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Mycotoxins produced by *Fusarium* spp. of Taiwan[1]

Tsung-Che Tseng

Institute of Botany, Academia Sinica, Nankang, Taipei, Taiwan, Republic of China

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Abstract. *Fusarium* spp. are commonly found in Taiwan, and cause disease in many economic crop plants such as corn, rice, sorghum, and sugarcane. Many *Fusarium* spp. are known to produce mycotoxins, but little research has been done on them in Taiwan. This work reports the production of mycotoxins by some species. *Fusarium* spp. were isolated from crop plants and soil from various districts of Taiwan and examined for their ability to produce mycotoxins. A total of 174 *Fusarium* isolates were obtained. *Fusarium moniliforme* was found to be the most common fungus (31%), followed by *F. oxysporium* (29%), *F. roseum 'Graminearum'* (26%), and *F. solani* (13%). Sixty-one randomly selected isolates were tested for their ability to produce toxins on rice. Extracts of rice cultures inoculated with each *Fusarium* isolate were analyzed for mycotoxins by thin-layer-, gas-, and high-performance liquid chromatography. Zearalenone was produced by approximately 21% of the *Fusarium* isolate tested. Among them, *F. oxysporium* and *F. roseum 'Graminearum'* were the predominant producers. Three percent of *F. roseum 'Graminearum'* isolates produced deoxynivalenol. One isolate of *F. roseum 'Graminearum'*, designated as PKH 5-1, produced T-2 toxin at a rate of 2.3 mg/kg. Two isolates of *F. moniliforme* produced moniliformin. Twelve *F. moniliforme* isolates from corn were screened for fusarin C. All isolates were cultured on corn kernel at various temperatures and for various incubation periods. The toxin was analyzed by thin-layer-, gas-, and high-performance liquid chromatography, and further confirmed by mass spectrometry. Results revealed that more than 83% of the isolates were able to produce fusarin C on corn culture in amounts ranging from 50 to 4,830 μg/kg dry weight. All of the toxin producers synthesized a large amount of fusarin C over a 4-week period at 32°C. This is a new report of a subtropic species of *F. moniliforme* producing fusarin C.

Key words: Deoxynivalenol; Fusarin C; *Fusarium* spp.; *Moniliformin*; T-2 toxin; Zearalenone.

Introduction

Mycotoxins produced by *Fusarium* spp. in cereal grains cause mycotoxicoses in animals and human beings. Estrogenic syndromes in farm animals, and alimentary toxic aleukia, akakbitoxicoses, and scabby grain toxicoses in humans have been reported. The toxins implicated in these mycotoxicoses have been identified as zearalenone and trichothecenes; they occur naturally on corn, barley, wheat, rice, and other cereal grains.

Zearalenone is a natural, toxic metabolite produced mainly by *F. roseum 'Graminearum', F. moniliforme, F. tricinctum,* and *F. oxysporum*. It is usually produced on corn and barley in storage. When fed to animals, particularly swine, it causes hyperestrogenism (Mcnutt *et al.*, 1928; Lelievre *et al.*, 1962; Ericken, 1968; Bristol and Djurickovic, 1971). Trichothecenes, a group of sesquiterpenoids, are the active secondary metabolites produced by *Fusarium* spp. and

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Myrothecium, as well as *Trichoderma* (Hsu *et al.*, 1972; Ichinoe and Kurata, 1983; Ueno *et al.*, 1973). Hemorrhage is a typical symptom, which in acute case of toxicosis may lead to death. Many of the fungi, particularly *Fusarium* spp., that produce trichothecenes also produce zearalenone. Moniliformin, one of the *Fusarium* mycotoxins, was first isolated from American strains of *F. moniliforme*; it is highly toxic to animals and may be involved in the incidence of cancer in rats (Cole *et al.*, 1973; Springer *et al.*, 1974; Marasas *et al.*, 1979). Fusarin C is a polyketide produced by a *F. moniliforme* strain isolated from corn kernels in areas of China and South Africa with high incidences of esophogeal cancer (Marasas *et al.*, 1984 and Marasas *et al.*, 1981).

In Taiwan, *Fusarium* spp. are the most prevalent pathogens on rice, corn, sorghum, and many other crop plants. In the past decade, most of the research related to *Fusarium* spp. was restricted mainly to the areas of ecology, pathogenicity, and disease control. This report deals with the ability of the fungi to produce zearalenone, trichothecenes, moniliformin, and fusarin C.

Materials and Methods

Isolation of ***Fusarium*** *spp.*

Crop plants of corn, rice, sugarcane, and sorghum, which had pink discoloration either on the kernels or stems, as well as field soils, were collected from various locations in Taiwan and investigated mycologically for *Fusarium* spp. Seeds and stems were surface sterilized for one min with 2% sodium hypochloride. After being thoroughly rinsed in sterile distilled water, the materials were directly transferred to a modified peptone-PCNB medium (Papavizas, 1967). Plates were incubated at 20°C with a 12-hour photoperiod and examined at regular intervals; the dominant fungi were then isolated in pure culture for further identification. Soil samples collected from the fields were dried, ground, and examined for the presence of *Fusarium* spp. One-half gram of the mixed soil was put into a test tube with 10 ml of 0.15% water agar. After shaking vigorously, a series of dilutions (1:10) of the medium was made. One ml of each of dilutions was spread on the surface of the modified peptone-PCNB medium in replicate dishes and then incubated at 20°C. The colonies were counted after a 7-day incubation

All cultures formed were single spore. The single -spore isolation technique devised by H. N. Hansen (1964) was used. The Snyder and Hansen system (1940) was adopted for identification and classification of *Fusarium* spp.

Screening for ***Fusarium*** *Mycotoxin- Producing Strains*

A total of 61 randomly selected isolates of *Fusarium* spp. were grown on autoclaved hulled rice (*Oryzae sativa* var. Taichung No. 6) with a moisture content of 40%. The inoculated rice cultures were kept at 28°C for 7 days and at 12°C for 21 days, except during moniliformin analysis, the culture media were incubated at 31°C for 7 days. At the end of this period, the cultures were dried at 85°C for 18 h and then ground with a mill. The dried rice cultures were analyzed for zearalenone and trichothecenes by a previously described method (Tseng *et al.*, 1985). The average recoveries of deoxynivalenol and T-2 toxin from rice cultures, based on gas-liquid chromatographical analyses, were 72.46% and 99%, respectively. Calibration curves for deoxynivalenol and T-2 toxin were estimated authentic compounds. The sensitivity of gas-liquid chromatography for detecting deoxynivalenol and T-2 toxin was less than 10 ng. The recovery of zearalenone, measured by high performance liquid chromatography, was 74.06%; the sensitivity was estimated to be lower than 5 ng. All of the experiments were carried out in triplicate. Moniliformin was measured by the method of Rabie *et al.* (1978).

Twelve *F. moniliforme* isolates from corn were screened for fusarin C. All isolates were cultured on corn kernels at various temperatures and for various

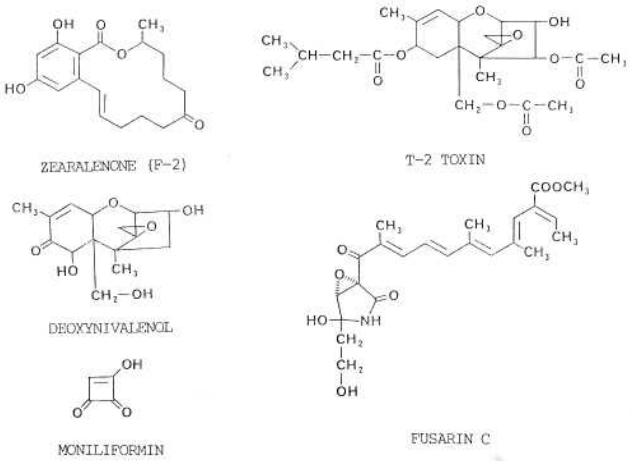

Fig. 1. Chemical structures of some *Fusarium* mycotoxins.

incubation periods. The toxin was analyzed by thin-layer, gas and high-performance liquid chromatography, and further confirmed by mass spectrometry as previous described (Tseng *et al.*, 1990). The chemical structures of zearalenone, deoxynivalenol, T-2 toxin, moniliformin, and fusarin C are illustrated in Figure 1.

Results and Discussion

Four species of *Fusarium*, including *F. moniliforme*, *F. roseum 'Graminearum'*, *F. solani*, and *F. oxysporum*, were isolated from crop plants (e. g. rice, corn, sugarcane, and sorghum) and from the field soils. *F. moniliforme* was the most prevalent fungus (31%), followed by *F. oxysporum* (29.3%), *F. roseum 'Graminearum'* (26.4%), and *F. solani* (13.2%) (Table 1). *Fusarium moniliforme* and *F. roseum 'Graminearum'* were isolated most frequently from sorghum, *F. oxysporum* was isolated most frequently from sugarcane, while *F. solani* was isolated mainly from field soils.

Zearalenone, Thiochothecenes and Moniliformin Producers

Of the 174 *Fusarium* isolates collected, 61 randomly selected isolates were examined for the production of zearalenone, T-2 toxin, deoxynivalenol, and moniliformin. As shown in Table 2, the species differ in their ability to produce various mycotoxins. Twenty-one percent of the tested isolates of *Fusarium* species were zearalenone producers, among which *F. oxysporum* and *F. roseum 'Graminearum'* were confirmed as the predominant producers. Two isolates of *F. roseum 'Graminearum'* (3.2%) were able to produce deoxynivalenol. One isolate of *F. roseum 'Graminearum'* (1.6%) produced T-2 toxin. Two isolates of *F. moniliforme* (3.2%) were moniliformin producers. Zearalenone producing isolates were widespread among crop plants and field soils (Table 3). Deoxynivalenol producing isolates were obtained from rice and sugarcane (Table 4). The T-2 toxin producer, designated as *F. roseum 'Graminearum'* PKH 5-1, was isolated from sorghum (Table 5). The peak "a" on the gas chromatogram (Fig. 2) was further confirmed by a GC-MS method (Miro-

Table 1. ***Fusarium*** *species isolated from crop plants and field soils*

Source of Isolates	Isolate from soil (S) or diseased plant (DP)	No. of isolates				Total *Fusaria*
		F. oxysporum	*F. roseum 'Graminearum'*	*F. solani*	*F. moniliforme*	
Rice	DP	6	12	1	11	30
(*Oryza sativa* L.)	S	5	0	6	0	11
Corn	DP	0	10	1	10	21
(*Zea mays* L.)	S	7	0	5	1	13
Sugarcane	DP	20	5	0	7	32
(*Saccharum officinarum* L.)	S	9	1	7	0	17
Sorghum	DP	2	18	2	25	47
(*Sorghum vulgare* Pers.)	S	2	0	1	0	3
Total (%)		51(29.3)	46(26.4)	23(13.2)	54(31)	174

Table 2. ***Fusarium*** *mycotoxin producing species isolated in Taiwan*

Species	No. of isolates examined	No. of toxin producing isolates	Frequency of toxin-producing isolates (%)*			
			DON	F-2	T-2	Mo
F. moniliforme	19	4	0	10.52(2/19)	0	10.52(2/19)
F. oxysporum	21	8	0	38.09(8/21)	0	0
F. solani	12	0	0	0	0	0
F. roseum 'Graminearum'	9	6	22.22(2/9)	33.33(3/9)	11.11(1/9)	0
Total (%)	61	18	0.032(2/16)	21.31(13/61)	0.016(1/61)	0.03(2/61)

*DON, deoxynivalenol; F-2, zearalenol; Mo, moniliformin.

Table 3. *Zearalenone producing isolates of* ***Fusarium*** *species isolated from crop plants and field soils*

Species	No. of toxinogenic isolates/No. of isolates				Total
	Rice	Corn	Sugarcane	Sorghum	
F. moniliforme	1/5	1/5	0/5	0/4	2/19
F. oxysporum	2/4	1/4	4/12	1/1	8/21
F. solani	0/3	0/1	0/7	0/1	0/12
F. roseum 'Graminearum'	2/4	1/2	0/2	0/1	3/9
Total	5/16	3/12	4/26	1/7	13/61

Table 4. *Deoxynivalenol producing isolates of* ***Fusarium*** *species isolated from crop plants and field soils*

Species	No. of toxinogenic isolates/No. of isolates				Total
	Rice	Corn	Sugarcane	Sorghum	
F. moniliforme	0/5	0/5	0/5	0/4	0/19
F. oxysporum	0/4	0/4	0/12	0/1	0/21
F. solani	0/3	0/1	0/7	0/1	0/12
F. roseum 'Graminearum'	1/4	0/2	1/2	0/1	2/9
Total	1/16	0/12	1/26	0/7	2/61

Table 5. *T-2 Toxin producing isolates of* ***Fusarium*** *species isolated from crop plants and field soils*

Species	No. of toxinogenic isolates/No. of isolates				Total
	Rice	Corn	Sugarcane	Sorghum	
F. moniliforme	0/5	0/5	0/5	0/4	0/19
F. oxysporum	0/4	0/4	0/12	0/1	0/21
F. solani	0/3	0/1	0/7	0/1	0/12
F. roseum 'Graminearum'	0/4	0/2	0/2	1/1	1/9
Total	0/16	0/12	0/26	1/7	1/61

cha *et al.*, 1976).

T-2 toxin produced by *F. moniliforme* has been reported by Ghosal *et al.* (1978). Vesonder *et al.* (1981) also indicated that *F. moniliforme* (NRRL 3197) produces T-2 toxin and deoxynivalenol. However, the strain's taxanomic position was reexamined, and was shown to be a cultural variant of the species of *F. tricinctum* (Cda.) Sacc. and not a strain of *F. moniliforme.* In our studies, 19 isolates of a *F. moniliforme* were examined for T-2 toxin. Three isolates designated as PRC 3-3, PRD 3-3, and PKH 5-3 were frist suspected of being T-2 toxin producers based on gas-liquid chromatographic analyses. However, when the culture extracts were further examined by GC-MS, all three cultures were negative for T-2 toxin. Later, we found that all of the cultures contained an unknown compound that exhibites the same retention time as authentic T-2 toxin. Therefore, we suggest that it is important to be cautious in the analysis of trichothecene, particularly when it is produced by *F. moniliforme.*

Table 6 illustrates the 18 isolates of *Fusarium* mycotoxin producers that were obtained from crop plants and field soils. Two isolates of *F. moniliforme*, IBAS-5 and IBAS-6, produced a considerable amount of moniliformin (112 mg/kg and 131 mg/kg respectively) but no other *Fusarium* toxins. About 72% (13/18) of the isolates including *F. moniliforme, F. oxysporum* and *F. roseum 'Graminearum'* are zearalenone producers. *Fusarium oxysporum* (PSD 4-1) produced the largest amount of zearalenone, at the level of 859 μg/kg. Mirocha (1977) has reported that *Fusarium roseum* can produce large quantities of zearalenone (3,000-15,000 mg/kg). Our zearalenone producers synthesized only small quantities of this mycotoxin. Thus *Fusarium roseum* isolated from different geographic areas may exhibit different zearalenone-producing abilities; this remains

Table 6. ***Fusarium*** *mycotoxin producing isolates collected from crop plants and field soils*

Isolates	Toxins (μg/kg dry weight)			
	Deoxynivalenol	Zearalenone	T-2 toxin	Moniliformin
F. moniliforme (PRD 3-3)	0[b]	108[a]	0	0
F. moniliforme (PCG 2-2)	0	4.2	0	0
F. moniliforme (IBAS-5)	0	0	0	112,000
F. moniliforme (IBAS-6)	0	0	0	131,000
F. oxysporum (SRB 6-6)	0	4.2	0	0
F. oxysporum (SCM 3-3)	0	13.5	0	0
F. oxysporum (PSE 4-4)	0	17.6	0	0
F. oxysporum (SSA 3-3)	0	121.5	0	0
F. oxysporum (SKD 5-1)	0	48.3	0	0
F. oxysporum (PRI 6-1)	0	2.1	0	0
F. oxysporum (PSD 4-1)	0	859	0	0
F. oxysporum (PSI 6-5)	0	40.6	0	0
F. roseum 'Graminearum' (PRI 6-6)	281	0	0	0
F. roseum 'Graminearum' (PSD 4-4)	215	0	0	0
F. roseum 'Graminearum' (PRC 3-2)	0	13.3	0	0
F. roseum 'Graminearum' (PRL 4-2)	0	27.6	0	0
F. roseum 'Graminearum' (PCM 7-1)	0	48.6	0	0
F. roseum 'Graminearum' (PKH 5-1)	0	0	2,830	0

[a]Average of triplicate determinations.
[b]Not detectable.

a problem for further investigation.

Fusarin C Producers

Twelve randomly selected isolates of *F. moniliforme* were examined for the production of fusarin C. Preliminary experiments showed that the extracts of *F. moniliforme* isolates contained fusarin C, based on the presence of a bright yellow spot on the TLC plate under visible light, with an R_f value ranging from 0.31 to 0.35 (Fig. 3). Similar results were reported by Farber and Sanders (1986).

Table 7. *Production of fusarin C by the isolates of* ***Fusarium moniliforme*** *growing on corn at various temperatures and incubation periods*

Isolates	Fusarin C (μg/kg dry weight)					
	28°C			32°C		
	2	3	4	2	3	4WK
PCA 2-1	82.6[a]	132.2	360.7	84.6	186.3	399.2
PCA 2-2	50.0	72.3	87.5	57.6	82.7	98.2
PCA 2-3	346.4	756.5	980.4	484.4	810.6	1080.2
PCA 3-1	735.3	1860.4	3240.3	890.3	2600.7	3980.4
PCA 3-2	220.3	237.3	936.2	380.2	841.5	900.8
PCA 5-1	790.2	1846.2	2802.1	690.3	1900.4	4830.2
PCA 5-3	996.1	2604.1	3420.7	930.2	2730.2	3612.0
PCA 5-4	460.5	1245.6	3243.6	710.0	2130.1	4210.0
PCA 5-5	302.8	822.1	1242.2	24.7	936.0	1510.6
PCA 5-6	ND[b]	ND	ND	ND	ND	ND
PCA 6-1	765.7	1488.4	2976.5	800.4	1610.5	3120.5
PCA 6-2	ND	ND	ND	ND	ND	ND

[a]Average of triplicate determinations.
[b]Not detectable.

The fusarin C content of samples of *F. moniliforme* isolates was quantified by comparing the height of fusarin C peaks in HPLC chromatograms with those of

The presence of fusarin C in a TLC- purified extract of *F. moniliforme* PCA 5-1 was further confirmed by mass spectrometry (molecular ion $M^+=431$, $C_{23}H_{29}NO_7$) (Fig. 4). Attempts were made to analyze fusarin C from purified extract of sample PCA 5-1 by gas chromatography. The TMS derivatives of the sample showed a peak ($R_t=3.0$ min) in the same position as authentic fusarin C (Fig. 5). Upon spiking the extract with authentic fusarin C, and analysis by GC, we again detected an increased, single, symmetrical peak in the position of fusarin C. The limit of detection was about 0.01 μg/g. This analytical method, developed in our laboratory, will be a useful technique for fusarin C analysis, both in cultural extracts as well as in cereal products.

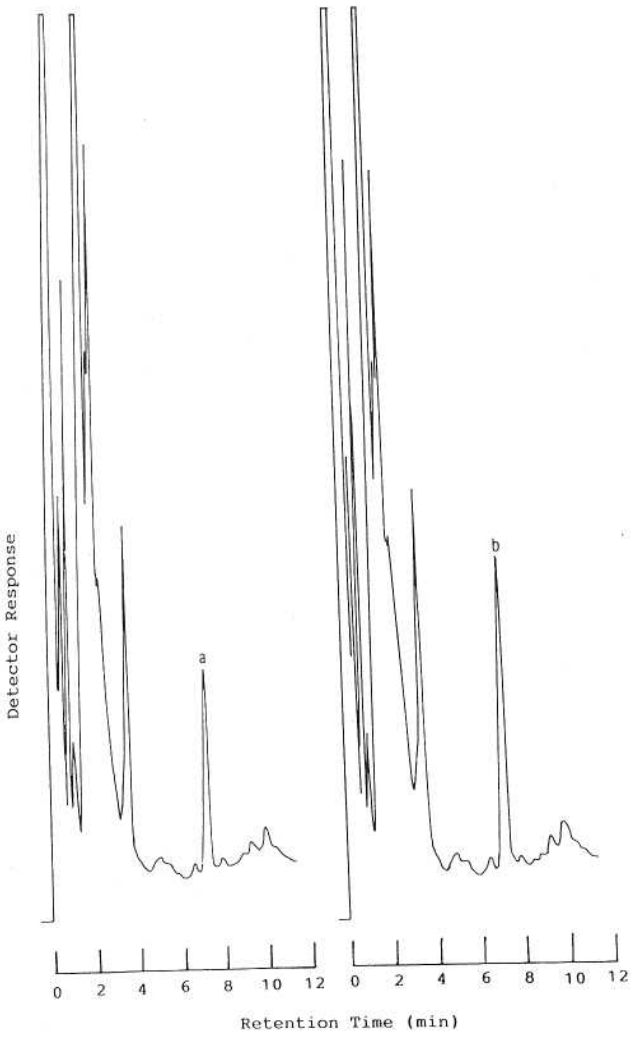

Fig. 2. Gas chromatograms of the TMS derivatives of T-2 toxin produced by *Fusarium roseum 'Graminearum'* (PKH 5-1) isolated from sorghum. a, sample extract (2 μl); b, sample extract (2 μl)+standard TMS- T-2 toxin (0.945 μg). Conditions: 1. Column: 3% OV-17 (1/8'×6'); 2. N_2 gas: 30 ml/min; 3. Injector temperature: 310°C; 4. Column temperature: 200-280°C, 7.5°C/min.

standard fusarin C solutions. HPLC analysis of purified extract of PCA 3-2 showed a peak eluting in the same position as that of fusarin C. (Fig. 6).

The amounts of fusarin C produced by the twelve isolates of *F. moniliforme* are shown in Table 7. Ten of the twelve isolates tested were able to produce fusarin C when growing on corn, in amounts ranging from 50 to 4830.2 μg/kg dry weight. Isolate PCA 5-1 was the best fusarin C producer. The effect of temperature on fusarin C biosynthesis was significant. All of the toxin producers except PCA 3-2 produced larger amounts of fusarin C over a 4-week period at 32°C than they did at 28°C.

A previous study, also performed with corn cultures, demonstrated the ability of 14 isolates of North American *F. moniliforme* to produce fusarin C at 28°C (3 weeks), in amounts ranging from 18.7 to 332 μg/g dry weight (Farber and Sanders, 1986). Also, Gelderblom *et al.* (1984) reported that 20 strains of *F. moniliforme* were able to produce fusarin C on corn in amounts ranging from 63 to 724 μg/g dry weight, when the corn cultures were incubated for 2 weeks at 25°C, followed by 2 weeks at 15°C. Apparently, the isolates of Taiwanese *F. moniliforme* used in this study produced lower amounts of fusarin C than do South African and North American strains. Also, the optimal temperature for the production of fusarin C by our isolates was

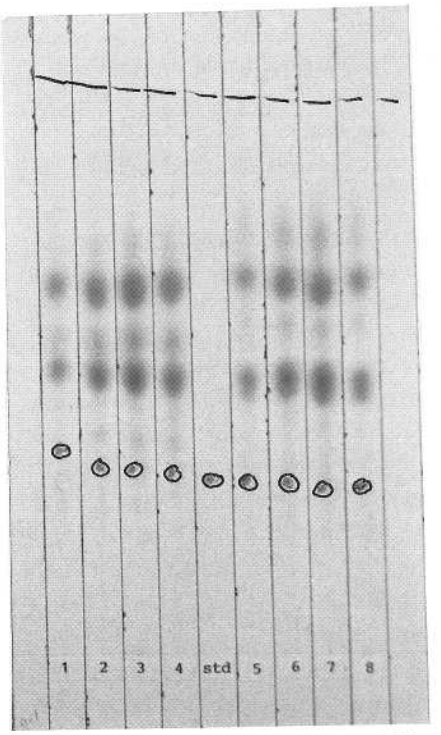

Fig. 3. Thin-layer chromatograms of extracts of *F. moniliforme* isolates. Developing solvents: $CHCl_3$: CH_3OH(9:1: v: v); lanes 1-8, *F. moniliforme* PCA 2-3, PCA 3-1, PCA 3-2, PCA 5-1, PCA 5-1, PCA 5-2, PCA 5-3. PCA 5-4, PCA 5 -5, PCA 6-1; Std=fusarin C.

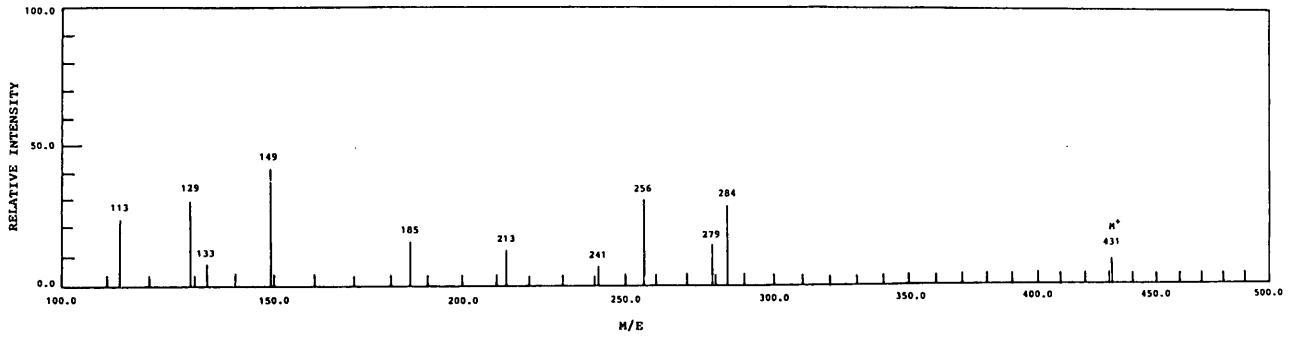

Fig. 4. Mass spectrum of fusarin C purified from the extract of sample PCA 5-1.

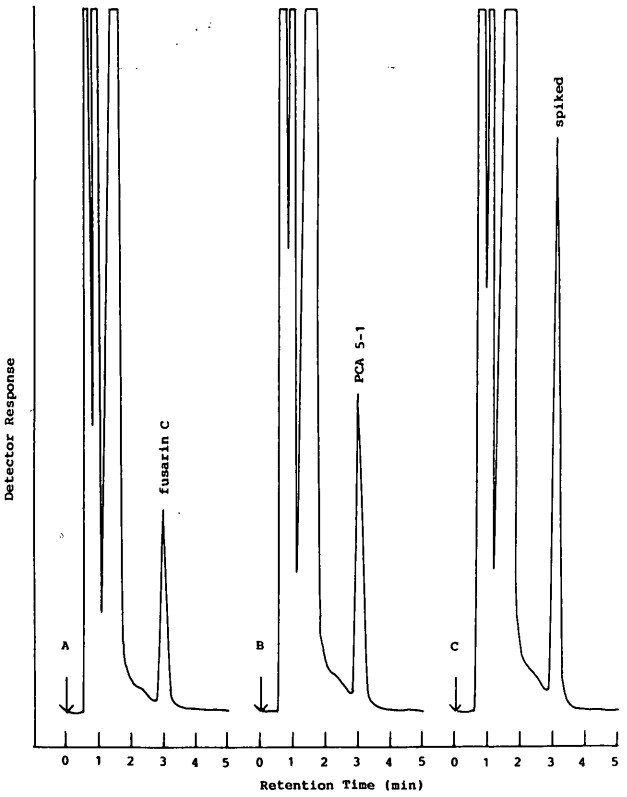

Fig. 5. Gas Chromatograms of the TMS derivatives of fusarin C standard (0.034 mg/ml) (A) and the purified (B) and spiked purified extracts of sample PCA 5-1 (C). Conditions: 1. Column: SE-30 (3 mm ×1 m, 10% Chromosorb W, 80 -100 mesh); 2. N_2 gas: 30 ml/min; 3. Injector temperature: 190°C; 4. Column temperature: 170°C.

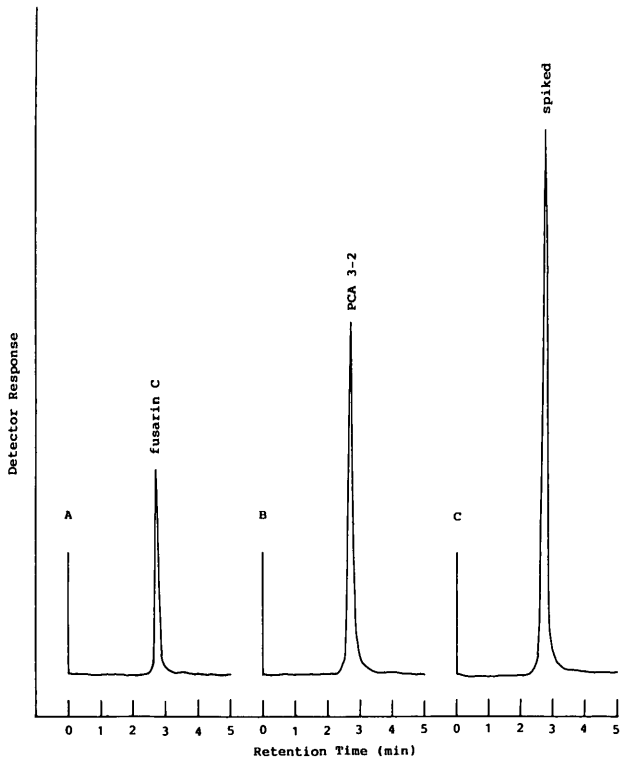

Fig. 6. LC chromatograms of 1 μl fusarin C standard (0.027 mg/ml)(A) and the purified (B) and spiked purified extracts of sample PCA 3-2 (C). Conditions: 1. Column: LiChrosorb RP-18 (4 mm×25 cm); 2. Mobile phase: CH_3OH: $CHCl_3$ (1:19); 3. Flow rate: 1.0 ml/min; 4. Detector: U. V. at 365 nm, sensitivity at 0.1 AUFS.

higher than that in the previous reports. The significance of this is unclear at present. Farber and Sander (1986) have indicated that slight changes in aeration, temperature, and pH can have drastic effects on the biosynthesis of fusarin C by *Fusarium* spp. However, that the difference is due to the geographical origin of the fungi still cannot be ruled out. Recently, 39 isolates of *F. moniliforme* from crop plants were examined for

fumonisins. About 64% of the isolates were proved to produce fumonisin (unpublished data).

In summary, the production of *Fusarium* mycotoxins by isolates of *Fusarium* spp. in Taiwanese crop plants and field soils was studied. Sixty-one randomly selected isolates were examined for the toxins. Zearalenone was found to be produced by approximately 21% of the *Fusarium* isolates tested. Among them, *F. oxysporium* and *F. roseum 'Graminearum'* were the predominant producers. Three percent of *F. roseum 'Graminearum'* isolates produced deoxynivalenol. One isolate of *F. roseum 'Graminearum'*, designated as PKH 5-1, was a T-2 toxin producer at a low level of 2.3 mg/kg. Two isolates of *F. moniliforme* produced moniliformin. Zearalenone producers were common in our crop plants and soil, but they produced a much lower quantity of mycotoxin than did other zearalenone producers. When twelve *F. moniliforme* isolates from corn were screened for fusarin C, more than 83% of the isolates were able to produce fusarin C on corn cultures in amounts ranging from 50 to 4,830 μg/kg dry weight. Apparently, the *Fusarium* mycotoxin producers are widespread in our crop plants and soil. Further investigation will focus on the mycotoxins in Taiwanese cereal grains, which may cause mycotoicoses in animals and human beings.

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台灣鐮孢菌產生眞菌毒素之研究

曾聰徹

中央研究院植物研究所

鐮孢菌爲危害台灣經濟作物，包括玉米，水稻，高粱，甘蔗等之主要病害，每年因罹病減產而損失慘重。過去幾十年來，有關鐮孢菌之研究範疇，主要著重於分類、生態、病理以及病害防治，至於該菌產生眞菌毒素方面的研究報告，非常缺乏。一直到 1986 年，我們研究室開始有系統地從全省各地經濟作物栽培地區，廣泛收集鐮孢菌株，並同時探討其產毒能力。從 174 菌株經鑑定結果發現，*Fusarium moniliforme* 佔 31%爲全省最普遍的菌株，其次依序爲 *F. oxysporim* (29%)，*F. roseum 'Graminearum'* (26%)，*F. solani* (13%)。經逢機取 61 菌株，分別接種於糙米培養基，於 28°C，一星期之後，移至 12°C三星期。培養基經萃取後，利用薄層色層分析法，氣相色層分析法及高壓液相分析法，檢測眞菌產毒能力，結果發現有 21%的被試鐮孢菌株，具產生 zearalenone 能力，其中包括兩種主要產毒菌：*F. oxysporium* 和 *F. roseum 'Graminearum'*；3%的菌株產生 deoxynivalenol，產毒者被證實爲 *F. roseum 'Graminearum'*；唯一產生 T-2 toxin 的菌株，命名爲 PKH 5-1，亦是 *F. roseum 'Graminearum'*，其產毒量爲 2.8 mg/kg；有兩株 *F. moniliforme* 具產生 monilifomin 能力。本研究室發現，具產生 zearalenone 的鐮孢菌株，廣存於台灣經濟作物及土壤中，但產毒量不高。最近探討玉米栽培地區收集之 *F. moniliforme* 菌株共十二株，並篩選其產生 fusarin C 眞菌毒素之能力。所有被試之菌株，皆培養於玉米培養基中，毒素之檢測係採用薄層色層分析，氣相色層分析及高壓液相分析方法，並使用質譜儀加以確定。實驗結果，發現有 83%以上之被試菌株，在玉米培養基中，皆具產毒之能力，其產毒量於 50 至 4,832 μg/kg 乾重量之間，並發現所有產毒菌，其最適產毒之條件爲培養於 32°C，四週。這是從亞熱帶地區所分離之 *F. moniliforme*，首次發現具產生 fusarin C 眞菌毒素之研究報告。