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Growth, yield and Fusarium wilt resistance of six FHIA tetraploid bananas (*Musa* spp.) grown in the Australian subtropics

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ABSTRACT

Six tetraploid hybrids from Fundación Hondureña de Investigación Agrícola (FHIA) were evaluated in Australia over a five year period. They included three AAAA hybrids (FHIA-02, FHIA-17 and FHIA-23) and three AAAB hybrids (FHIA-01, FHIA-18 and SH-3640.10) and they were compared with industry standards, 'Williams' (AAA, Cavendish subgroup) and 'Lady Finger' (AAB, Pome subgroup). They were screened for their resistance to Fusarium wilt race 1 and subtropical race 4 caused by the pathogen *Fusarium oxysporum* f.sp. *cubense* and they were also grown for several cycles on farms not infested with Fusarium wilt to record their agronomic characteristics. The AAAB hybrids, all derived from female parent 'Prata Anã' (AAB, Pome subgroup) were the most resistant to both races of Fusarium wilt and were very productive in the subtropics. They were significantly more productive than 'Lady Finger', which was susceptible to both races of Fusarium wilt. The AAAA hybrids, with the exception of FHIA-02 which was very susceptible to Fusarium wilt and displayed the poorest agronomic traits of the six hybrids, produced bunch weights as good as Cavendish but were significantly slower to cycle. FHIA-17 and FHIA-23, both derived from the female parent 'Highgate' (AAA, Gros Michel subgroup), were also significantly more resistant to Fusarium wilt than 'Gros Michel', while FHIA-17 demonstrated a level of resistance similar to 'Williams' and FHIA-23 was intermediate between 'Lady Finger' and 'Williams'.

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1. Introduction

Rowe and Rosales (1994) stated that the objectives of the Fundación Hondureña de Investigación Agrícola (FHIA) breeding program were to develop productive dwarf dessert banana, plantain and cooking banana hybrids with resistance to black Sigatoka (*Mycosphaerella fijiensis*) and race 4 of Fusarium wilt (*Fusarium oxysporum* f.sp. *cubense*). Black Sigatoka is a very destructive leaf disease of banana (Jacome et al., 2003; Cook et al., 2013) and the fungus invades the leaf tissue causing necrosis leading to loss of functional leaf area and diminished yield. Many of the FHIA tetraploid hybrids have resistance to this pathogen due to the use of elite banana diploids with resistance to *Mycosphaerella* leaf spots in their breeding program (Ortiz, 2013). Fusarium wilt, on the other hand, is a lethal disease of banana which colonizes and occludes the xylem of susceptible cultivars to cause a terminal wilt (Stover, 1972; Ploetz, 1994; Ploetz and Churchill, 2011). Unlike black Sigatoka, no effective chemical control measures are possible against Fusarium wilt, hence the emphasis on genetic resistance.

'Goldfinger' (FHIA-01), a tetraploid banana produced by FHIA, was released to the Australian industry in 1995 (Whiley, 1996). It was promoted as an apple-flavoured dessert banana with resistance to Fusarium wilt race 1 and subtropical race 4, as well as resistance to black and yellow Sigatoka (*M. fijiensis* and *M. musicola*, respectively). The study reported here was initiated during this time to provide agronomic information and an assessment of resistance to Fusarium wilt to the banana industry on a range of FHIA hybrids which could provide economic alternatives for the Australian industry standards, 'Williams' (AAA, Cavendish subgroup) or 'Lady Finger' (AAB, Pome subgroup), in those areas affected by Fusarium wilt. This work also formed a small component of a much larger International *Musa* Testing Program (IMTP) coordinated by the International Network for the Improvement of Banana and Plantain, with Australia being one of 18 countries participating in the IMTP phase II program (Jones, 1994; Orjeda, 2000). However, the results from the Australian trial sites were never presented in their entirety.

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Table 1
Description and disease resistance/susceptibility of FHIA hybrids to Fusarium wilt (*Fusarium oxysporum* f.sp. *cubense* race 1 and subtropical race 4) and black Sigatoka, *M. fijiensis*).

Hybrid	Description and synonym	R1	STR4	BS
FHIA-01	AAAB, Pome hybrid dessert type 'Goldfinger'	R	R	HR
FHIA-02	AAAA, Williams hybrid? dessert type 'Mona Lisa'	S	S	HR
FHIA-17	AAAA, Highgate hybrid dessert type	R	S	R
FHIA-18	AAAB, Pome hybrid dessert type 'Bananza'	R	R	HR
FHIA-23	AAAA, Highgate hybrid dessert type	R	S	R
SH-3640.10	AAAB, Pome hybrid dessert type 'High Noon'	R?	R	S

From Daniells and Bryde (2001). S—susceptible, R—resistant, HR—highly resistant.

Varietal observation trials were conducted in tropical north Queensland (17°38′S) at the same time on 4–10 plants for each hybrid and published in departmental reports (Daniells and Bryde, 2001; details provided in Tables 1 and 5). However this study, for the first time, gives a comprehensive account of the agronomic characteristics and Fusarium wilt resistance/susceptibility of six FHIA hybrids grown in a subtropical region of Australia.

2. Materials and methods

2.1. Plant materials

Tissue cultured material of the hybrids was kindly supplied by Fundación Hondureña de Investigación Agrícola and used to establish a field block at South Johnstone Research Station (SJRS; 17°S, 147°E). Suckers collected at SJRS from the FHIA hybrids, as well as standard reference lines, were subsequently used to re-establish tissue cultured plants. These plants were micropropagated and established in the field for experimental work when they reached a height of 20 cm in 2.5 L planter bags (Smith and Hamill, 1993).

2.2. Establishment and maintenance of field trials

The Wamuran, Queensland site (27°S, 153°E and an altitude of 380 masl) previously formed part of a commercial Cavendish plantation and was characteristic of many of the steep-land farms in subtropical areas of the eastern coast of Australia. The soil is classified as a yellow dermosol (McKenzie et al., 2004) and is a heavy clay–clay loam. The slope varied from 10° to 40° and had a north-east aspect. Two sites were free of Fusarium wilt disease (*F. oxysporum* f.sp. *cubense* or *Foc*), while another site used for disease screening was infested with a subtropical race 4 vegetative compatibility group (VCG 0120) (Moore et al., 2001).

The Cudgen, New South Wales site (28°S, 154°E and an altitude of 32 masl) was part of a commercial Lady Finger plantation before replanting with Cavendish. The soil on the near-level site was classified as a red ferrosol (McKenzie et al., 2004) and was infested with race 1 *Foc* (VCG 0124/5) (Moore et al., 2001).

A series of field trials were carried out over an extended period, commencing in November 1996 and concluding in November 1999 (Table 2). Plants were established at a density of 1680 plants/ha with a spacing of 2.5 m × 2.5 m and grown using standard commercial practices (Broadley et al., 2004). Fertilizer as N, P, K plus trace elements (Nitrophoska®) was broadcast by hand at the rate of 150–200 g per plant every 3 months and water was supplied through overhead sprinklers. Weeds were controlled by hand hoeing and detrashing to remove old necrotic leaves was performed by hand at each site every 4–6 weeks to keep stools clean. Lorsban® (chlorpyrifos 500 g/L ai.) was the only pesticide applied to the plants and was used mainly for the control of banana weevil borer (*Cosmopolites sordidus*) and was applied at the recommended rate twice yearly at the sites used to collect agronomic data.

2.3. Agronomic measurements

Blocks were visited weekly and when banana plants started bunching, pseudostem height (from the soil surface to the point of intersection of the 2 upper-most leaves) and pseudostem circumference (at 30 cm above ground) were measured. The number of green leaves was also recorded at bunching and then again at harvest. Other parameters recorded at harvest included: date, bunch weight, bunch stalk weight, number of hands, number of fingers in bunch, number of fingers in third proximal hand, and length of middle finger of the outer whorl of the third proximal hand. Productivity (t/ha/yr) was calculated as tonnes of fruit (bunch weight minus stalk weight) produced per hectare (planting density of 1680 plants) over a year. In the case of the ratoon crop data both the plant crop and the first ratoon fruit weights were combined.

2.4. Assessment of Fusarium wilt infection

Plants were judged to have external symptoms of disease if they displayed any sign of wilting, yellowing of foliage, petiole buckling or splitting of the pseudostem base. However the most definitive test was to rate plants on internal symptoms of Fusarium wilt which were recorded at or near harvest of the plant crop. Plants were removed from the soil and cut transversely through the rhizome about one-quarter of the way above the rhizome's base. The cut surface of the rhizome was rated for discolouration on a scale of 1–6 (Jones, 1994; Orjeda, 1998): (1) no vascular discolouration; (2) isolated points of vascular discolouration; (3) less than one-third of the vascular tissue discoloured; (4) one- to two-thirds of the vascular tissue discoloured; (5) greater than two-thirds of the vascular tissue discoloured; and (6) total vascular discolouration or discolouration of leaf bases or both. Samples of infected pseudostem or rhizome tissue from diseased plants were collected for analysis of vegetative compatibility group.

2.5. Experimental design and statistical analyses

A completely randomised design was used with between 6 and 9 treatments, depending on site, consisting of varieties where each variety was replicated between 13 and 29 times (one replicate was a single plant). Unequal replication for each banana hybrid and cultivar was due to differences in availability of planting material. This design was selected as recommended for banana field experiments by Orjeda (1998). For the agronomic characteristics, data was analyzed by ANOVA and tested using the significance level of $P = 0.05$. Severity of *Foc* infection was analyzed using the Kruskal–Wallis test. Incidence of Fusarium wilt was compared using generalized linear models for a binomial distribution with logit link followed, where significant, by pair-wise *t*-tests. Again testing was at $P = 0.05$.

3. Results

Four tetraploid FHIA hybrids have shown good levels of resistance to Fusarium wilt at both the race 1 and subtropical race 4 field

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