Effect of Potato Virus Y on Growth, Yield, and Chemical Composition of Flue-Cured Tobacco in Chile

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ABSTRACT

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The effect of potato virus Y (PVY) on growth, yield, and chemical composition of flue-cured tobacco cultivars Coker 86 and NC-744 was primarily determined by the time of inoculation. On Coker 86, early inoculations (15 and 28 days after transplanting) caused height reductions of 37.0 and 34.7% and yield reductions of 71.5 and 74.8%, respectively. Effects were less detrimental on NC-744, suggesting this cultivar possesses a degree of tolerance to the Chilean necrotic strain of PVY. Nevertheless, plant height and dry weight were reduced 9.9 and 16.3% and 36.9 and 38.9%, respectively, by inoculations 15 and 28 days after transplanting. PVY also modified the chemical composition of cured leaves. Total nicotine content was always higher in cured leaves from diseased plants than in those from healthy controls. Because early inoculations caused the most detrimental effects, the first month after transplanting should be considered the most critical period for PVY infection.

Potato virus Y (PVY) affects tobacco and other solanaceous crops worldwide (6). The disease has been named *necrosis severa* (NS) in Chile because severe leaf necrosis and necrotic lesions develop on veins and stalks. Leaf malformation and dwarfing have also been observed on highly susceptible cultivars (7). Severe outbreaks of NS have been recorded since 1977 (5).

Flue-cured, burley, and oriental tobaccos have been affected almost equally. Yield reductions between 13.4 and 57.9% were estimated for flue-cured tobacco during 1979–1980 (5), and complete losses have occurred in highly infected fields. At present, NS is considered the major constraint for the tobacco industry in Chile.

The objective of our investigation was to evaluate the effect of time of inoculation with PVY on growth, yield, and chemical composition of two flue-cured tobacco cultivars.

MATERIALS AND METHODS

Flue-cured Coker 86 (one of the most susceptible cultivars to PVY under Chilean conditions) and breeding line NC-744 (resistant to PVY in North Carolina [3]) were seeded on fumigated soil (methyl bromide, 1 lb/10 m^2) and covered with cheesecloth. Symptomless plants were selected for uniformity and transplanted in the usual manner to experimental plots, each consisting of three 20-plant rows 110 cm apart, with plants spaced 50 cm within rows. Only plants in the center rows were inoculated; the outer two rows were planted to minimize vector transmission among treatments. Usual cultural practices for flue-cured tobacco were followed during the growing season, except that plants were sprayed approximately every week for aphid control. Plants were topped about 75 days after transplanting.

The necrotic PVY isolate N-2 originally recovered from tobacco in Chile was used as inoculum. Isolate N-2 caused necrotic lesions on root-knot-susceptible (Burley 21 and McNair 944) and root-knot-resistant (NC-95 and Speight G-28) tobacco cultivars. It also caused necrotic symptoms on NC-744 and Coker 86. N-2 was serologically identified as PVY using PVY-antisera provided by G. V. Gooding, Jr., North Carolina State University, Raleigh.

Inoculum was prepared from greenhouse-grown Coker 86 plants systemically infected with N-2. The newest leaves showing symptoms were collected, ground in a blender with four volumes (w/v) of 0.05 M potassium phosphate buffer (pH 7.2), filtered through cheesecloth, and kept in ice until used. About 1% (w/v) Carborundum (600 mesh) was added to the inoculum before the newest two or three leaves of each plant were rubbed with a cotton pad dipped in the virus suspension. All plants in the middle rows of each treatment were inoculated 15, 28, 44, or 60 days after transplanting. Noninoculated plants served as controls. All treatments were randomized and arranged as a complete block design with five treatments and replicated three times.

The effect of time of inoculation on plant growth was estimated using plant height and dry weight of cured leaves. Plant heights were determined every week on 60 plants per inoculation date, starting 15 days after transplanting (24 November) until plants were topped (27 January). The final heights (75 days after transplanting) were statistically analyzed for variance.

Dry weights were determined from leaves harvested from 36 plants per treatment. Bottom, middle, and upper leaves from each plant were harvested in that order as they reached maturity, characterized by a pale yellow discoloration of the leaf blade. Leaves were cured as usual for flue-cured tobacco in an oven initially heated at 30 C and thereafter gradually heated to 70 C. The curing period was about 110 hr. Leaves were weighed after curing, and composite samples from upper and bottom leaves per treatment were sent for chemical analysis to the Laboratory for Tobacco Analysis, Compañía Chilena de Tabacos, Valparaíso, Chile. Data were statistically analyzed by analysis of variance and orthogonal class comparison.

RESULTS

Effect on yield and growth. All inoculated plants had symptoms of NS, characterized by chlorotic mottle and

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veinbanding, followed by leaf distortion and necrotic lesions primarily on midrib veins. Symptoms appeared first on Coker 86 and about 7–10 days later on NC-744 plants. Coker 86 was affected more severely than NC-744 (Table 1, Fig. 1). The effects of PVY on growth and yield of both cultivars were significantly (P = 0.01) related to the time of inoculation. The most detrimental effects were observed when plants were infected either 15 or 28 days after transplanting. For instance, dry weights were reduced 71.5 and 74.8% for Coker 86 and 36.9 and 38.9% for NC-744 when inoculations were made 15 and 28 days, respectively, after transplanting (Table 1). Inoculations made 44 and 60 days after transplanting did not affect yields. Similarly, height was substantially reduced only when plants were inoculated soon after transplanting (Fig. 1). The effect of PVY on height was greater on Coker 86 than on NC-744 for any inoculation date. A linear response between inoculation date (X) and the percentage of height reduction (Y) was highly significant ($P = 0.01$) for Coker 86 ($Y = 61.8 + 0.7\ X$) but not for NC-744 ($Y = 93.8 + 0.2\ X$). However, highly significant ($P = 0.01$) linear response was obtained between time of inoculation (X) and final dry weight (Y) for Coker 86 ($Y = -7.4 + 3.7\ X$) and NC-744 ($Y = 135.6 + 3.0\ X$). The growth rate (Fig. 1) was substantially reduced only for Coker 86 plants inoculated 15 or 28 days after transplanting. This was closely associated with severe leaf malformation and dwarfing.

Effect on chemical composition. The total nicotine content was consistently higher in cured leaves from diseased plants than in those from healthy controls (Table 2). Differences between healthy plants and inoculated treatments were highly significant for upper and bottom leaves of NC-744 and for bottom leaves of Coker 86, analyzed by orthogonal class comparison. Both Coker 86 and NC-744 had higher amounts of nicotine in upper leaves and lower amounts in bottom leaves. The total nicotine content of healthy cured leaves was higher in Coker 86 (2.84 and 1.46%, respectively, for upper and bottom leaves) than in NC-744 (2.13 and 1.24%, respectively, for upper and bottom leaves) (Table 2).

The amount of reducing sugar also appeared to depend on leaf position in both cultivars, the bottom leaves having a lower content than the upper leaves (Table 2). The effect of PVY on reducing sugar was rather inconsistent in both cultivars, except for a substantial reduction observed in bottom leaves of Coker 86 plants.

Diseased leaves of both cultivars had higher total nitrogen than healthy leaves (Table 2). The effect of PVY on total nitrogen was highly significant on both upper and lower leaves of NC-744 but on only lower leaves of Coker 86.

DISCUSSION

PVY had a significant detrimental effect on growth, yield, and chemical composition, with the magnitude a function of the time of inoculation, the cultivar, and the leaf position on the stalk. Our results agreed with previous work relating the effect of PVY to the length of time the virus was in the host plants (9). Early infections, 15 or 28 days after transplanting, caused the most substantial adverse effect on the factor assessed. This is also consistent with a recent report showing that young root-knot-resistant plants were more susceptible to PVY infections than older plants tested under controlled-temperature conditions (8). Consequently, the first month after transplanting should be regarded as the critical stage of tobacco for NS development. Later infections by PVY may have little or no effect on growth, yield, and chemical composition.

Considering that PVY infection and dissemination are primarily from outside sources after transplanting (4), efforts should be made to prevent the spread of PVY within a tobacco field during this critical period.

Yield reductions caused by Chilean necrotic strains of PVY appeared to be higher than those reported in the United States for flue-cured and burley tobaccos but similar to those reported for flue-cured tobacco in New Zealand (2,5,6,10–12).

The greatest effect of PVY on yield reduction was observed on upper leaves of plants inoculated 15 or 28 days after transplanting (Fig. 2). For instance, yield reductions were 90 and 94% for upper leaves but only 14 and 9% for bottom leaves of Coker 86 plants inoculated 15 and 28 days, respectively, after transplanting (Fig. 2). A similar trend was observed for NC-744. Consequently, NS substan-

Table 1. Effect of potato virus Y on plant height and dry weight of flue-cured tobacco cultivars Coker 86 and NC-744

Inoculation date[a]	Height (cm)	Percent height reduction[b]	Dry weight[c] (g/plant)	Percent dry weight changes[d]
		Coker 86		
15	71.5	−37.0	54.2	−71.5
28	74.1	−34.7	48.0	−74.8
44	100.9	−11.1	201.2	+ 5.6
60	99.3	−12.5	202.5	+ 6.3
Healthy	113.5	...	190.5	...
		NC-744		
15	100.5	− 9.9	183.0	−36.9
28	93.4	−16.3	177.3	−38.9
44	101.6	− 9.0	316.2	+ 8.9
60	112.5	+ 0.8	303.7	+ 4.7
Healthy	111.6	...	290.2	...

[a] Days after transplanting. Inoculations were with necrotic PVY strain N-2.
[b] Compared with healthy plants and determined 75 days after transplanting when plants were flowering, just before being topped.
[c] Determined on cured leaves.
[d] Percentage of healthy plant values.

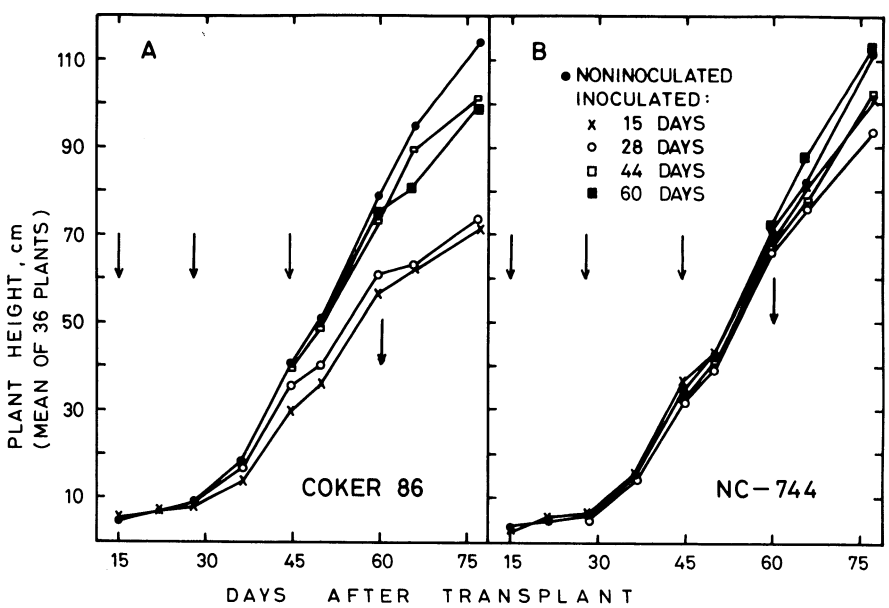

Fig. 1. Effect of time of inoculation with the necrotic strain N-2 of potato virus Y on growth of flue-cured tobacco cultivars Coker 86 and NC-744. Arrows indicate inoculation dates.

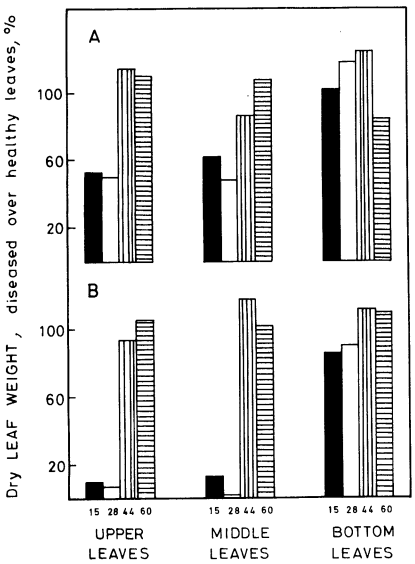

Fig. 2. Dry-weight yield of cured leaves from **(A)** NC-744 and **(B)** Coker 86 inoculated 15, 28, 44, or 60 days after transplanting. Upper, middle, and bottom describe the position of leaves on the stalk.

tially reduced yield of the best-quality leaves. These results also agree with previous work relating leaf composition to position on the stalk (1).

PVY modified the chemical composition of cured leaves. The total nicotine content was the most significant factor affected. Leaves harvested from infected plants had higher total nicotine content than leaves from healthy plants of the same cultivar. This increment, however, may be attributed primarily to an undesirable type of nicotine (12).

The sugar/nicotine (S/N) ratio has been used as a simple quality index. A good S/N ratio varies between 5 and 9. Lower or higher ratios are usually associated with an imbalanced leaf composition (13). According to our results (Table 2), the S/N ratio was significantly modified by PVY in both Coker 86 and NC-744, although the effect appeared to be more severe on cured leaves of Coker 86 plants. The S/N ratio appeared to be normal in cured upper leaves from diseased NC-744 plants. The S/N ratio in healthy cured leaves, however, appeared to be rather high, probably because of inadequate irrigation or fertilization (13).

Necrotic symptoms developed in both NC-744 and Coker 86 tobacco cultivars but were less severe in NC-744. Growth rate, plant height, and yield reduction were also less affected, suggesting a degree of tolerance in NC-744 to the PVY necrotic strain in northern Chile.

Table 2. Effect of potato virus Y on chemical composition of cured leaves from tobacco cultivars Coker 86 and NC-744

Inoculation date[a]	Total nicotine (%)		Reducing sugar (%)		Sugar/nicotine		Total nitrogen (%)	
	Upper[b]	Bottom[b]	Upper	Bottom	Upper	Bottom	Upper	Bottom
				Coker 86				
15	3.15	1.79	12.50	6.98	4.00	4.00	2.25	2.57
28	3.61	2.41	12.77	7.87	3.50	3.30	2.55	2.70
44	3.62	1.86	15.67	17.55	4.30	9.40	1.91	1.63
60	3.61	2.17	17.06	15.53	4.70	7.20	2.18	1.89
Healthy	2.84	1.46	14.86	13.98	5.20	9.60	1.92	1.67
				NC-744				
15	3.17	1.25	19.79	13.37	6.20	10.70	1.69	1.60
28	3.19	1.60	18.25	16.67	5.70	10.40	1.90	1.60
44	2.88	1.73	17.57	13.17	6.10	7.60	1.87	1.73
60	2.10	1.21	20.12	17.20	9.60	14.20	1.40	1.35
Healthy	2.13	1.24	21.37	18.97	10.00	15.30	1.33	1.19

[a] Days after transplanting. Inoculations were with necrotic PVY strain N-2.
[b] Upper = upper 10 or 11 leaves, bottom = lower 10 or 11 leaves on the stalk, approximately.

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