Relationship Between Leaf Roll Symptoms and Yield in Netted Gem Potato

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ABSTRACT

The relationship between symptom severity and yield of tubers was determined in field experiments with Netted Gem potatoes. Plants with slight, moderate, and severe symptoms yielded 65, 80, and 92% less than those with no symptoms. Plants with mild symptoms (slight rolling of the leaves, but no stunting or chlorosis) yielded as much as those with no symptoms. The equation:

$$\text{Yield loss (\%)} = 100\ (n_d k)/(n_h + n_d)$$

where n_d is the number of plants with slight, moderate, or severe symptoms; n_h is the number with no or mild symptoms; and $k = 0.8$, accurately estimated the loss in yield in both 1970 and 1972 field plot tests. A second equation, containing three constants, is given for use where greater accuracy is required.

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Disease ratings based on symptom severity are commonly used to express the level of disease in samples collected from a plant population. However, the loss caused by the disease cannot be estimated for the population unless a relationship between disease severity and yield is determined. Blodgett (1) developed a mathematical model to assess the yield loss from leaf roll in potato (*Solanum tuberosum* L.) populations. This model took into account the partial compensation by adjacent hills for the decrease in yield of the diseased hill. This approach was further investigated in field studies (2, 4). Other workers have compared the yields of leaf-roll-affected and healthy potatoes grown in adjacent plots (3). Each of these previous investigators grouped all their diseased plants into one severity class, disregarding any differential effect that disease severity may have on yields.

We show here that the severity of leaf roll symptoms and yields of individual plants of Netted Gem potatoes are related and that this relationship can be integrated into an equation to accurately estimate yield loss from the disease.

MATERIALS AND METHODS.—Netted Gem potatoes from stocks naturally infected with the potato leaf roll virus were set out in field plots in 1970 and 1972. The experiments were irrigated by sprinkler as required to maintain optimum soil moisture.

The 1970 experiment had been planned for another purpose. The stock used was derived from foundation seed, which, in retrospect, must by chance have grown in 1969 next to a plot where leaf roll was prevalent and the green peach aphid (*Myzus persicae*) was active toward the end of the growing season. Tubers from these exposed plants were harvested and stored over winter in a root cellar. The next spring, in preparation for the original experiment, one 'eye' was removed from the bud-end of uniform tubers and green-sprouted in the greenhouse. The sprouted eyes were transplanted at 10-cm intervals in eight rows, each 12 m long and 90 cm apart.

Tubers used for the 1972 experiment came from a commercial crop and were collected in the fall of 1971 from plants which exhibited mild leaf roll symptoms. In the spring, these tubers were cut into 60-g seed-pieces and planted at 30-cm intervals in four rows, each 10 m long and 1 m apart. An equal number of seed-pieces from foundation seed were planted as checks. All experimental rows were alternated with additional rows planted with foundation seed.

In early September, while the plants were still green, each plant was rated for severity of leaf roll symptoms. The population fell naturally into five easily recognizable groups on the basis of symptom severity: 0a = healthy = no symptoms; 0b = mild = normal height and color, slight rolling of leaves; 1 = slight = 75% of normal height, foliage slightly chlorotic, leaves with pronounced rolling; 2 = moderate = 40% of normal height, foliage chlorotic, leaves with severe rolling; and 3 = severe = 30% or less of normal height, severe chlorosis, and rolling of leaves.

At harvest, 2 weeks after plants had been rated for leaf roll symptoms, tuber yields were determined and recorded so that subsequent comparison of position, disease class, and yield for each plant was possible.

The experiments were treated as completely randomized designs and results were subjected to analysis of variance. Duncan's multiple range test was used to determine the statistical validity of yield differences among disease classes. The relationship between disease severity and yield was determined by linear regression. Frequencies of the six possible sequences of three healthy and diseased plants were compared with the frequencies expected by chance by a chi-square test. Expected frequencies were derived from expansion of $(H + D)^3$ where H = fraction with no or mild symptoms, D = fraction with slight, moderate, or severe symptoms, and $H + D = 1$ (1).

RESULTS AND DISCUSSION.—Plants with slight rolling of leaves, but no visible stunting or chlorosis (rating class 0b), yielded the same ($P > 0.05$) as those with no symptoms of leaf roll (class 0a) (Table 1). Plants in rating classes 1, 2, and 3 yielded progressively less than those in class 0. The differences between classes were significant ($P < 0.05$) except for that between classes 2 and 3 for 1972. The relationship was linear for classes 1, 2, and 3 and was 280 and 197 g/plant per unit of severity for the 1970 and 1972 tests. However, this linear relationship did not hold for the change from class 0 to class 1. The results for the 2 years agreed remarkably closely when plant yields for each rating class were expressed in terms of yield of the healthy plants (Fig. 1).

An equation relates severity to yield loss:

$$\text{Yield loss (\%)} = 100(n_1k_1 + n_2k_2 + n_3k_3)/(n_0 + n_1 + n_2 + n_3) \quad \text{(Eq. 1)}$$

where n_0, n_1, n_2, and n_3 are the numbers of plants in rating classes 0, 1, 2, and 3, and k_1, k_2, and k_3 are the mean yield losses incurred by plants in rating classes 1, 2, and 3 relative to those in class 0. Based on the results of the 1970 experiment, these constants have the values: $k_1 = 0.65$, $k_2 = 0.80$, and $k_3 = 0.92$. The estimated yield loss for the 1970 experiment calculated from equation 1 was 54.7% compared to the measured loss of 54.5% (Table 1).

Because the relationship between yields of rating classes 1, 2, and 3 is essentially linear, the three yield loss constants (k_1, k_2, and k_3) can be replaced by a single constant k. Based on our 1970 data, the value of this constant was 0.8.

Equation 1 can now be simplified to:

$$\text{Yield loss (\%)} = 100(n_dk)/(n_h + n_d) \quad \text{(Eq. 2)}$$

where n_h and n_d are the numbers of plants in rating class 0 and in classes 1 + 2 + 3, respectively, and k is the loss in yield incurred by a diseased plant relative to a healthy one. Using this equation, the estimated yield loss for the 1970 test was 54.3%. The accuracy of equation 2 is affected by the numbers of plants in classes 1 and 3. However, the equation will estimate the yield loss reasonably accurately if there are few plants in these two classes, or the number of plants in one class is less than twice that in the other.

As a test of the accuracy of equations 1 and 2, they were used to estimate the loss in the 1972 experiment. The yield loss estimates were 58.8% using equation 1, and 60.9% using equation 2, compared to the measured loss of 59.5% (Table 1).

Influence of adjacent plants.—Blodgett and others (1, 2, 4) reported that healthy potato plants next to diseased ones partly compensated for the loss in yield of the adjacent diseased ones. As the position of each plant in both the 1970 and 1972 experiments was recorded, our data were analyzed to determine if measurable compensation occurred (Table 2). Healthy plants situated between two diseased ones within the row yielded 25.6% (1970) and 25.5% (1972) more ($P < 0.05$), and those between a healthy and a diseased one yielded 6.5 and 6.7% more ($P < 0.10$) than those situated between two healthy plants. Diseased plants yielded the same ($P > 0.05$) whether they were between two healthy, two diseased, or a healthy and a diseased plant.

Kirkpatrick and Blodgett (2) developed an equation to estimate the potential yield of potato crops affected by leaf roll based on the theoretical distribution of the six possible sequences of healthy and diseased plants in sequences of three. Using their equation, the estimated yield losses in our 1970 and 1972 experiments were 25.6 and 29.5%. This is only half the loss actually measured (Table 1). In both our experiments, the distribution of plants in each of the six sequences was the same as would be expected ($P > 0.10$).

TABLE 1. Yield of Netted Gem potatoes with different degrees of symptom severity from leaf roll virus infection

Rating	1970		1972	
class[a]	Number	g/plant	Number	g/plant
0	46	2,092 A[b]	27	1,547 A
(0a)	(25)	(2,110 A)		
(0b)	(21)	(2,070 A)		
1	16	724 B	34	523 B
2	56	438 C	29	287 C
3	25	163 D	23	126 C
All	143	954	113	626
Yield, % of potential		45.6		40.5
Yield loss, %		54.4		59.5

[a]Rating classes 0a and 0b are subdivisions of class 0 with no and mild symptoms, respectively; 1 = slight; 2 = moderate; and 3 = severe (see text for detailed descriptions).

[b]Within a column, means followed by the same letter do not differ, $P = 0.05$.

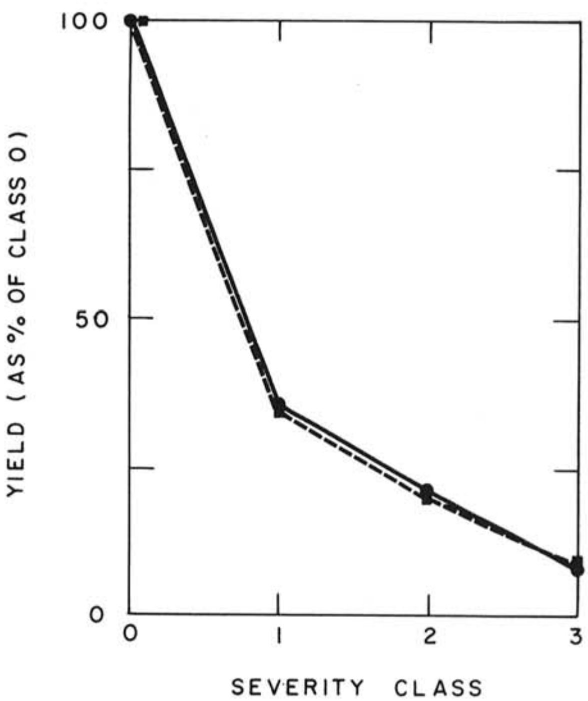

Fig. 1. Yield of leaf-roll affected potato plants, classified according to symptom severity, in relation to that of apparently healthy plants (solid line—1970; broken line—1972).

Equations 1 and 2, using the loss constants $k_1 = 0.65$, $k_2 = 0.80$, $k_3 = 0.92$, and $k = 0.8$ derived from the 1970 data, estimated the actual loss to within 0.3 and 0.1% points for the 1970 experiment, and to within 0.7 and 1.4% points for the 1972 experiment. The substantial underestimation of the loss using Kirkpatrick and Blodgett's equation may be in part because they included plants with mild leaf roll in their diseased group rather than in their healthy one. We found that these plants yielded the same as those with no symptoms of leaf roll.

TABLE 2. Yield of Netted Gem potatoes from the center plant of three, in various within-row sequences of apparently healthy (H) and leaf-roll-virus-affected (D) plants

	1970		1972	
Sequence	Number	Yield	Number	Yield
H-H-H	8 (5)[a]	1,881 B[b]	0[c] (2)	1,329 B
H-H-D[d]	24 (20)	2,004 B	13 (10)	1,418 AB
D-H-D	14 (21)	2,363 A	14 (16)	1,668 A
H-D-H	5 (10)	398 C	5 (5)	300 C
H-D-D[d]	39 (42)	438 C	26 (31)	285 C
D-D-D	53 (45)	398 C	55 (50)	365 C

[a]Numbers in parentheses are those expected for each sequence based on $(H + D)^3$ where H = fraction of plants healthy, D = fraction of plants diseased, and $H + D = 1$. Actual and expected numbers do not differ, $P = 0.10$.

[b]Within a column, means followed by the same letter do not differ, $P = 0.05$.

[c]Yield of the H-H-H sequence in 1972 based on 115 healthy plants from check rows.

[d]Each unbalanced sequence was grouped with its mirror image.

Although plants with mild symptoms of leaf roll do not contribute to loss in yield in the current year, they are an indication of the loss that will occur the next year if tubers from them are used for seed. A selection of tubers from plants rated in class 0b in the 1970 experiment produced plants with moderate to severe symptoms when planted in the field the next year.

An increase in the severity of leaf roll symptoms was found to be reflected by a decrease in yield, showing that symptom severity and yield are related. The marked yield decrease (65%) for plants with slight (class 1) compared to those with no or mild symptoms (class 0) may indicate that there is a threshold level, below which the disease has little effect on potato yields.

Our data confirm the findings of others (1, 2, 4) that healthy plants partially compensate for the loss in yield by diseased ones. However, equations 1 and 2 accurately estimated the yield loss without specific correction for this factor. Presumably, k_1, k_2, k_3, and k account for the yield compensation by the healthy plants.

Equations 1 and 2 appear to be highly practical for estimating the yield loss from leaf roll in the field. However, the values of the constants should be verified experimentally before using the equations in areas that differ substantially in climate from that of southern Alberta, or with potato cultivars other than Netted Gem.

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