Multiple Regression of Tobacco Black Shank, Root Knot, and Coarse Root Indexes on Soil pH, Potassium, Calcium, and Magnesium

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ABSTRACT

Multiple-regression analysis offers an opportunity to obtain more reliable information on root disease-soil analysis relationships than does simple correlation. Data on incidence of tobacco black shank (*Phytophthora parasitica* var. *nicotianae*), root knot (*Meloidogyne incognita acrita*), and coarse root (*Pratylenchus penetrans* and *P. brachyurus*) and soil pH, K_2O, CaO, and MgO for 13 crop years were analyzed. The relative reliability of the following conclusions is judged by the consistency and magnitude of the responses: (i) black shank: pH, strong positive linear; K_2O, moderate quadratic, min 500 lb./acre; CaO, inconclusive; MgO, weak positive linear; (ii) root knot: pH, moderate negative linear; K_2O, moderate quadratic, max 800 lb./acre; CaO, moderate quadratic, min 1,300 lb./acre; MgO, weak quadratic, min 300 lb./acre; (iii) coarse root: pH, moderate quadratic, min 6.0; K_2O, strong positive linear; CaO, weak quadratic, min 1,200 lb./acre; MgO, weak negative linear. Fortunately, soil analyses found in cigar-wrapper tobacco fields in north Florida and southwest Georgia are mostly favorable to control of diseases, with the exception of black shank, which is aggravated by liming but controlled rather well by other means. Phytopathology 60:1513-1516.

Multiple-regression analysis offers an opportunity to obtain more reliable information on relationships of disease incidence to soil analyses than does simple correlation. When the effect of one factor has been removed, there may appear a quite different relationship to another factor from that indicated by simple correlation, which measures the effect of one factor, unadjusted for the effect of any additional factors. The sign of a linear relationship may even be reversed.

Some studies on the relationship of black-shank incidence to soil analyses have been reported. Valleau et al. (10) considered the presence of lime in the soil more of a factor in the persistence of the fungus than was soil pH. Irvine & Valleau (4) observed that fields with soil pH of 6.5 or above were more likely to develop the disease and carry the fungus from year to year than those of pH 5.6 or below. Kincaid & Gammon (5) reported highly significant positive linear correlations of black-shank incidence with soil pH and calcium.

Troutman & LaPrade (9) found that incidence of black shank was much higher in soil at pH 7 than at pH 4. McCarter (8) concluded that, within the range generally recommended for tobacco production, soil pH was not an important factor. Wills (11) stated that "the ecological significance of soil reaction on this disease is still uncertain".

Dukes (1) and Dukes & Apple (2) studied the inoculum potential of the black-shank *Phytophthora* in 99 soil samples as related to widely varying soil analyses. They derived three quadratic equations which showed max at pH 6.51, 4.368 meq of exchangeable calcium/100 g of soil (about 2,450 lb. of CaO/acre), and 2.447 meq of exchangeable magnesium/100 g of soil (about 987 lb. of MgO/acre). Soil P_2O_5 and exchangeable K_2O showed no appreciable effect.

Little information has been reported on the relationship between nematode diseases and soil factors. Kincaid & Gammon (5) found that incidence of root knot and coarse root varied inversely with soil pH. Gammon & Kincaid (3) reported that actual numbers of parasitic nematodes in the root decreased with increasing pH.

Materials and Methods.—Data from three experiments were used in the preparation of this paper. The first two, 1954-1958 and 1959-1962, were designed to study the effect of soil pH on cigar-wrapper tobacco. Soil pH was adjusted by amendments of sulfur or hydrated lime to provide a range of pH values corresponding to that of cigar-wrapper tobacco fields in the vicinity of Quincy, Florida. Soil analyses made each year during the latter part of the crop season showed that, with increasing soil pH, there were increases in soil potassium and magnesium as well as in calcium. The third experiment, 1955-1958, was designed to study the effect of sources and levels of applied nitrogen, phosphorus, potassium, calcium, and magnesium on the crop. Soil analyses varied widely in this experiment. The soils were all classified as fine sandy loams.

Methods of soil analysis were as follows: Soil pH was determined by glass electrode on one part of soil to one part of water by volume. Five g of soil were extracted with 25 ml of 0.7 N ammonium acetate plus 0.54 N acetic acid buffer solution at pH 4.8. Potassium, calcium, and magnesium in the extract were determined by means of a flame photometer.

The first experiment was conducted in an area where tobacco had been grown each year for several years;

the soil was moderately to heavily infested with the pathogens of black shank (*Phytophthora parasitica* Dast. var. *nicotianae* [Breda de Haan] Tucker), root knot (*Meloidogyne incognita acrita* Chitwood, 1949), and coarse root or nematode root rot (*Pratylenchus penetrans* [Cobb, 1917] Filipjev & Stekhoven, 1941 and *P. brachyurus* [Godfrey, 1929] Filipjev & Stekhoven, 1941). The second and third experiments were conducted in an area where tobacco was grown in alternate years; incidence of black shank was low, but root knot and coarse root were high in some seasons.

Shortly after completion of leaf harvest, plants from each plot were pulled and rated for each disease from 0 (none) to 100 (most severe). The average rating was recorded as the disease index. Cigar-wrapper tobacco cultivars were used in all experiments.

In the multiple-regression analyses, indexes of the three soil-borne diseases, black shank, root knot, and coarse root, were the dependent variables. Soil pH and lb. per acre of K_2O, CaO, and MgO were the independent variables.

Regression equations were determined in a step-wise manner. The variable explaining the largest amount of variation in the total sum of squares was fitted first. Before the selection of the next factor to be included in the model, the data were adjusted to remove the effect of the first variable. The second factor was then selected, being that variable which explained the greatest amount of the remaining variation. The procedure was continued until no further significant reductions were found. Location parameters were not included, and, therefore, the error term was slightly inflated. All tests of significance were based on the 90% level of confidence.

Regression equations took the following form: Disease index $= b_0 + b_1(\mathrm{pH}) + b_2(\mathrm{pH})^2 + b_3(K_2O) + b_4(K_2O)^2 + b_5(\mathrm{CaO}) + b_6(\mathrm{CaO})^2 + b_7(\mathrm{MgO}) + b_8(\mathrm{MgO})^2$. Interactions were not sought. Equations were calculated for the three diseases for the 13 crop years (9 calendar years); also for the 4 or 5 years of each experiment combined, but year parameters were not included. For example, one equation for the 5 years of the first experiment was as follows: Black-shank index $= 13.54 - 0.166(K_2O) + 1.550(\mathrm{pH})^2 + 0.000150(K_2O)^2 - 0.00000719(\mathrm{CaO})^2$. The occurrence of a significant quadratic effect without the corresponding linear term suggested that the response was approaching a max or min beyond the limits of the independent variable.

The disease index for each soil factor which contributed significantly to the response was calculated and located so as to fall within the limits of the dependent and independent variables involved.

Results.—Results are presented graphically in Fig. 1. Curves are identified by the experiment number, and by the last digit of the year number, or, for years combined, by the letter "C". Conclusions are given for each disease where responses to a given soil factor were predominantly consistent as to sign and of sufficient magnitude to be considered important. In the following section, the word "strong", "moderate", or "weak" indicates the authors' description of the relative reliability of the conclusion. For quadratics, the estimated average location of the maxima or minima is also given. Results are described as follows: (i) black-shank index: pH, strong positive linear; K_2O, moderate quadratic, min 500 lb./acre; CaO, inconclusive; MgO, weak positive linear; (ii) root-knot index: pH, moderate negative linear; K_2O, moderate quadratic, max 800 lb./acre; CaO, moderate quadratic, min 1,300 lb./acre; MgO, weak quadratic, min 300 lb./acre; (iii) coarse-root index: pH, moderate quadratic, min 6.0; K_2O, strong positive linear; CaO, weak quadratic, min 1,200 lb./acre; MgO: weak negative linear.

With the approval of J. L. Apple, Department of Plant Pathology, North Carolina State University, Raleigh, who directed Dukes' research (1), and the cooperation of Dukes in furnishing additional soil analyses, we subjected Dukes' black-shank data to multiple-regression analysis. Our estimated regression equation, in terms of pH and of P_2O_5, K_2O, CaO, and MgO in lb./acre was as follows: Black-shank index $= -82.65 + 30.41(\mathrm{pH}) + 0.00525(\mathrm{MgO}) - 0.00476(K_2O) + 0.00469(P_2O_5) - 2.418(\mathrm{pH})^2$. This equation indicated a disease-index max at pH 6.3, and linear relationships with magnesium and phosphorus (both positive) and with potassium (negative). Calcium apparently did not influence the disease index.

Discussion.—Our results indicated a strong positive linear relationship of black shank to soil pH within the range of our data, mostly between pH 5 and 6. The data of Dukes (1) and Dukes & Apple (2), extending beyond pH 7, showed a quadratic relationship, with a max at pH 6.3, according to multiple-regression analysis of the data. The quadratic curve, superimposed in an arbitrary position over our linear curves (Fig. 1-C), shows a close association. Thus, both sets of data support the conclusion that an essentially linear relationship exists between black shank and soil pH within the range generally recommended for tobacco.

The response of black shank to soil calcium is left in question. Some reports (1, 5, 6, 10) indicated a definite relationship. However, our results and those of Dukes (1) and Dukes & Apple (2), as recalculated by multiple regression, indicated no significant response. Wills & Moore (12), however, working with nutrient solutions, concluded that black-shank development was directly correlated with the amount of calcium at the time of inoculation, regardless of prior nutrition.

If only one soil is used, the relationship between soil pH and calcium is such that both would be expected to be similarly related to a dependent variable such as black-shank index. When several soils or locations are considered, effects of soil texture and exchange capacity will result in such variations in calcium activity and quantity that previously observed responses to calcium may become insignificant, although the response to pH remains. On the other hand, the percentage of the exchange complex occupied by calcium might show a relationship to black-shank incidence.

The regression of black shank on soil CaO (Fig. 1-C,

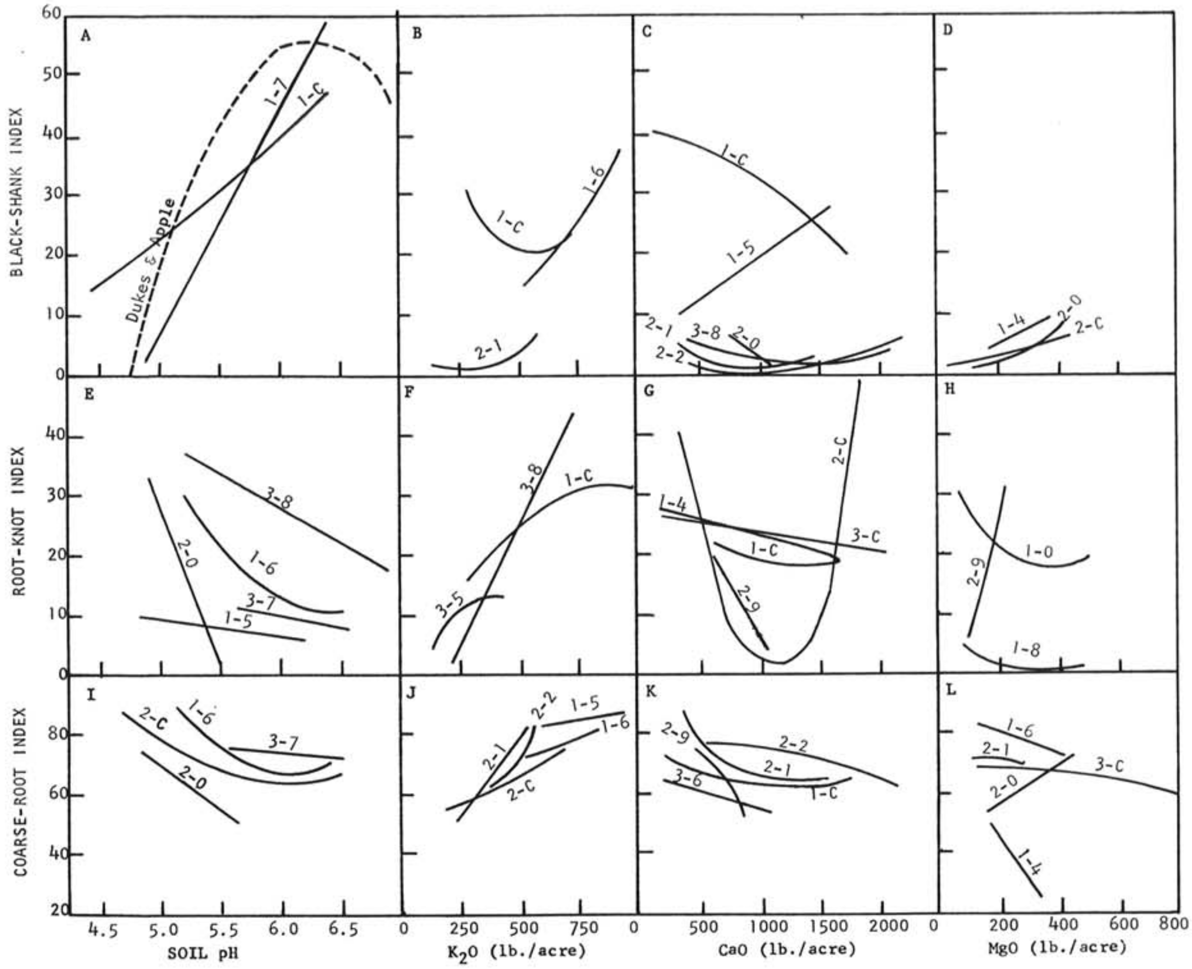

Fig. 1. A-L) Regression of tobacco black shank (*Phytophthora parasitica* var. *nicotianae*), root knot (*Meloidogyne incognita acrita*), and coarse root (*Pratylenchus penetrans* and *P. brachyurus*) indexes on soil analyses. Curves are identified by the experiment number, and by the last digit of the year number or, for years combined, by the letter "C". Experiment 1 ran from 1954 to 1958, experiment 2 from 1959 to 1962, and experiment 3 from 1955 to 1958. The broken line in A is taken from the data of Dukes (1) and Dukes & Apple (2), recalculated by multiple regression and used by permission of the authors.

curve 1-C) illustrated a change of sign from a positive correlation coefficient, +0.314, to a negative term, −0.00000719 $(CaO)^2$, in the multiple regression equation.

In corroboration of our observation on the positive effect of soil potassium on root-knot incidence, Marks & Sayre (7) noted that high potassium accelerated development and increased final populations of *Meloidogyne incognita* in cucumber roots; *M. javanica* and *M. hapla*, however, were not influenced by potassium. Black-shank responses appear quite different from those of the nematode diseases, which, on the other hand, are similar to each other.

Disease min indicated by our results fortunately fall within or near the range of soil analyses found in cigar-wrapper tobacco fields in northern Florida and southwest Georgia as follows: Soil pH, 5.6-6.2; K_2O, 300-700 lb./acre; CaO, 600-1,200 lb./acre; and MgO, 150-400 lb./acre. Further interpretation must await a determination of the optima for yield and various aspects of quality. The root-knot max at 800 lb. of K_2O/acre (Fig. 1-F), which approaches the highest level found in field soils, is not considered serious because soil nematicides are applied routinely. The positive linear relationship between black shank and soil pH (Fig. 1-A) is unfortunate in view of the prevailing practice of liming to pH around 6 for the sake of leaf quality. Reasonably satisfactory black-shank control is achieved, nevertheless, by black-shank resistance and crop rotation.

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