 1500 mm.

3.2 Trial layout: Five banana and plantain hybrids (CRBP 39, FHIA 21, FHIA 23, FHIA 25, and BITA 3) were evaluated in comparison with a resistant diploid (Calcutta 4) and two susceptible cultivars (Orishele and Grande Naine) (table 1). Elementary parcels contained 6 plants of each variety and there were 4 blocs of 8 parcels. Plants were separated by 1.8 m within row and 2 m between rows. To maintain a high level of inoculum, elementary parcels were surrounded by a row of plants of cultivar Poyo, which is highly susceptible to *Mycosphaerella* diseases. During the dry seasons plants were irrigated by hosepipe for 2 hours three times weekly. An organic fertilizer of cocoa parch was applied before planting. No chemical was used.

3.3 Data recording: The number of leaves, plant height and girth were measured monthly. Weekly observations of pathological parameters began 3 months after planting. The number of leaves, the youngest leaf with symptoms, the youngest leaf spotted and dates of cigar leaf state 2 were recorded (Ganry & Laville, 1983). The severity of disease was evaluated at 6 months after planting, at flowering and at harvest and infection index (II) computed according to the modified formula of Gauhl (1994); $II = \Sigma nb \times 100 \times 100 / (N - 1) T$

Where;

N = number of leaves in each grade of the disease; b= grade (0-6); N= number of grades used in the scale, here is a constant = 7; T= total number of leaves scored.

Intervals (days) between planting, flowering and harvest were calculated. At harvest, bunch weight and characteristics of the 3rd and 7th hand were recorded.

3.4 Data analysis: Data were analysed and averages were separated with NEWMAN-KEULS test at α = 5 % level.

4 RESULTS

4.1 Agronomic data

4.1.1 Pseudostems height and girth: The growth curves had similar increase phases for all banana genotypes (Fig. 1). This trend was slightly disrupted 5 months after planting in the reference

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banana (Grande Naine) and by 6 months for BITA 3, Orishele, CRBP 39 and FHIA 25. This phenomenon took place later in FHIA 21 and FHIA 23 (fig 1). At flowering cv. Grande Naine was shorter (196 cm) than cv. BITA 3 (366 cm). After 7 months cv. FHIA 21 (346 cm) and FHIA 23 (304 cm) exceeded 300 cm before flowering. Reference cultivars Grande Naine (69 cm) and Orishele (74 cm) were thinner than the hybrids. At 6 months, hybrid FHIA 25 (114 cm) had the thickest girth (Fig 2). Two disruptions were observed in girth increase; the first was 4 months after planting and was seen only in hybrids and secondly at 5 months when the girth of cv. Grande Naine and Orishele stopped increasing. In hybrids CRBP 39 and FHIA 21 the second disruption was characterized by a slowing down of girth increase.

Table 1 : List of hybrids of bananas and plantain evaluated in Azaguie district, southern Côte d'Ivoire

Génotypes		**Code ITC**	**Origine**
1) Wild type	Calcutta 4	0249	Génotype p m
2) Banana	Grande naine	0180	Cultivar, (land race)
	BITA 3	1297	Hybride IITA
	FHIA 23	1265	Hybride FHIA
	FHIA 25	1418	Hybride FHIA
3) Plantain	Orishele	/ / /	Cultivar (land race)
	CRBP 39	1344	Hybride CARBAP
	FHIA 21	1332	Hybride FHIA

Table 2: Planting to Flowering Time (PFT), Flowering to Harvest Time (FHT) and Growth cycle (GC) of banana hybrids at Azaguié.

Varieties	FHIA 21	FHIA 23	FHIA 25	BITA 3	CRBP 39	Grande Naine
PFT	238 b	280 a	251 b	202 c	231 b	193 c
FHT	102 b	-	130 a	89 c	108 b	84 c
GC	337 a	-	352 a	290 b	341 a	289 b

4.1.2 Leaves: Number of leaves produced varied between 34 and 39. Cultivar Grande Naine (34) and hybrid FHIA 21 (39) were on the lower and upper extremes, respectively, while the others were intermediate (Fig 3). At flowering, numbers of leaves varied from 9 to 16 (table 4). Hybrid FHIA 25 had significantly more leaves (16) than cv. Grand Naine (9.7).

The susceptible plantain reference cultivar Orishele (3 leaves) had different number of leaves than hybrid FHIA 23 (10 leaves) while this number was below 10 for Grande Naine. At harvest, hybrid FHIA 25 exhibited more than 10 leaves compared to the reference cultivars Grand Naine and Orishele with about 3 leaves. Hybrid FHIA 21 and CRBP had an average of 8 leaves.

4.1.3 Days to flowering, fruit filling time and growth cycle: Days to flowering showed three homogenous groups (table 2), early flowering by 200 days (6 months after planting) for cultivars Grande Naine and BITA 3; intermediate flowering (within 8 months); and delayed flowering (after 9 months), for hybrid FHIA 23.

Growth cycle was short for cv. Grande Naine (290 days = about 9 months) and above 11 months for FHIA 21, FHIA 25 and CRBP 39. Fruit filling time varied from 84 days (cv. Grande Naine) to 130 days (hybrid FHIA 25). For all varieties fruit-filling time was about 3 months. However cv. Grande Naine was harvested before fruits were completely full because of their premature ripening following death of leaves. FHIA 23 wasn't harvested since its growth cycle is long (Kobenan *et al.*, 2001), and was longer than the period covered in this report.

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Table 3: Bunch Weight (BW), Number of Hands (NH) and Number of Fruits (NF) of banana and plantain hybrids produced under organic fertilization in southern Côte d'Ivoire.

Parameter	Banana					Plantains	
	FHIA 23	FHIA 25	BITA 3	G Naine	Orishele	FHIA 21	CRBP 39
BW (Kg)	-	45,5 a	22,5 b	17,5 b	-	30,2 a	18,8 b
NH	-	15,33 a	9 b	10,3 b	-	9,6 a	7,6 b
NF	-	272 a	136 b	183,2 b	-	149 a	112 b

Table 4: Number of Leaves at Flowering (NLF) and at Harvest (NLH) of banana hybrids at Azaguié (Côte d'Ivoire).

Varieties	NLF	NLH	YLS	YLN	II
FHIA 21	13.8 b	8.6 b	5.4 c	9.8 c	33.3 c
CRBP 39	13.3 b	7.3 c	10.3 a	11.8 a	10.8 e
FHIA 23	10.2 cd	-	4.1 e	7.1 d	29.5 c
Orishele	10.3 cd	3.8 de	4.7 d	7.5 d	47.5 b
Grand Nain	9.7 d	2.9 e	3.9 ef	5.6 e	57.4 a
BITA 3	11.0 c	5.9 c	7.1 b	10.7 b	23.7 d
FHIA 25	15.9 a	9.8 a	-	-	0.0 f

4.1.4 Bunch and fruit characteristics: Hybrid FHIA 25 had the heaviest bunch averaging 30kg (fig 4), which was nearly three times the bunch weight of the reference cultivar Grande Naine (17 kg). The average weight was 22 kg for hybrid BITA 3 which was not significantly different from the reference cultivar (table 3a). The number of hands and fruits was, respectively, 15 and 272 for hybrid FHIA 25, 9 and 136 for cv. BITA 3, and 10 and 183 for cv. Grande Naine.

Hybrid FHIA 21 produced bunches averaging 30 kg (fig. 4) while the bunch of CRBP 39 weighed 18 Kg (fig. 4. Hybrid FHIA 21 showed higher potential of production with 149 fruits and 9 hands compared to cv. CRBP 39 (112 fruits, 7 hands). Hybrid CRBP 39 was not significantly different from the reference cultivar Orishele.

At the time of emergence of the inflorescence, the number of erect leaves was ranked from 9 to 16 (Table 4). Hybrid FHIA 25 with the highest number of leaves showed a clear difference with the other varieties of banana. It was followed by the hybrid FHIA 21 with an average of 14 leaves. The susceptible plantain cultivar Orishele and hybrid FHIA 23 had the same number of leaves. The susceptible cultivar Grande Naine had less than 10 leaves.

At the time of harvest, the number of remaining leaves on hybrid FHIA 25 was 10 leaves while the cultivar Grand Naine had 3 leaves. Hybrids of banana plantain FHIA 21 and CRBP 39 were an average of 8.6 and 7.3.

4.2 Pathological parameters

Significant differences were observed between bananas for the number of young leaves with streak. CRBP 39 and BITA 3 had the highest number of leaf with streak. Generally, cv. CRBP 39, FHIA 21 and Orishele had higher number than the desert banana, FHIA 23 and Grand Naine.

Regarding the youngest leaf with necrosis, the highest number was observed for CRBP 39, BITA 3 and FHIA 21. Cultivar Grand Naine was susceptible with an average rank inferior to 6.

The average index of infection on hybrid FHIA 25 was zero as there were no symptoms on the leaves of this cultivar. The average index of infection was weak for the hybrids CRBP 39 (10.8 %) and it was at the medium for the hybrids FHIA 21, FHIA 23 and BITA 3 (Table 4). The susceptibility of the reference cultivar Orishele was marked by higher value of the infection index, 48 %.

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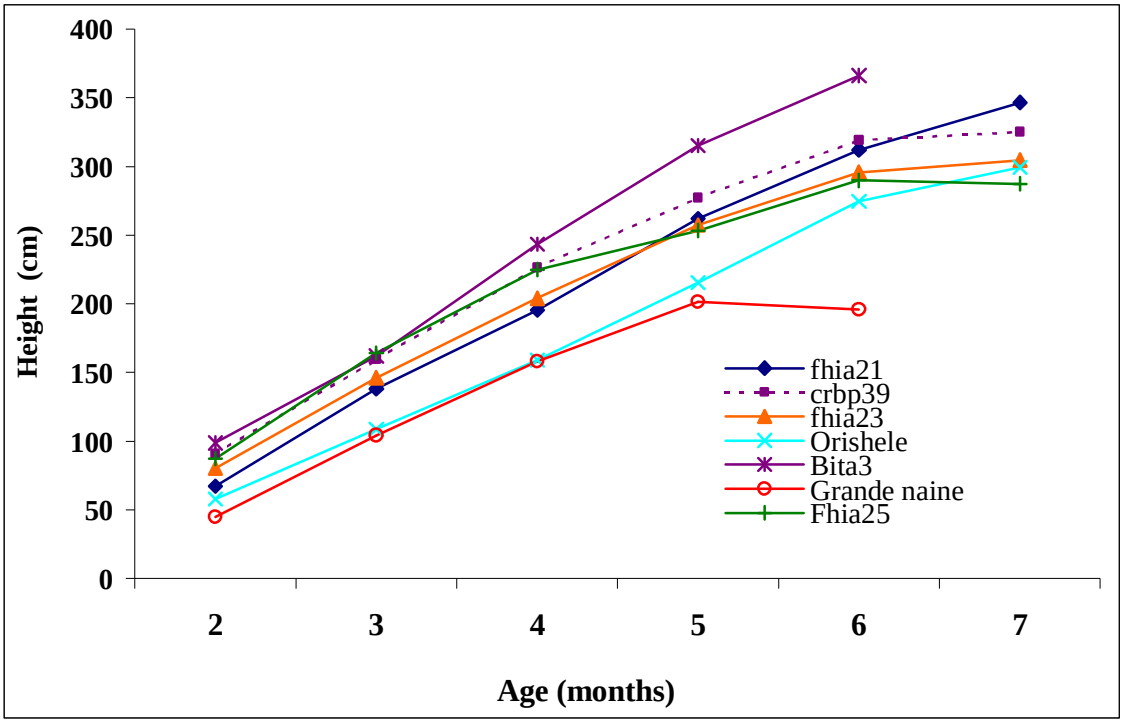

Figure 1: Evolution of pseudostem height of banana and plantain hybrids; IMTPIII-INIBAP (south of Côte d'Ivoire)

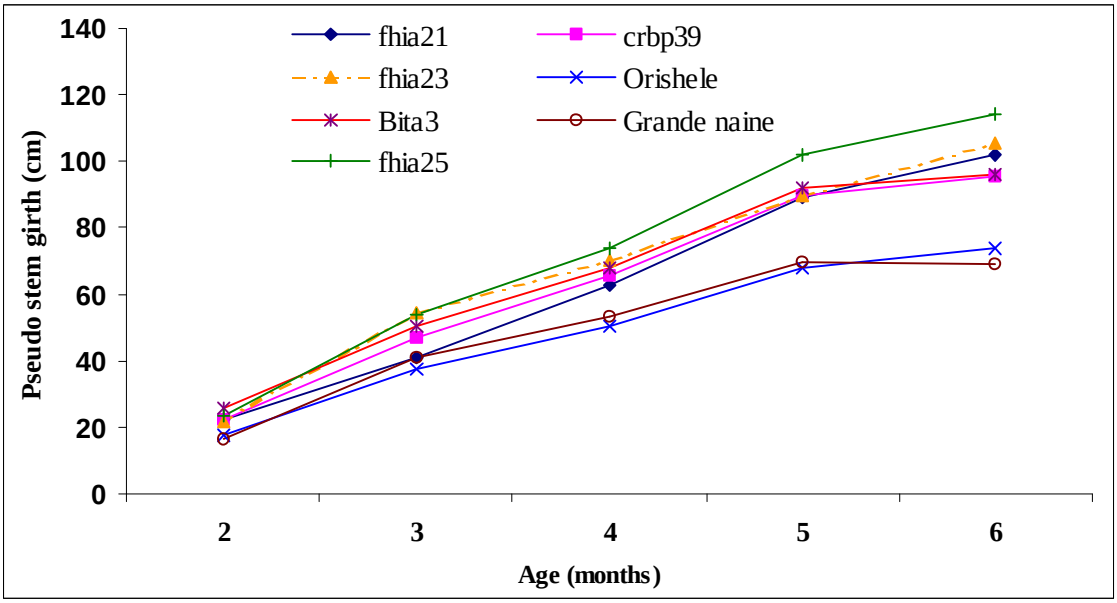

Figure 2: Evolution of pseudo stem girth of banana and plantain hybrids; IMTPIII-INIBAP (south of Côte d'Ivoire).

5 DISCUSSION

The results showed the hybrids have higher resistance to the black leaf streak disease compared to the local checks. For the most susceptible cultivars, such as Grand Naine and Orishele, young leaf with symptoms averaged between 3 and 4. Young symptoms were some times observed on

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leaves in rank 2 when humidity was high, which favoured high pathogen pressure. Brun (1963), Vakili (1968), Meredith & Lawrence (1970) and Fouré *et al.* (1990) have observed young leaves with symptoms at rank 4, 6, 7 and 9. This difference can be related to environmental factors, the disease pressure and strains. Symptoms development until necrosis is fast for cv. Grand Naine, the rate of sexual sporulation can be high and the number of functional leaves at harvest is reduced.

Partial resistance or tolerance of cultivar FHIA 21 and FHIA 23 to Sigatoka disease is characterized by a freezing of symptom development on the leaves 3 to 6. A lot of small streaks were observed on the upper surface of the leaves. Results obtained were similar to those of Fouré *et al.* (1990) on cultivar Pisang Ceylan (sub-group Mysore, AAB). Disease evolution to necrosis stage is slow and could be related to a moderated spores' production rate. Their number of leaves at harvest time is not drastically reduced.

Similar observations have been reported in Cameroun (Napoudja & Tomekpe, 1999; Cohan *et al.*, 2003) and Ghana (Dzomeku *et al.*, 2000). Clear resistances with higher number of leaves have been determined in hybrids BITA 3, PITA 14, FHIA 21 and CRBP 39 compared to reference cultivars. Hybrid FHIA 23 has also been studied in Central America and is reported to have 3 to 4 functional leaves at harvest time (Orellana *et al.*, 2002; John & Manuel, 2003; Molina & Castaño-Zapata, 2003). In this work, the results seem better particularly for hybrid FHIA 21 which had an average of 7 functional leaves at harvest time, as previously reported in Ghana (Dzomeku *et al.*, 2000). These results suggest that hybrid FHIA 21 is more resistant in Africa than in South America. Hybrid CRBP 39 showed the same response as in Cameroon where it had an average of 13 leaves at the emergence of bunch and at harvest time (Cohan *et al.*, 2003).

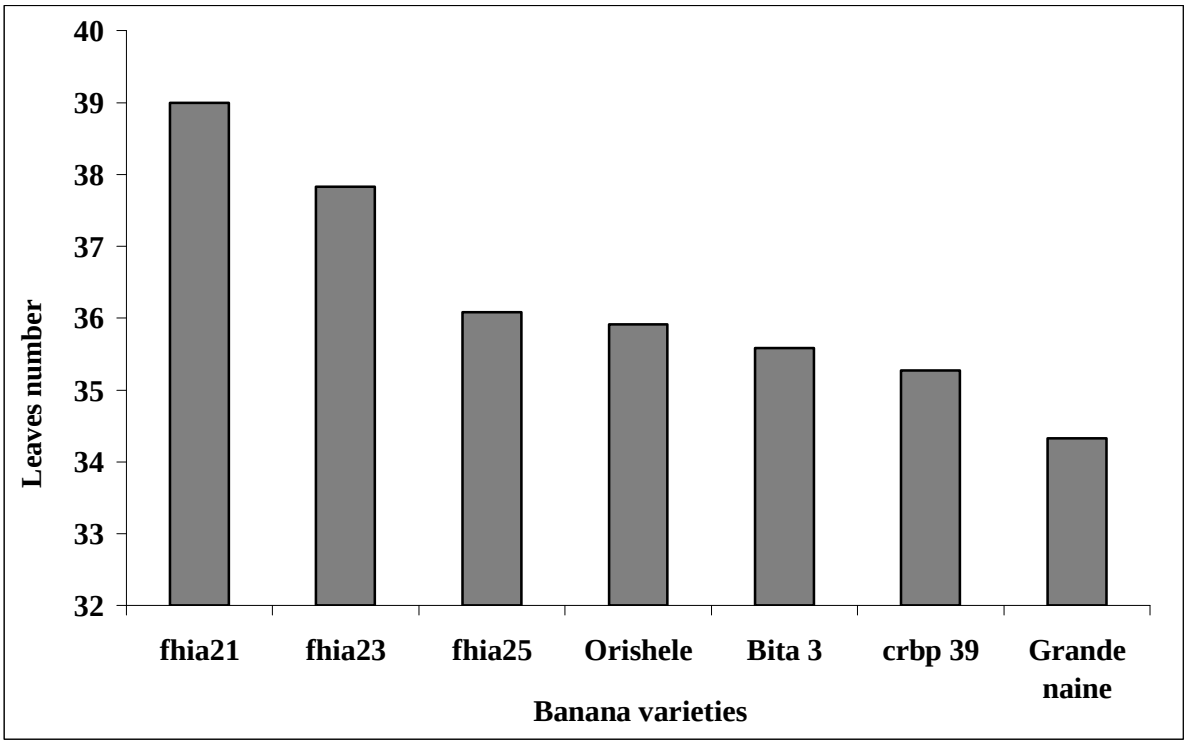

Figure 3: Number of leaves produced by banana and plantain hybrids; IMTPIII-INIBAP (south of Côte d'Ivoire).

Cultivar of banana showed higher susceptibility compared to plantain, especially on two parameters of disease development time and average infection index. Banana CRBP 39 and FHIA 25 presented a high resistance level to Sigatoka disease with a very weak average index for CRBP 39 and nil for FHIA

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25. The weak rate (21 %) of diseased plants for the hybrid CRBP 39 could be due to genotype variation or the presence of a very or seldom pathogenic strain.

Hybrids produced more than the reference cultivars with the hybrid cooking plantain FHIA 25 being the best. This hybrid had more than 45 kg of bunch and was followed by FHIA 21 with 30 kg. These weights are significantly higher than that of the reference plantain cultivar Orishele (18.4 Kg). This observation is related to the number of functional leaves (more than 10 leaves) at the time of bunch emergence whereas 8 leaves are necessary for the fruits to fill out well.

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Figure 4: Bunch of FHIA 25 (45 kg, left), FHIA 21 (30 kg, middle) and CRBP 39 (18 kg, right).

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