

## **Selection of a New Somaclone Cultivar 'Tai-Chiao No. 5' (AAA, Cavendish) with Resistance to Fusarium Wilt of Banana in Taiwan**

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### **Abstract**

The exploitation of somaclonal variation is an efficient approach to select improved Cavendish-type banana cultivars with superior horticultural traits and resistance to Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *cubense* race 4 (Foc race 4) in Taiwan. 'TC3-1035', an improved somaclonal variant of 'Tai-Chiao No. 3', was selected and released as a new banana cultivar 'Tai-Chiao No. 5' in 2007. It inherited the semi-dwarf status and moderate resistance to Foc race 4 of 'Tai-Chiao No. 3', but not the susceptibility to flower thrips, *Thrips hawaiiensis*, at shooting stage. It also has a higher yield potential. Under suitable field management, plant height of 'Tai-Chiao No. 5' is 2.7 m, and its fruit size, shape and yield capacity are as good as those of 'Pei-Chiao', which is the most widely planted Cavendish cultivar in Taiwan. During the 7-year consecutive evaluation trials, Fusarium wilt incidence in 'Tai-Chiao No. 5' plants was 5-25% whereas 10-50% plants were affected in 'Pei-Chiao' established in the same infested plot. This is an indication of the stable resistance of 'Tai-Chiao No. 5' to Foc race 4. With additional benefit of easy ripening and good eating quality, 'Tai-Chiao No. 5' is now well accepted, both in the local and Japanese market. Currently, a total of 0.9 million tissue-culture plantlets, about 450 ha, have been released to banana growers in Taiwan.

### **INTRODUCTION**

Banana (*Musa* spp.) is an important fruit crop in Taiwan, and the Taiwan banana industry has mainly been oriented to export to Japan (Hsiao, 1997). The most widely grown banana cultivars are of the Cavendish type, such as the Giant Cavendish 'Pei-Chiao' (AAA). Currently, the total acreage of banana crop is around 11,000 ha, and the volume of banana produced annually is around 200,000 tonnes (Chen, 2007), with 5% of the volume exported from Taiwan (less than 2% of the total volume of banana imported yearly in Japan).

The drastic decline of banana production in Taiwan is associated with several factors, such as high labour cost, typhoon damage, unstable supply to Japan and, most importantly, the epidemic of Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *cubense* (Foc) race 4, since 1967 (Su, 1986). To alleviate the impact of Fusarium wilt on the banana industry in Taiwan, management of infested 'Pei-Chiao' orchards, including rotation with paddy rice, soil amendments and the implementation of clean tissue-culture plantlets, was done but with only short-term effect (Su et al., 1986).

Mass planting of plantlets in heavily infested banana orchards could lead to the identification of different somaclonal variants. Even though most of them are off-types, some somaclonal variants show stable resistance to Foc race 4 (Hwang et al., 1988; Hwang et al., 1989; Tang and Hwang, 1994). Through recurrent selection, a somaclonal

variant 'GCTCV-215', retaining the horticultural traits of 'Pei-Chiao' and with moderate resistance to Foc race 4, was released as a commercial cultivar 'Tai-Chiao No. 1' in 1991 (Hwang et al., 1992). Due to it being prone to wind damage, having slow growth in regions with a longer cool period, succumbing to corky scab damage on the fruit peel induced by flower thrips, *Thrips hawaiiensis*, at shooting stage, and having 10% lower yield, only about 500 ha of 'Tai-Chiao No. 1' are currently still grown in Taiwan, down from 1,500 ha during 1991-1993 (Hwang and Ko, 2004). In 1998, another cultivar 'Tai-Chiao No. 3', selected from 'Tai-Chiao No. 1', characterised by its semi-dwarf status and with similar resistance reaction to Foc race 4, was extended to banana growers (Tang and Hwang, 1998). Due to its lower yield, lower adaptability during winter and sensitivity to thrips infestation, as also observed for its parent (Hwang and Ko, 2004), 'Tai-Chiao No. 3' was accepted only on a small scale.

To meet the growers' need for a Cavendish cultivar with superior traits, such as high yield, similar growth cycle, good eating quality and stable resistance to Foc race 4, a new improved banana cultivar was urgently needed. 'Formosana', directly selected from a banana orchard established with 'Pei-Chiao' and affected severely by Fusarium wilt, was evaluated and then released as a new-generation Cavendish cultivar on more than 1,500 ha again. It satisfied all banana growers' needs described above and was good for sustaining the banana industry in 2001 (Hwang and Ko, 2004). Unfortunately, since the infrastructure of Taiwan banana exported to Japan changed from only one export sector to more than 20 business units in 2005, competition for market sharing among new Taiwanese export sectors of banana in Japan, in combination with the incorrect rumour that 'Formosana' would be an inferior cultivar in the domestic market of Taiwan, lead to a very narrow acceptance of 'Formosana' banana by Japanese importers (Hsu, 2008).

To ensure the survival of the export-oriented banana industry in Taiwan, a new banana cultivar with not only superior horticultural traits similar to those of 'Pei-Chiao' but also with good resistance to Foc race 4 needs to be identified. The objective of this study was to illustrate the features of a new somaclonal variant 'TC3-1035', which was selected from 'Tai-Chiao No. 3' and released as a commercial cultivar 'Tai-Chiao No. 5' for farmers' option in 2007.

## **MATERIALS AND METHODS**

The first evaluation trial of tissue-cultured plants of 'TC3-1035' was conducted at the Taiwan Banana Research Institute Experimental farm from 1999 to 2000. Horticultural traits, such as plant height, pseudostem girth, number of fruits per hand at shooting, host reaction to Foc race 4 and bunch net weight at harvest, were recorded. Plants derived from the widely distributed 'Pei-Chiao' and established in the same field plot were used as check treatment under randomised complete block design (RCBD). Each studied cultivar had four replications, with 25 plants per replicate. The host reaction to Foc race 4 was defined as: HR - highly resistant (disease incidence <10%); MR - moderately resistant (disease incidence 10-25%); MS - moderate susceptible (disease incidence 26-50%); and HS - highly susceptible (disease incidence >50%).

During 2000-2001, another evaluation trial of 'TC3-1035' tissue-culture plants was carried out, studying resistance expression of 'TC3-1035' plants to Foc race 4, horticultural traits described above and time from planting to harvest, in five different banana plantations infested by Fusarium wilt in Kaohsiung and Pingtung counties in southern Taiwan that account for 60% of the total acreage of banana crop in Taiwan. Check cultivar and experimental design were the same as in the first evaluation trial.

The comparison of horticultural traits and resistance expression to Foc race 4 for tissue-culture plants of 'TC3-1035', 'Tai-Chiao No. 3' and 'Tai-Chiao No. 1', was carried out from 2002 to 2003. All data collected in different evaluation trials were statistically analysed by Duncan's multiple range test ( $P = 0.05$ ).

For sensory evaluation of 'TC3-1035' banana after harvest, taste quality, such as aroma, firmness and sweetness of banana pulp at colour index stage 7 (with physiological spot on the peel under 20°C storage atmosphere) was differentiated by qualified identifiers to rate each evaluated fruit quality in 2006. Each different rating of aroma was defined as: 1 = strong aroma; 2 = moderate aroma; 3 = weak aroma; 4 = without aroma. Rating for peel firmness was 1 = high; 2 = moderate; 3 = slight; 4 = low. Rating for sweetness was: 1 = high; 2 = moderate; 3 = less; 4 = low. Data collected were analysed with Grey correlation analysis. Fruit of 'Pei-Chiao' harvested from the same field and treated similar to that of 'TC3-1035' was used as check cultivar.

## **RESULTS AND DISCUSSION**

### **Evaluation of Horticultural Traits and Host Reaction of 'TC3-1035' to Foc race 4**

In the first trial, growth of 'TC3-1035' plants was quite similar to that of 'Pei-Chiao' (Table 1). Yield of 'TC3-1035' in this trial was significantly lower than that of 'Pei-Chiao', but a moderately resistant reaction to Foc race 4 was observed for 'TC3-1035' plants.

Besides showing moderate resistance to Foc race 4 in the consecutive trial in Kaohsiung and Pingtung counties, 'TC3-1035' was comparable with 'Pei-Chiao' in terms of days from planting to harvest, plant height and girth of pseudostem at shooting stage (Table 2).

In the third trial, plants of 'Tai-Chiao No. 3' were 22 and 43 cm shorter than those of 'TC3-1035' and 'Tai-Chiao No. 1', respectively (Table 3). The pseudostem girth of 'Tai-Chiao No. 3' was also wider than that of 'TC3-1035' and 'Tai-Chiao No. 1'. In addition, 'TC3-1035' took just about 1 year from planting to harvest, about 30-50 days faster than 'Tai-Chiao No. 3' and 'Tai-Chiao No. 1', in the first growth cycle, which is another benefit for banana growers. The rather moderately susceptible reaction (29-38% disease incidence) to Foc race 4 in plants of the three evaluated clones in this trial may be explained by poor drainage and higher inoculum of the soil (Table 3).

Based on its horticultural traits and stable resistance to Foc race 4 at shooting and harvesting stage, the somaclonal variant 'TC3-1035' was successfully released as a new cultivar 'Tai-Chiao No. 5' in 2007. More than 450 ha of banana orchards have been planted with 'Tai-Chiao No. 3' in 2009.

### **Sensory Evaluation of 'TC3-1035'**

During a panel test, eating quality of fruits of 'TC3-1035' and 'Pei-Chiao' were quite similar, even though 'TC3-1035' banana seemed slightly better in terms of peel firmness and sweetness (Table 4).

## **CONCLUSIONS**

Fusarium wilt is a major constraint for sustainable banana industry in many tropical and subtropical countries (Hwang and Ko, 2004). The identification of some promising somaclonal Cavendish variants after mass screening plantlets in infested fields allows countries like Taiwan and others to sustain the banana industry and more

importantly for the livelihood of small growers (Hwang and Ko, 2004). So far, four commercial Cavendish-type cultivars with moderate resistance to Foc race 4 have been released separately in Taiwan, namely 'Tai-Chiao No. 1', 'Tai-Chiao No. 3', 'Formosana' and 'Tai-Chiao No. 5' ('TC3-1035' was released as a cultivar in 2007). In addition, some clones highly resistant to Foc race 4, like 'GCTCV-105' and 'GCTCV-119', were released. These have however some limitations in growth or taste and are thus grown only on a limited scale in the south for local markets only (Hwang and Ko, 2004). To sustain the banana industry in Taiwan, the priority now is to release cultivars like 'Tai-Chiao No. 5' ('TC3-1035'), which retains the horticultural traits of 'Pei-Chiao', to areas infested by Fusarium wilt but with low acceptance of other Foc race 4-resistant cultivars, such as 'Formosana', which has less curvature of the fruit finger and requires 1-2 days more when ripened under 17-19°C lower temperature. On the other hand, the government and some export sectors have the common will to relaunch the high-yielding and moderately resistant 'Formosana' banana again to Japan in order to recover the share of Taiwanese banana in Japan's market to 10% in the near future (W.F. Hsu, pers. commun.).

Only by deployment of cultivars resistant to Foc race 4 in combination with other effective management tools, such as clean plantlets, proper planting site selection, good soil and water management, rotation and early sanitation into IPM, a slowdown of the epidemic of Fusarium wilt in banana may be achieved (Hwang et al., 1984; Hwang and Ko, 2004).

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## Tables

Table 1. Evaluation of horticultural traits, yield and resistance to Foc race 4 in 'TC3-1035' plant derived from plantlet in 1999-2000.

Clone	Plant height (cm)	Pseudostem girth (cm)	No. of hands per bunch	Bunch weight (kg)	Reaction to Foc race 4 <sup>z</sup>
TC3-1035	286 a <sup>y</sup>	72.9 a	7.5 b	20.0 b	MR
Pei-Chiao	262 a	72.4 a	8.4 a	26.2 a	HS

<sup>z</sup> Resistance rating is defined as highly resistant (HR): disease incidence <10%; moderately resistant (MR): disease incidence between 10-25%; moderately susceptible (MS): disease incidence between 26-50%; and highly susceptible (HS): disease incidence >50%.

<sup>y</sup> Means analysed by Duncan's multiple range test with same alphabetic letter was not significantly different at  $P = 0.05$  level.

Table 2. Evaluation of horticultural traits, yield and resistance to FOC race 4 in 'TC3-1035' plant derived from plantlet in 2000-2001<sup>z</sup>.

Clone	Time planting - harvest (days)	Plant height (cm)	Pseudostem girth (cm)	No. of hands per bunch	Bunch weight (kg)	Reaction to Foc race 4 <sup>y</sup>
TC3-1035	394 a <sup>x</sup>	257 a	69.2 a	7.9 a	20.6 a	MR
Pei-Chiao	384 a	278 a	72.0 a	7.9 a	19.7 a	HS

<sup>z</sup> Evaluation trial was conducted over five different location.

<sup>y</sup> Resistance rating is same as Table 1.

<sup>x</sup> Means analysis is same as Table 1.

Table 3. Comparison of horticultural traits among plants of 'TC3-1035' and its parent 'Tai-Chiao No. 3' in 2002-2003<sup>z</sup>.

Clone	Plant height (cm)	Pseudo-stem girth (cm)	No. of hands per bunch	No. of fingers per hand	Time planting - harvest (days)	Bunch weight (kg)	Fusarium wilt incidence (%)
TC3-1035	266 b	69.4 a	8.5 a	143 a	372 a	25.3 a	28.9 a
Tai-Chiao No. 3	245 b	76.3 a	10.1 a	192 a	423 a	23.8 a	38.2 a
Tai-Chiao No. 1	288 a	70.2 a	13.9 a	158 a	404 a	23.5 a	37.2 a

<sup>z</sup> Planted on August of 2002, and being harvested between March and April of 2003.

<sup>y</sup> Means analysis is same as Table 1.

Table 4. Sensory evaluation of ‘TC3-1035’ fruit after post-harvesting in 2006.

Clone	Grey coefficient <sup>z</sup>			Grey correlation	Ranking
	Aroma	Firmness	Sweetness		
TC3-1035	0.667	1.001	0.728	0.799	1
Pei-Chiao	0.667	0.809	0.697	0.725	2

<sup>z</sup>Data were statistically analysed by Grey relation analysis.

## Figures



Fig. 1. Status of plant of ‘TC3-1035’ (left), ‘Pei-Chiao’ (middle), and ‘Tai-Chiao No. 3’ (right) at shooting stage.



Fig. 2. Comparison of the resistant reaction of tissue culture plants of ‘TC3-1035’ (left) and ‘Pei-Chiao’ (right) in a *Fusarium oxysporum* f. sp. *cubense* race 4 infested orchard.



Fig. 3. Fruit bunch of plant of 'TC3-1035' (left) and 'Pei-Chiao' (right) harvested from the same banana orchard.