Association of Potato Early Blight, Nitrogen Fertilizer Rate, and Potato Yield

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ABSTRACT

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The relationship between rate of nitrogen fertilizer application and potato yield was studied in the presence and absence of potato early blight caused by *Alternaria solani*. An analysis of the quadratic equation representing the response of yield to nitrogen fertilizer application indicated an optimum rate of 133 kg N/ha in the absence of potato early blight and 160 kg N/ha in its presence. Increased rates of nitrogen fertilizer application reduced the apparent infection rate and the final amount of early blight disease. Increased early blight severity was associated with decreased crop yields. Economic evaluation of the association of early blight severity, tuber yield, and nitrogen fertilizer rate suggests that, in view of current market prices and the potential for potato early blight epidemics, present recommendations for nitrogen fertilizer rates should be reevaluated.

Additional key words: crop loss, *Solanum tuberosum*

Constant reevaluation of recommended fertilizer rates is easily justified as nitrogen fertilizer prices continue to increase. Although overfertilization is thought to be common among eastern U.S. potato growers, some observers have suggested that, as the price of nitrogen fertilizer continues to increase, the practice will greatly diminish. With that prospect in mind, it can be hypothesized that "senescent type pests" (ie, pests that attack the more mature plant tissues) could become more troublesome.

This may be particularly true with potato early blight disease caused by *Alternaria solani* (Ellis and Martin) Jones and Grout. In addition, use of protective fungicides could be significantly reduced through the BLITECAST fungicide recommendation system (7) for control of potato late blight disease caused by *Phytophthora infestans* (Mont.) de Bary. In the absence of protective fungicides during unfavorable weather for late blight and the prospect of *P. infestans* specific fungicides, early blight epidemics may become more common.

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Potato early blight symptoms first occur on the lower senescing leaves, which become chlorotic and abscise prematurely. Excessive defoliation may lead to death of the plant and consequent yield loss. The pathogen can also attack potato tubers and produce a shallow, dry, corky rot (4,8).

Substantial potato crop losses occur as a consequence of potato early blight disease (9,10), but such losses can be reduced with protective fungicide applications (3,5,15).

Inadequate soil fertilization or early plant senescence are factors that frequently contribute to the development of early blight epidemics. Also, *A. solani* is a weak parasite in that it attacks tissues weakened by age or stress (2). High nitrogen and low phosphorous fertilizer levels result in reduced early blight severity (1,13). It is sometimes reasoned that high levels of nitrogen fertilizer prolong plant vigor and delay plant maturity.

The following study was designed to investigate the interrelationship of potato early blight disease severity on potato yield and the effect of rate of nitrogen fertilizer application on both of these factors. The objective was to develop a better understanding of the dynamics of nitrogen fertilizer rate on early blight disease severity and potato crop yield.

MATERIALS AND METHODS

The uniform plot of Hagerstown silt clay loam at The Pennsylvania State University's Department of Plant Pathology Research Farm at Rock Springs (Centre County) was prepared with standard commercial practices and planted with *Solanum tuberosum* (L.) 'Kennebec' on 1 May 1978. A mechanical planter was used to open the rows and apply phosphorus and potassium fertilizers each at 140 kg of actual element per hectare. Ammonium nitrate was applied manually in the open furrows to obtain 0, 50, 100, 150, or 200 kg of actual elemental nitrogen per hectare in the plots.

Treatment plots were 4.5 m (five rows wide) by 7.6 m. Each treatment was replicated four times. Foundation quality whole seed (B size) was placed by hand at a spacing of 23 cm and covered with disks mounted under a tractor. All treatment plots received standard commercial pesticides to control weeds (preplant EPTC [5-ethyl dipropylthiocarbamate], 8.2 kg a.i./ha) and insects (aldicarb, 3.4 kg a.i./ha).

Two complete sets of experimental treatments were used to evaluate the impact of potato early blight. One experimental set received nine weekly foliar sprays of mancozeb (1.3 kg a.i./ha) for early blight protection. The second experimental set did not receive mancozeb and was inoculated with a standardized suspension of 10^5 *A. solani* conidia per milliliter of glass distilled water. On 7 July 1978 at 2000 hr EDT, the spore suspension was applied with a mist sprayer to the middle row of the appropriate plot for each treatment.

Additionally, the systemic fungicide metalaxyl was applied at 1.75 L/ha every 2 wk to all plots (30 June and 17 August) to protect against potato late blight. In other studies we have observed that metalaxyl does not appear to be effective against early blight.

In the two experimental sets, the subtreatments were separated from each other by open alleyways 3 m wide. The two experimental sets were physically separated by a barren strip 12 m wide.

Disease severity (the proportion of leaf area with symptoms) was assessed according to the Horsfall-Barratt scale (6) at six sites along each inoculated row for each treatment for all replications. Assessments were recorded weekly for 5 wk beginning 1 August 1978. Potato vines were treated with a vine killer on 28 August and 6 September 1978. The middle row of each five-row unit was harvested on 12 September 1978 and the

Table 1. Regression equations for yield response (y) in metric tons/ha to nitrogen fertilizer and associated statistics for the potato cultivar Kennebec affected by potato early blight disease

Disease	Equation[a]	R^{2b}	Residuals[c]
Present	$y = 20.8 + 0.264x - 0.0008x^2$	98.4	OK
Controlled	$y = 28.1 + 0.293x - 0.0011x^2$	92.2	OK

[a] Nitrogen rates (x) ranged from 0 to 200 kg N/ha.
[b] Coefficient of determination expressed as percent.
[c] Plotting the residuals vs. the predicted value of the dependent variable allows inspection of patterns that may indicate invalid statistical assumptions. Scattered patterns are judged satisfactory (ie, OK).

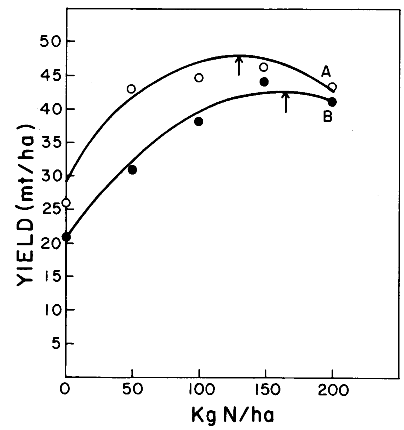

Fig. 1. Yield response of Kennebec potatoes to nitrogen application in the absence (A) and presence (B) of early blight. Arrows indicate the calculated optimum nitrogen rate for maximum yield.

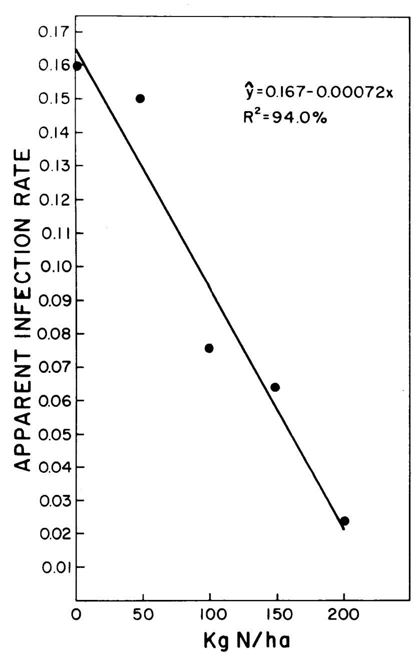

Fig. 2. Effect of nitrogen fertilizer application on the apparent infection rate of potato cultivar Kennebec by *Alternaria solani.*

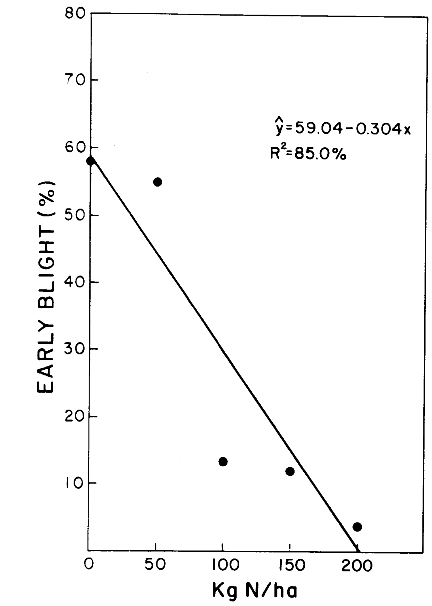

Fig. 3. Effect of nitrogen fertilizer on the final severity of early blight disease of potato cultivar Kennebec.

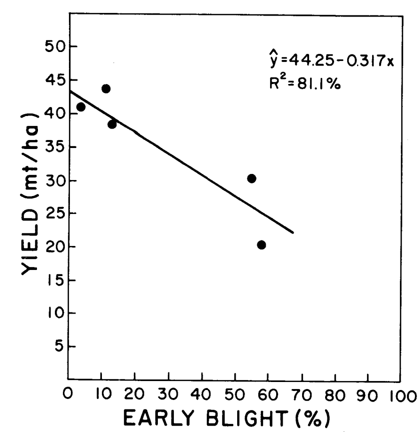

Fig. 4. Relationship between yield of potato cultivar Kennebec and final early blight disease severity.

tubers were sized to obtain the weights of U.S. No. 1 tubers expressed as metric tons per hectare (t/ha).

Samples of the U.S. No. 1 grade tubers from each experimental treatment were selected and placed in 4 C storage for 4 mo. After storage, the samples were washed and their specific gravity determined with a hygrometer. The samples were reconditioned at 16 C for 3 wk, then peeled, sliced, and deep fat fried at two times 1 wk apart to evaluate chip color. All determinations were replicated four times.

Data were analyzed by analysis of variance and regression techniques with The Pennsylvania State University's Computation Center IBM System 370 computer and standard library programs at the center.

RESULTS

Control of potential interplot spread of the early blight disease epidemic from the inoculated experimental set was apparently satisfactory, as no disease was observed on plants in the uninoculated area at the time of vine killing.

The yield curves in response to nitrogen application differed for the two experimental sets and this association was attributed to differences caused by early blight disease. Figure 1 shows the response curves from the blight vs. no blight plots as the mean of the four replications for each of the five rates of nitrogen fertilizer. The yield response curves were analyzed by linear regression analysis of a quadratic model. Those equations and the associated statistics are given in Table 1. With the first derivative of these two equations, the maximum yield response could be obtained as an optimum value of applied nitrogen. The optimum nitrogen rate was calculated as 133 kg N/ha in the absence of potato early blight and 160 kg/ha in the presence of potato early blight.

Regression analysis of the logit transform values of the proportion of disease gave apparent infection rates (14) that decreased with increasing nitrogen application (Fig. 2). The final amount of early blight disease recorded also decreased with increased rate of applied nitrogen (Fig. 3). As the final amount of disease severity increased, tuber yield decreased (Fig. 4).

The relationships of applied nitrogen fertilizer to terminal disease severity and of terminal disease severity to yield were integrated by algebraic substitution of the two regression equations shown in Figures 3 and 4:

$$y = 44.25 - 0.317\ (59.04 - 0.304\ N)$$

where y is the predicted yield in metric tons per hectare and N is the number of kilograms of nitrogen applied per hectare. That relationship reduces to the prediction equation that is plotted in Figure 5 along with the actual observed values. Correlation of the observed to predicted values gave a highly significant correlation coefficient (0.904**).

An economic evaluation of the relationship of nitrogen to yield in the presence of potato early blight was made by using current prices for nitrogen fertilizer and the value of harvested crop effective 15 September 1979 (Fig. 6). Based on these factors, the maximum net return was 162 kg N/ha, which is considerably higher than the current recommended rate for commercially produced processing potatoes for much of the eastern U.S. potato production region.

After tuber samples were stored 4 mo at 4 C, modest reductions in specific gravity were associated with the three highest levels of nitrogen fertilizer. Chip color after frying was equally impaired by

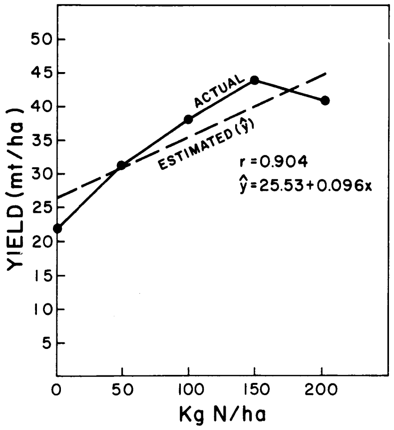

Fig. 5. Actual (observed) and expected (y) tuber yield in response to nitrogen fertilizer application (x) in the presence of potato early blight disease on cultivar Kennebec.

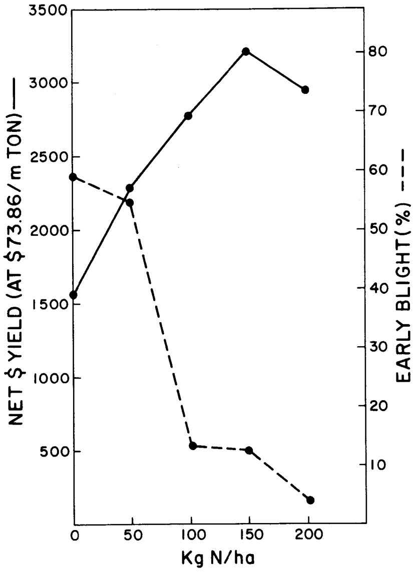

Fig. 6. Expected net dollar return plotted against applied nitrogen fertilizer for the selling price of potatoes at harvest on 15 September 1979 (—), and the terminal early blight severities plotted against applied nitrogen fertilizer (--).

all levels of nitrogen fertilizer (relative to the no nitrogen check plots). No interaction of specific gravity or chip color with early blight disease was suggested.

DISCUSSION

In the past, fertilizer recommendations for major food crops were based solely on agronomic evaluations. Little or no consideration has been given to the direct and indirect effects of fertilizer rate on pest epidemics and their effects on yield. Recently Reddy et al (11,12) demonstrated that, in central India, nitrogen top dressing could be used to manage bacterial leaf blight of rice caused by *Xanthomonas oryzae* (Uyeda and Ishiyama). Bacterial leaf blight of rice is accentuated by higher rates of nitrogen fertilizer, and with their method, bacterial leaf blight of rice would be controlled by withholding final top dressing at panicle initiation if the disease is observed.

The opposite situation exists with the senescent type of diseases of potatoes. Additional applications of nitrogen fertilizer may allow the grower to forestall senescence and hence control certain pests that can reduce crop yield. Far more information will be needed to construct pest management systems focusing on the interrelationship of the nitrogen fertilizer and pest control. Moreover, other essential elements may play similar roles in pest control opportunities.

Commercial potato chip manufacturers often state that nitrogen fertilizer is bad for potatoes from both the economic and quality standpoints. Many Pennsylvania potato growers ignore this and apply nitrogen at rates that could be considered too high. However, given the current state of potato technology, it now seems more obvious why growers would use slightly higher rates of nitrogen fertilizer when potato early blight may be encountered. The significant drop in specific gravity and reduced potato chip quality associated with nitrogen fertilization are consequences that they must tolerate since economically suitable alternatives for early blight control are lacking in the northeast United States.

Research programs developing cultivars for potato production must take into account the relationship between nitrogen fertilizer and senescent type of pests of potato. If today's relatively high rates of nitrogen fertilizer become no longer economical, tomorrow's potato varieties must be commercially suitable when produced at reduced rates of nitrogen fertilizer. Reduced nitrogen fertilizer application and the likelihood of reduced amounts of or limited spectrum protectant fungicides must be factors in the design of potato management strategies. Obviously, cultivars with resistance to many pests of the senescent type will be needed. The present practice of using nitrogen fertilizer for pest control cannot long continue.

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