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Cultural and Rainfall Factors Involved in Disease Development of Fusarium Wilt of Sweet Potato

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Environmental factors such as soil moisture, land management, and weather conditions affecting Fusarium wilt of sweet potato were investigated in major sweet potato cultivation regions in Korea. Fusarium wilt occurred mainly in reclaimed terracing lands, which are flattened and located in hilly to mountainous areas at the base of the mountain, in early seasonal cultivation regions. Disease severity was lower in reclaimed fields with natural slope. The development of Fusarium wilt in the fields was highly correlated with precipitation during planting period (r = -0.96). Fusarium wilt was more severe in fields with less than 20 cm of available soil depth than in fields with over 20 cm of available soil depth. Greenhouse studies were consistent with field studies that less soil moisture content caused severe Fusarium wilt of sweet potato. These results indicate that low rainfall and moisture of soil with low effective soil depth during planting period are important environmental factors influencing the development of Fusarium wilt.**

Keywords : Fusarium wilt, rainfall, soil moisture, sweet potato

Fusarium wilt caused by *Fusarium oxysporum* f. sp. *batatas* (Wollenw.) Snyd. & Hans is the most serious disease of sweet potato in the United States in the early 20th century (Harter and Field, 1914). However, the cultivation of resistant cultivars has reduced the impact of the disease (Clark and Moyer, 1988). Meanwhile, Fusarium wilt of sweet potato has been a serious problem in Japan since the 1970s. Ogawa (1988) reported its ecology and possible application of nonpathogenic *Fusarium* sp. for its control. This disease was first reported by Park (1967) in Korea and has caused major economic losses in sweet potato producing areas such as Haenam starting the middle of the 1990s. Symptoms of stunted vine growth and dropped older leaves occur 2-4 weeks after transplanting in the field. In severe cases, decayed pith within the stem causes plant death.

Until 1990, the common seasonal cultivation of sweet potato in Korea was planting in June and harvesting in November without using polyethylene film. Since that year, however, sweet potato cultivation has shifted to early seasonal cultivation, wherein planting with polyethylene film covering is done in April and harvesting in September. After shifting to early cultivation, Fusarium wilt of sweet potato became a major disease in Korea. Sweet potato is mainly cultivated in reclaimed hillsides in the country. Most of the small (< 0.2 ha) fields are reclaimed with natural slope. However, larger fields (> 1.0 ha) are reclaimed by cutting the land to reduce the slope, which will be referred to as "terracing" in this paper. These terracing fields become flat rather than retaining their natural slope. Fusarium wilt occurs severely in reclaimed terracing fields in Haenam, Yeongam, and Naju regions.

Fusarium wilt of sweet potato is severe at 28-30°C, but it is prevalent in cooler regions of sweet potato cultivation (Clark and Moyer, 1988). This suggests that factors other than temperature could be involved in the disease development. The objective of this study was to evaluate the influence of environmental factors caused by the different cultivation styles and land management on the disease development of Fusarium wilt in sweet potato fields heavily-infected with *Fusarium oxysporum*.

Materials and Methods

Disease survey. Sweet potato cultivation areas in Haenam, Yeongam, Yeochon, and Naju in Jeonnam Province were surveyed for the occurrence of Fusarium wilt in 1998 and 1999. Sweet potato plants showing stunting of vine growth and abscission of older leaves were regarded as infected plants. Detailed interpretative soil maps (1:25,000) of the Haenam region edited by the Agricultural Science Institute of the Rural Development Admini-

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stration (1993) were used to confirm the soil characteristics. Rainfall and temperature data of Haenam and Yeochon were obtained from the Korea Meteorological Administration.

Field study of Fusarium wilt based on different planting time and effective soil depths. A survey of the occurrence of Fusarium wilt was conducted in reclaimed terracing fields located at the Songsan and Bongsan series of soils in Haenam in 1998 and 1999, respectively. Songsan series fields were gravelly sandy loam with rapid drainage and moderately rapid permeability. Bongsan series fields were gravelly loam with good drainage and permeability.

The field was divided into two blocks with effective soil depths below and over 20 cm. The sweet potato propagates were planted on 25 April (1st), 7 May (2nd), and 29 May (3rd) in 1998; and 20 April (1st), 30 April (2nd), 21 May (3rd), and 11 June (4th) in 1999 using randomized block design. Each plot consisted of four 0.75 m rows planted with 25 cuttings per row. Development of Fusarium wilt was recorded at 3-4-week interval after planting. Sweet potato was cultivated by using the conventional method (Oh et al., 1996).

Effect of soil moisture on severity of Fusarium wilt.

Pathogen inoculation. *Fusarium oxysporum* f. sp. *batatas* B203 was isolated from infected sweet potato in Haenam through the single spore isolation procedure. Morphological characteristics were examined under the light microscope. The morphology of the isolate was matched with the description of *Fusarium oxysporum,* and morphologically matched fungal isolates were constantly obtained from infected plant tissues during this experiment. The isolate was grown on potato dextrose agar (PDA) for 7 days and was used as an inoculum.

Infested soils were prepared by mixing 1 × 1 cm cubes of *Fusarium oxysporum* B203 culture from PDA plates with sterilized sandy soils which were sterilized at 150°C for 3 h in the dry oven (1 plate/1000 g soil). Sterile-distilled water was poured onto the infested soils. The soils were cycled to incubate the inoculum through a dry-wet regime for a total of five times for 4 weeks in a glasshouse. After mixing with sterilized sandy soils and incubating for 4 weeks, a final inoculum concentration of 10^4 conidia/g soil was obtained, as determined by serial dilutions of soil extracts on Komadas medium (Komada, 1975). Five terminal vine cuttings with leaves of a sweet potato variety "Yulmi" were planted in a Wagner pot (1/5000 a) containing the infested soil. Sterilized sandy soil without inoculating the pathogen was used as control.

Control of soil moisture and measurement of disease development. Jet-fill tensiometers were placed at 15-cm depth on planted pots containing sterilized sandy soil, as control, or infested soil. Soils were watered until pF 2.48. Soil moisture was constantly maintained at pF 2.48 (2.4-2.5) or pF 2.7 (2.68-2.72) throughout the entire experiment. Development of Fusarium wilt was measured as the number of plants with stem rot, length of the foot rot lesion at the base of stem, number of wilted plants, and number of wilted leaves at 30 days after planting. Stem rot was determined by noting a vascular ring with at least 20% discoloration in cross-section of sweet potato stems sliced 2 cm above the soil level (Smith and Snyder, 1971).

Results

Effects of cultural practices and land reclamation managements on the occurrence of Fusarium wilt. Fusarium wilt was not observed in fields without polyethylene film mulching in the Yeochon region (common seasonal cultivation) in 1998 and 1999. However, 9 out of 52 fields and 25 out of 87 fields were infested in early seasonal cultivation areas with polyethylene film mulching in 1998 and 1999, respectively. Average temperature during transplanting period with mulch was 16.9°C and 14.8°C, while that during transplanting period without mulch was 20.3°C and 21.3°C in 1998 and 1999, respectively. Meanwhile, precipitation during transplanting period with mulch was 150.5 mm and 61.0 mm, while that during transplanting period without mulch was 381.9 mm and 216.5 mm in 1998 and 1999, respectively (Table 1).

Sixteen out of 20 reclaimed terracing fields were infected with Fusarium wilt, but only 2 out of 33 reclaimed fields with natural slope were infected with the disease. In the Bongsan series, 10 out of 11 reclaimed terracing fields were infected with Fusarium wilt, while none of the fields with natural slope was infected by the disease (Table 2).

Table 1. Fusarium wilt incidence of sweet potato and weather factors during planting period in the production areas of Jeonnam province from 1998 to 1999

Planting period	Region	Year	No. of surveyed fields	No. of infested fields[c]	Weather factors during planting period		
					Av. temp (°C)	Rainfall days	Precipitation (mm)
Early[a]	Haenam Yeongam Naju	1998	52	9	16.9	15	150.5
		1999	87	25	14.8	5	61.0
Common[b]	Yeochon	1998	26	0	20.3	15	381.9
		1999	31	0	21.3	10	216.5

[a] Sweet potato was planted from April 10 to May 20 and [b] from June 1 to June 30.
[c] No. of fields with over 1% plant showing wilt or stunting symptoms.

Table 2. Incidence of Fusarium wilt based on different soil series and reclamation methods of sweet potato cultivation fields

Soil series	No. of diseased fields with different disease incidence (%)									
	Terracing					Natural slope				
	Fields	0[a]	1~20	21~50	>50	Fields	0	1~20	21~50	>51
Bongsan	11	1	5	2	3	12	12	0	0	0
Anryong	5	1	1	2	1	1	1	–	–	–
Ugog	3	1	2	0	0	13	12	1	0	0
Weongog	0	–	–	–	–	2	2	0	0	0
Nasan	0	–	–	–	–	5	4	1	0	0
Songsan	1	1	0	0	0	0	0	0	0	0
Total	20	4	8	4	4	33	31	2	0	0

[a]Percentage of wilted or stunted plants in each field.

Table 3. Effect of planting time and effective soil depth of field on occurrence of Fusarium wilt of sweet potato

Year	Planting date	Fusarium wilt incidence[a] based on effective soil depth (%)		Precipitation[c] (mm)
		Below 20 cm	Over 20 cm	
1998	25 April	100 a[b]	13.3 b	64.0
	7 May	100 a	8.3 c	80.0
	29 May	100 a	34.7 a	53.5
1999	20 April	100 a	36.7 a	0.0
	30 April	100 a	22.0 b	34.5
	21 May	100 a	2.7 c	65.0
	11 June	100 a	9.3 c	55.0

[a]Percentage of wilted plants from 200 plants in a plot.
[b]Means followed by the same letter within a column are not significantly different by Duncan's multiple range test at 5% level.
[c]Precipitation during 15 days, from 5 days before to 9 days after planting.

Field study of Fusarium wilt based on different planting time and effective soil depths. The incidence of Fusarium wilt on sweet potato grown at effective soil depth below 20 cm was 100%, while that of sweet potato grown at effective soil depth above 20 cm ranged from 2.7% to 34.7% (Table 3). Fusarium wilt in the fields with effective soil depth above 20 cm was highly correlated with precipitation during planting period, with correlation coefficients of -0.89** and -0.96** in 1998 and 1999, respectively (Fig. 1).

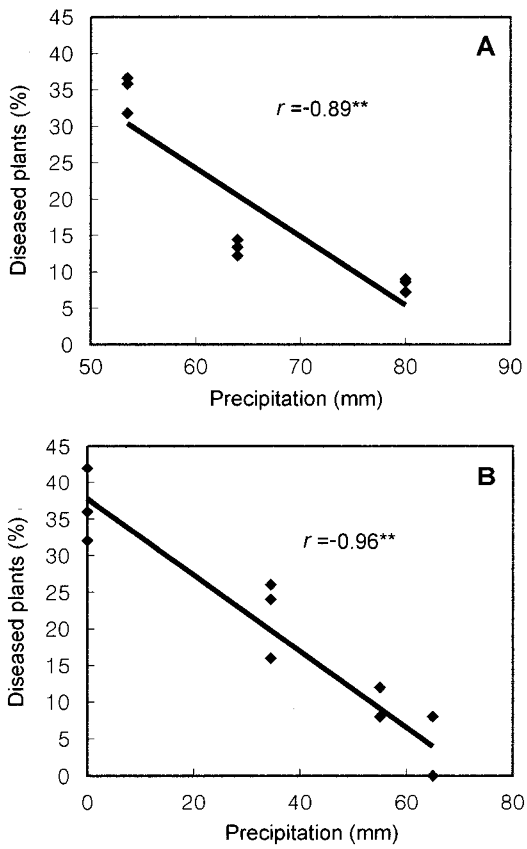

Fig. 1. Correlation between Fusarium wilt incidence and precipitation from 5 days before to 10 days after planting in 1998 (A) and 1999 (B).

Effects of soil moisture on severity of Fusarium wilt. In the glasshouse test, Fusarium wilt development was significantly higher in dry (pF 2.70) soil than in soil of moderate (pF 2.48) soil moisture (Table 4). Wilt symptoms and stem rot lesions appeared 100% only in Fusarium-inoculated soil with pF 2.70. In addition, the number of healthy leaves was significantly reduced in the dry soil condition. The presence of Fusarium in the soil caused older leaves to drop by 21 days. Abscission of older leaves was not observed in plants in the low moisture soil of control. Foot rot lesion in infested soil with moderate soil moisture was 4.1 mm in length, whereas, it was 13.1 mm in infested soil with dry soil moisture.

Discussion

For optimal growth, sweet potato requires a minimum average daily temperature of 24°C and approximately 20

Table 4. Effect of soil moisture content on the development of Fusarium wilt in a glasshouse

Soil moisture (pF)	Inoculation	Disease development			No. of leaves in a stem
		Foot rot lesion length (mm)	Plants with stem rot[a] (%)	Wilted plants[b] (%)	
2.48	Control	0.5 c[c]	0	0	9.9 a
	Inoculated	4.1 b	0	0	9.6 a
2.70	Control	1.0 c	0	0	6.9 b
	Inoculated	13.1 a	100	100	5.1 c

[a] Stem of sweet potato was sliced 2 cm above the soil level, and over 20% discolored vascular ring in cross-section was counted as stem rot.
[b] The plants were watered until saturated condition at 28 days after planting, and wilted plants were counted at 30 days after planting.
[c] Means in a column followed by different letters are significantly different according to Duncans multiple range tests at 5% level.

mm of moisture per week (Clark and Moyer, 1988). Because precipitation and temperature during April is low in Korea (Table 1), polyethylene film mulching has been used to conserve soil moisture and to prevent frost damage in early planting. However, polyethylene mulching is not required in the Yeochon region where there is high rainfall and temperature during the planting period. Survey results indicate that Fusarium wilt disease of sweet potato only occurred in early planting. By comparing the differences of the two cultivation practices, we were able to find major environmental factors involved in the development of Fusarium wilt of sweet potato.

Fusarium is active and survives well in dry soil; therefore, there is an increasing severity in dry rather than wet condition (Cook, 1981). However, Ogawa (1988) reported that sufficient soil moisture to support growth of sweet potato would also favor Fusarium wilt development. In this paper, we showed that Fusarium wilt mainly occurred in reclaimed terracing fields and early seasonal cultivation fields. The effective soil depth in reclaimed terracing fields is generally below 20 cm. As a consequence, reduced water-holding capacity in reclaimed terracing fields due to shallow soil depth seems to be the cause of increasing Fusarium wilt incidence. In contrast, sweet potato fields in Yeochon are mostly reclaimed with natural slope, and soil moisture is sufficient during planting period due to high rainfall. Hence, wilt disease did not occur in Yeochon.

It is known that Fusarium wilt of sweet potato is severe at high temperature (Clark and Moyer, 1988) because of the quick movement of the pathogen in plant (Harter and Whitney, 1927). McClure (1949) showed that the onset of sweet potato wilt infection usually developed in freshly cut transplants. In our field tests (Table 1 and Fig. 1), the incidence of Fusarium wilt was not directly correlated with temperature during planting time, but with rainfall and soil moisture content. These results were supported by the findings from the glasshouse studies. Stem rot and wilt symptoms were most severe when plants were watered and then the soil was allowed to dry, repeatedly (Table 4). Yang et al. (2000) reported that Fusarium disease in fruits and vegetables was more severe when the roots were damaged by the quick change of soil moisture. These results indicate that low rainfall and moisture of soil with low effective soil depth might cause damage to sweet potato rooting, such that the pathogen infects the plant easily through the damaged root. Therefore, low rainfall during planting period is a more important factor in terms of plant pathogen infection than temperature. Disease incidences were 34.7% and 9.3%, whereas, precipitation during planting period were 53.5 mm and 55.0 mm in 1998 and 1999, respectively (Table 3). This might have resulted from the difference in soil texture of tested fields, which were sandy loam and loam in 1998 and 1999, respectively. In fruits and vegetables, Fusarium disease was more severe in sandy loam soil than in loam soil because of the drastic change in soil moisture in sandy soil (Yang et al., 2000). Exceptionally, wilt disease occurred in some reclaimed fields with natural slope such as Ugog and Nasan series (Table 2). In this case, EC and available phosphate content of soil at diseased spot were higher than at healthy spot in the same field (data not shown). Fusarium disease of fruits and vegetables was more severe when EC and available phosphate content were high in soil under PVC house cultivation condition in Korea (Yang et al., 2000). More detailed researches on the influence of soil texture and soil chemical properties on sweet potato wilt disease are required.

Disturbance of pathogen infection to plant could be essential for the control of Fusarium wilt. Researches on application of fungicide, wound healing of the cuttings before transplanting, application of humus to maintain soil moisture, and implementation of irrigation at planting time are required for the effective control of Fusarium wilt of sweet potato.

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