Estimating Losses Caused by Tobacco Vein Mottling Virus in Burley Tobacco

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ABSTRACT

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Procedures are described for estimating losses caused by tobacco vein mottling virus (TVMV) on burley tobacco in individual fields and for the entire crop in North Carolina. The estimations take into account TVMV-cultivar interaction, compensation effect of uninfected plants, and disease incidence. The effect of the virus on different cultivars was studied in naturally infected fields or in artificially inoculated experimental plots. Using the proposed method, we estimated the yield loss of burley tobacco from TVMV in North Carolina in 1978 at 406,940 lb, valued at $520,883. These estimates were based on reported average incidence of TVMV of 12.2% in the 1978 burley tobacco crop in North Carolina.

Disease loss estimates are useful for many purposes but are especially valuable in evaluating disease control systems and in allocating resources for research (1,8–11), particularly in the early stages of investigation of diseases that may cause serious damage. Tobacco vein mottling virus (TVMV) was first reported in 1972 on burley tobacco (*Nicotiana tabacum* L.) in North Carolina (5). Since then, the virus has been described (18) and has been found to be widespread on burley tobacco in North Carolina and other states (6,14). Natural infection of most burley cultivars grown in North Carolina reduces yield on plants that show only mild vein mottling symptoms and no obvious stunting.

During the past few years, we have developed a system for estimating losses caused by this virus. To develop the system, we needed to know 1) the effect of the virus on commercial cultivars grown in defined areas, 2) the percentage of crop acreage planted to each cultivar, 3) disease incidence in the entire crop, and 4) the effect of compensating yield increases in uninfected plants. We report here our progress to date and present our system for others to evaluate.

MATERIALS AND METHODS

Data were gathered for 3 yr on the effect of TVMV on the yield of burley tobacco cultivar Kentucky 14 (Ky 14). More than one-third of the burley crop acreage in North Carolina was planted in Ky 14 during this study. Each year, data were taken from a field of Ky 14 belonging to a different commercial grower and with TVMV incidence of about 50%. Yields of 100 plants with TVMV symptoms were compared with yields of 100 symptomless plants after flower removal. Flower removal, followed by application of a chemical agent to prevent axillary bud development, is a usual practice on burley tobacco (3). Plants of comparable height with and without symptoms were selected randomly throughout a field, and an identifying tag was tied to each.

Usual harvest techniques were followed; plants were cut at the soil line at maturity, stacked in the field until the leaves wilted (24–72 hr), and hung under shelter until the leaves were completely dry. The cured leaves were then stripped from the stalks, weighed, and sold on the open market.

In 1973, data were obtained from leaf composites from the bottom, middle, and upper stalk positions, a customary practice in commercial grading (3). In 1976 and 1977, total leaf weights from individual stalks were recorded.

In 1976, additional data on virus incidence relative to plant height were obtained. Each plant in every fourth row in the field was recorded as either of normal height or one-fourth, one-half, or three-fourths of normal height and was classified as either symptomatic or asymptomatic. Compensating yield increases of healthy plants growing next to stunted plants were also estimated. Yield of the two outside plants of each triplet with a stunted plant of half normal height in the middle was compared with yield of the two outside plants of normal triplets.

Yield reduction for cultivars grown in North Carolina other than Ky 14 was estimated by averaging disease data obtained from sources in North Carolina, Kentucky, and Tennessee (6). In North Carolina, yields of symptomatic and asymptomatic plants were compared from field trials involving three replicates of each cultivar in a location with a known history of TVMV occurrence. Kentucky and Tennessee provided disease response data primarily from mechanically inoculated plots.

Estimates of the percentage of the total crop acreage planted to each cultivar were computed from sales records of F. W. Rickard Seeds, Inc., supplier of more than 90% of all seed for the North Carolina burley crop each year (16). Procedures used to estimate the percentage of the total burley crop infected with TVMV have been reported elsewhere (7).

RESULTS

Effect of TVMV on yield and quality. TVMV reduced yield of Ky 14 tobacco an average of 10.3% in 1973 (Table 1), 8.2% in 1976, and 9.8% in 1977. In 1976, leaves from individual asymptomatic plants weighed 91.4–217.2 g (average 159.2 g), and leaves from symptomatic plants weighed 66.0–217.1 g (average 146.2 g). In 1977, the weights ranged from 103.7 to 214.4 g (average 165.4 g) for individual asymptomatic plants and from 75.1 to 210.6 g (average 149.2 g) for symptomatic plants. Based on a one-tailed comparison

Table 1. Effect of tobacco vein mottling virus on the yield of burley tobacco cultivar Kentucky 14 in 1973

Stalk position of leaves	Weight (lb/A)[a]		Yield reduction	
	Asymptomatic	Symptomatic	lb	%
Bottom	419	412	7	1.7
Middle	1,148	968	180	15.7
Top	753	701	52	6.9
Total	2,320	2,081	239	10.3

[a]Based on weight of cured leaves from 100 plants with and 100 plants without virus symptoms extrapolated to 1 A.

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Table 2. Effect of tobacco vein mottling virus (TVMV) on yield of burley tobacco cultivars before and after adjustment for compensating yield increases of asymptomatic plants and percentage of the North Carolina crop planted to these cultivars in 1978

Cultivar	Yield reduction[a] (%)	Compensation[b] (%)	Adjusted yield reduction[c] (%)	Percentage of crop[d]
Ky 14	9.4	1.2	8.2	39.0
Burley 21 × Ky 14	15	1.9	13.1	6.0
Ky 17	15	1.9	13.1	4.0
Burley 21	20	2.5	17.5	2.0
Burley 21 × Ky 10	20	2.5	17.5	16.5
Ky 12 × L8	20	2.5	17.5	0.5
Ky 14 × L8	20	2.5	17.5	10.0
Burley 21 × Ky 16	25	3.1	21.9	8.0
Ky 10	35	4.4	30.6	1.0
Ky 16	35	4.4	30.6	4.0
Burley 37 × L8	40	5.0	35.0	2.0
VA 509	45	5.6	39.4	5.5
Others[e]	10	1.3	8.7	2.5

[a] Yield reduction for Kentucky 14 (Ky 14) is the mean of 3-yr data obtained in North Carolina. Yield reduction for other cultivars was estimated from data obtained in North Carolina, Kentucky, and Tennessee.

[b] Maximum yield compensation if all symptomatic plants were located between two asymptomatic plants.

[c] Percentage yield reduction from TVMV after allowing for compensating yield increases in asymptomatic plants.

[d] Percentage of each cultivar in the 1978 burley tobacco crop (16).

[e] Minimum effect of TVMV on yield assumed for other cultivars in 1978 crop.

Table 3. Incidence of tobacco vein mottling virus in each of four plant height categories in a 1-A field of burley tobacco cultivar Kentucky 14 in 1976

Plant height category	Total no. plants[a]	Plants with symptoms	Disease incidence (%)
Normal[b]	8,390	3,252	38.8
3/4 normal	410	44	10.7
1/2 normal	152	15	9.9
1/4 normal	48	4	8.3

[a] Observations were made on every fourth row in the field and adjusted to a 1-A basis.

[b] Normal is defined as the visually estimated mean height of the major proportion of the plant population in a given field.

of mean weight, asymptomatic plants weighed significantly more than symptomatic plants (0.05 level) in 1976 and 1977. No significant difference in market value was found between leaves from symptomatic and asymptomatic plants. The estimated effect of TVMV on the other cultivars grown in North Carolina in 1978 is reported in Table 2.

Plant height and disease incidence. Disease incidence was directly related to plant height (Table 3). This relationship was reflected in a significant interaction ($P = 0.01$) between these two variables in a χ^2 test in conjunction with a 2 × 4 contingency table of (symptomatic or asymptomatic) × (normal, 3/4 normal, 1/2 normal, or 1/4 normal height).

Yield compensation. Yield of plants of normal height next to plants of 50% of normal height averaged 5% greater than the mean yield of normal-height triplets. Yield reduction of plants of 50% of normal height was about 80%. Therefore, yield reduction adjusted for a stunted plant between two normal-height plants was in the order of 70%.

We lacked data on yield compensation for the entire range of stunting. However, we estimated the stunting effect by assuming a linear relationship between yield reduction and compensation by adjacent plants: for each 1% yield reduction in the stunted plants, the two adjacent plants compensate for yield in the order of 0.125%. For example, if TVMV depressed yield by 10% on a given cultivar, we assumed a net yield decrease of 8.75% (Table 2).

Estimating statewide losses from TVMV. As an example, we estimated losses from TVMV for the 1978 North Carolina crop. Average percentage yield reduction over all cultivars, $\text{PYR} \cdot C_{\bar{x}}$, equals

$$[(C_1 \times \text{PYR}_{c1}) + (C_2 \times \text{PYR}_{c2}) + \ldots + (C_n \times \text{PYR}_{cn})]/100,$$

where C_i = percentage of cultivar i in the total crop of n cultivars (Table 2), and PYR_{ci} = percentage yield reduction of the ith cultivar after adjusting for compensation of adjacent asymptomatic plants (Table 2). Substituting data from Table 2 into the equation, we obtain $\text{PYR} \cdot C_{\bar{x}} = 15.9$.

Percentage yield reduction for the entire crop, PYR_t, is then

$$(\text{PYR} \cdot C_{\bar{x}} \times \text{PCI})/100,$$

where PCI = percentage of crop diseased (12.2% in 1978 for North Carolina burley tobacco [7]). Therefore,

$$\text{PYR}_t = (15.9 \times 12.2)/100 = 1.9.$$

Next, yield loss, YL, is $Y_p - Y_a$, where Y_p is potential yield in the absence of TVMV and Y_a is actual yield (21,011,000 lb in 1978 [12]). Potential yield, Y_p, is

$$\frac{Y_a}{(100 - \text{PYR}_t)/100},$$

or

$$Y_p = \frac{21{,}011{,}000}{(100 - 1.9)/100} = 21{,}417{,}940.$$

Therefore, YL = 21,417,940 − 21,011,000 = 406,940 lb.

The loss in monetary terms is YL multiplied by price per pound ($1.28 in 1978 [12]), or 406,940 × $1.28 = $520,883.

Estimating losses from TVMV in a single field. Loss in a single field planted to one cultivar may be computed as follows:

$$\text{YR} = \frac{Y_a}{1 - (\text{PYR}_c \times \text{I})} - Y_a,$$

where YR = yield reduction, Y_a = actual yield, PYR_c = percentage yield reduction for the cultivar (expressed as a decimal), and I = incidence (%) of plants with symptoms (expressed as a decimal).

For example, in the field we used for data collection in 1976, the cultivar was Ky 14 ($\text{PYR}_c = 0.082$), disease incidence was 44% (0.44), and actual yield was 3,340 lb. Therefore,

$$\text{YR} = \frac{3{,}340}{1 - (0.082 \times 0.44)} - 3{,}340 = 125 \text{ lb},$$

or in monetary terms, $160.

DISCUSSION

Any model for estimating losses from an aphid-transmitted virus such as TVMV in burley tobacco must consider the time of infection; compensating effects of healthy plants next to diseased plants; and interactions among the virus, other pathogens, and stress factors such as nutrition and environment. Each of these factors can influence the confidence that may be placed in the final estimate.

Mechanically inoculating tobacco transplants with a virus is a valid way to compare tolerance levels among cultivars (4,13,15) but is of dubious value for estimating losses in commercial production. Inoculation of all plants (100% incidence) does not allow for compensation effects of healthy plants growing next to diseased plants. Compensation effects are difficult to quantify because they vary with disease distribution, incidence, and severity. In addition, cultivars probably vary in their capacity to compensate. We used only one class of stunted plants (50% of normal height) in a single cultivar (Ky 14) to serve as a first estimate of compensation across cultivars and disease severities until more definitive data are obtained.

We chose to study commercial fields with naturally infected plants to compensate for possible interacting factors such as other pathogens, nutrition, environment, and virus strains that affect yield differently. The yield reduction caused by TVMV on Ky 14 at three locations over three growing seasons is considered a reasonable estimate. Yield reduction caused by TVMV on the other cultivars, however, was based on only one location in North Carolina in 1 yr. Therefore, these data were averaged with estimates from Kentucky and Tennessee.

To determine disease incidence and yield reduction, plants were rated for the presence of symptoms about 2 wk after flower removal without distinguishing the severity of symptoms. This procedure no doubt led to the inclusion of some plants as symptomatic that became infected at or about the time of flowering. Infection at this stage of growth with potato virus Y (2), a virus similar to TVMV, or with tobacco mosaic virus (17) has little or no effect on yield. If infection by TVMV this late in the development of the plants also has no effect on yield, then our estimates of yield reduction are too low. Counterbalancing this bias are the incidence data, which also included plants infected at this time.

Because TVMV caused little or no stunting of burley cultivar Ky 14, yield reduction data were obtained only from plants of about normal height. Stunted plants may have biased the results if the virus interacted with other pathogens. Also, more stunted plants were asymptomatic than symptomatic (Table 3). The canopy provided by the healthy, taller plants may have protected adjacent shorter plants from landings by aphid vectors.

We think the approach described in this paper has merit for estimating losses resulting from TVMV on burley tobacco. However, we also are well aware that additional work is needed.

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