EFFECTS OF DIFFERENTIAL RATES OF NITROGEN AND PHOSPHORUS ON EARLY BLIGHT IN POTATOES

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Abstract

The Kennebec variety of potato was exposed to *Alternaria solani* inoculum during the 1970 and 1971 seasons to determine the effects of differential rates of nitrogen and phosphorus on the incidence of early blight. Both high nitrogen and low phosphorus treatments significantly reduced the incidence of early blight and the combination of high nitrogen and low phosphorus consistently gave the lowest incidence of the disease during both years. The data suggest that this combination of nutrients may be related to early blight resistance in the plant by extending the period of meristematic activity permitting the plant to wall off infection. Yield data indicated that there was too great a yield difference between fertilization for optimum early blight control and fertilization for optimum yield. Therefore, in Maine, potatoes should be fertilized for optimum yield with a reasonable specific gravity, and early blight should be controlled by the application of fungicides and sanitation measures.

Introduction

Early blight of potato and tomato caused by *Alternaria solani* (Ellis and Martin) Jones and Grout has become of increasing importance in recent years on potatoes in Maine. The disease has been considered by many to be related to plant senescence (1, 2, 8, 11, 12). Stavely and Slana (13) observed that *Alternaria alternata* penetrated tobacco leaves of all ages equally well, but the younger leaves were able to wall off the fungus to stop further advancement, while necrotic lesions were still very small. Douglas and Pavek (1) found that, in screening potatoes for field resistance to early blight, resistance was apparently related to inhibition of the development of the initial infection site.

Research on the relationship of host nutrition to early blight development has not been reported for potato, but Walker et al. (17) found that high nitrogen and high phosphorus reduced the disease in field tomatoes. Also in a field study, Horsfall and Heuberger (7) obtained similar reductions of the disease in tomato with high nitrogen nutrition. Thomas (15), however, found that low nitrogen reduced early blight and high phosphorus increased the disease in two out of three trials under greenhouse conditions. Horsfall and Dimond (6) concluded that early blight was a low sugar disease and that any factors reducing the sugar content of leaves would increase early blight infection. High nitrogen delays plant maturity especially when other elements are not adequately supplied, while high phosphorus hastens plant maturity (Tisdale and Nelson 16).

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TABLE 1.—*Percentage leaf surface showing early blight lesions, total sugar levels and plant height of Kennebec potato variety treated with differential levels of nitrogen and phosphorus.*

Treatment	Percentage disease		Percentage total sugars 1971	Plant height inches 1970	Plant height inches 1971
	1970 Reading	1971 Reading			
0-0-120	8.3bc	15.0a	7.8b	19.3b	15.5c
60-0-120	8.5abc	9.2b	7.9b	25.8a	20.6b
120-0-120	6.3c	4.0c	9.3a	25.3a	20.1b
Average	7.7b	9.4b	8.4a	23.5a	18.7a
0-60-120	11.0abc	12.8ab	8.0b	20.0b	13.2c
60-60-120	13.8ab	15.4a	7.7b	26.5a	20.8b
120-60-120	15.5a	14.1a	9.6a	25.8a	22.9ab
Average	13.4a	14.1a	8.4a	24.1a	19.0a
0-120-120	9.8abc	15.1a	8.8ab	19.6b	14.1c
60-120-120	14.5ab	17.0a	7.9b	26.0a	21.4ab
120-120-120	14.8ab	13.4ab	8.7ab	26.6a	24.0a
Average	13.0a	15.2a	8.5a	24.1a	19.8a
120-240-120	15.2ab	12.3ab	9.9a	28.8a	24.1a

The objectives of this research were as follows: (i) to study the effects of differential rates of nitrogen and phosphorus on the incidence of early blight of potato under field conditions; (ii) to observe the relationship between the percentage of sugars in the leaves and the extent of early blight disease; (iii) to determine the influence of differential rates of nitrogen and phosphorus on plant height, yield and specific gravity of tubers.

Materials and Methods

Ten differential levels of nitrogen and phosphorus were applied in combination with 120 and 30 lb per acre of potassium and magnesium respectively in a 2-year study, as presented in Table 1. The plots were arranged in a randomized complete block design with treatments replicated six times. Each plot consisted of three 36-foot rows with two disease spreader rows located between every two plots and a border disease spreader row on each side of the experiment. The spreader rows were inoculated with early blight spores in order that an infection of early blight would become established in these rows and thus provide inoculum to the plots with the various fertilizer treatments.

The Kennebec variety was planted with the various fertilizer treatments on May 23, 1970, and on May 11, 1971, using a two-row assisted-feed Lockwood planter with endless belt fertilizer attachments as described by Hawkins (4). Seed-pieces were spaced 9 inches apart in 34-inch rows. Fertilization of the spreader rows was at the rate of 120-120-120-30 lb per acre, banded at time of planting. Rapid soil tests prior to planting gave the following readings: pH 5.4, phosphorus low, potassium medium high, calcium low, magnesium medium.

The plots and spreader rows were cultivated and hilled twice during the growing season. Endosulfan was applied weekly at the rate of one pint per acre to control insects. Polyram was applied to all but the spreader rows at the rate of 1 ½ lb per acre on August 10, and August 28, 1970 to control late blight. No fungicides were applied during the 1971 growing season.

Preparation of inoculum:

Three isolates of the early blight causal fungus were grown on Difco potato dextrose agar at 26-28 C (79-82 F). The agar and fungal material were mascerated with 50 ml of sterile distilled water for one minute. Three ml of this suspension were pipetted onto filter paper in a petri plate. The plates were exposed to 150-foot candles of fluorescent light for 48 hours at a temperature of 25 C (77 F) to initiate the formation of conidiophores. The plates were then incubated in a dark laboratory cupboard at 20 C (68 F) until spores formed and then air-dried for storage.

On August 12, 1970, spores of all cultures were washed and brushed from the papers with a soft-bristled nylon toothbrush and used to prepare a final inoculum containing in excess of 5000 spores per cc. Inoculum was applied during the evening to the spreader rows using a hand sprayer. Rain which amounted to 0.82 inches had fallen during the day of inoculation. By evening the rain had ceased except for a light mist and the air temperature was 15 C (59 F). Inoculum was not applied during the 1971 season as the plots developed a natural infection of early blight.

In both years, ten plants were randomly selected from each plot and were given a rating based upon the percentage of leaf area covered by early blight lesions using the Horsfall-Barratt (5) system.

Sugar determinations:

From August 14-21, 1971, two second whorl leaflets were collected from each of ten plants selected at random in each treatment. Sap was expressed from the leaflets using an electric leaf squeezer as described by Hastings et al. (3). An Atago hand sugar refractometer was used to determine sugar content of each sample. A mean sugar percentage was determined for each treatment.

Harvest data:

The plots were harvested on October 1, 1970 and on September 22, 1971. The tubers were placed in 50-lb paper bags and placed in a storage not having temperature and humidity control. After a period, tubers from each treatment were sized, weighed and counted. Ten lb samples of each treatment were placed in 3 C (38 F) storage and were observed for early blight lesions on December 26, 1970.

Specific gravity of tubers was determined on each 10 lb sample by the air and water method as described by Murphy and Goven (10).

Disease readings, sugar content of leaves; plant heights in inches, yields per acre, and specific gravity data were subjected to analysis of variance. Differences among individual means were compared using Duncan's multiple-range test as described by Steel and Torrie (14).

Results and Discussion

Incidence of early blight:

Zero phosphorus treatments for both the 1970 and 1971 seasons gave a significant decrease in the percentage of leaf surface showing early blight lesions (Table1). The zero phosphorus treatments averaged 7.7% infection as compared to 13.4 and 13.0% infection for 60 and 120 lb per acre of phosphorus respectively in 1970. In 1971, zero phosphorus treatments averaged 9.4% infection as compared to 14.1 and 15.2% infection for 60 and 120 lb per acre of phosphorus respectively. Appreciable residual phosphorus in the soil was suspected since there were no significant differences in the percentage of total sugars, plant height, yield or specific gravity of tubers between 0, 60, and 120 lb

TABLE 2.—*Percentage leaf surface showing early blight lesions, total sugar levels and plant height of Kennebec potato variety treated with differential levels of nitrogen and phosphorus.*

Treatment	Percentage disease		Percentage total sugars	Plant height inches	Plant height inches
	1970 reading	1971 reading	1971	1970	1971
0-0-120	8.3bc	15.0a	7.8b	19.3b	15.5c
0-60-120	11.0abc	12.8ab	8.0b	20.0b	13.2c
0-120-120	9.8abc	15.1a	8.8ab	19.6b	14.1c
Average	9.7a	14.3a	8.2b	19.7b	14.3b
60-0-120	8.5abc	9.2b	7.9b	25.8a	20.6b
60-60-120	13.8ab	15.4a	7.7b	26.5a	20.8b
60-120-120	14.5ab	17.0a	7.9b	26.0a	21.4ab
Average	12.3a	13.9a	7.8b	26.1a	20.9a
120-0-120	6.3c	4.0c	9.3a	25.3a	20.1b
120-60-120	15.5a	14.1a	9.6a	25.8a	22.9ab
120-120-120	14.8ab	13.4ab	8.7ab	26.6a	24.0a
Average	12.2a	10.5b	9.2a	25.9a	22.3a
120-240-120	15.2ab	12.3ab	9.9a	28.8a	24.1a

of phosphorus in combination with the three rates of nitrogen. It is suggested also that residual soil phosphorus did not allow for a significant difference in disease incidence between 60 and 120 lb and between 120 and 240 lb of phosphorus.

The 1971 data show a significant decrease in the percentage of leaf area affected with early blight as the rate of nitrogen increased with zero phosphorus (Table 1). Zero, 60, and 120 lb of nitrogen per acre with zero phosphorus gave 15.0, 9.2 and 4.0% of leaf area infected respectively. The 120-0-120 treatment gave the lowest incidence of disease during both years though this effect was statistically significant only for the 1971 season.

In 1971, early blight incidence was significantly lower for the averaged 120 lb of nitrogen treatments (Table 2). The 0 and 60 lb per acre rate of nitrogen averaged 14.3 and 13.9% infection as compared to 10.5% infection for 120 lb of nitrogen. This decrease in early blight infection with the higher rates of nitrogen is in agreement with the findings of Horsfall and Heuberger (7) and Walker et al. (17). Furthermore, the work of Douglas and Pavek (1) and Stavely and Slana (13) suggest that increased nitrogen and decreased phosphorus may be associated with disease resistance by extending the period of meristematic activity during which the plant can wall of the invading fungus.

The over-wintering of inoculum:

A natural infection of early blight became established throughout the plots without application of inoculum during the 1971 season. Since a vine killer was not used during the fall of 1970, nor were the vines removed, many spores apparently survived the winter and served as a natural source of inoculum during the summer of 1971.

The percentage of total sugars:

The percentage of total sugars was significantly higher for 120 lb of nitrogen than for 0 or 60 lb as 0, 60, and 120 lb of nitrogen averaged 8.2, 7.8, and 9.2% total sugars respectively (Table 2). It was shown earlier that the treatments with 120 lb nitrogen averaged significantly less early blight than all others. This is in agreement with Horsfall and Dimond (6), who concluded that early blight is a low sugar disease, that is, the lower the sugar level in leaves, the higher the incidence of early blight infection. The higher sugar levels in the plants may have been responsible for reducing the incidence of early blight by providing energy for the meristematic activity needed to wall off the fungus in the early stage of infection.

The data presented in Table 1 show no relationship between the percentage of total sugars and the level of phosphorus since 0, 60, and 120 lb of phosphorus averaged 8.4, 8.4, and 8.5% total sugars respectively.

Plant height:

Plant height with zero nitrogen was significantly less than for plants which received nitrogen in both 1970 and 1971 (Table 2). The 0, 60, and 120 lb of nitrogen treatment averaged 19.7, 26.1, and 25.9 inches respectively in 1970 and 14.3, 20.9, and 22.3 inches respectively in 1971. Plant height was not significantly influenced by the three levels of phosphorus (Table 1).

Yield:

Yields from the zero nitrogen treatments were significantly lower than the 60 lb of nitrogen treatments in both years (Table 3). The data also show a trend towards decreased yields as phosphorus increased when 0 and 60 lb of nitrogen was used but when nitrogen was increased to 120 lb increasing phosphorus tended to increase yields. This supports Meyer et al. (9) who suggested that as the rates of phosphorus increased, absorption of nitrogen was depressed further limiting nitrogen and thus, yield.

Specific gravity of tubers:

As a measure of maturity, specific gravity of tubers was determined in order to study the relationship between maturity and early blight incidence. The more mature plants should produce tubers of a higher specific gravity and also have a higher incidence of early blight. It is of interest that the 120-0-120 treatment gave the lowest numerical specific gravity and the lowest numerical incidence of early blight in 1970 as presented in Tables 2 and 3. Data from other treatments, however, do not support this relationship.

Early blight tuber lesions:

No early blight tuber lesions were observed in any of the tuber samples. This was probably due to the fact that the 3 C (38 F) storage temperature prevented the development of tuber lesions.

Conclusion

High nitrogen and low phosphorus treatment significantly reduced the incidence of early blight infection and this combination of nutrients gave the lowest incidence of disease during both seasons. The data suggest that the high nitrogen low phosphorus combination may have extended the period of meristematic activity which enabled the plant to wall off the invading fungus and thus reduced the incidence of early blight.

Yield data indicate that the 120-240-120 fertilizer treatments gave the highest numerical yield with 363 and 300 hundred-weight per acre during the 1970 and 1971 seasons respectively. This was 76 and 63 cwt greater than was obtained from the 120-0-120 treatment. The latter treatment gave the lowest incidence of early blight, indicating that there was too great a yield difference between fertilization for optimum early blight control and fertilization for

TABLE 3.—*Yield and specific gravity of Kennebec potato variety treated with differential levels of nitrogen and phosphorus and exposed to early blight infection.*

Treatments	Total yield CWT/A 1970	Total yield CWT/A 1971	Specific gravity 1970	Specific gravity 1971
0-0-120	219d	129d	1.082abc	1.084bc
0-60-120	212d	126d	1.086a	1.083c
0-120-120	206d	117d	1.084ab	1.082c
60-0-120	298bc	231bc	1.085ab	1.090a
60-60-120	323abc	224bc	1.084ab	1.086abc
60-120-120	304bc	222c	1.086a	1.085abc
120-0-120	287c	237bc	1.079c	1.088ab
120-60-120	325abc	257abc	1.081bc	1.084bc
120-120-120	334ab	275ab	1.083abc	1.084bc
120-240-120	363a	300a	1.083abc	1.085abc

optimum yield. Therefore, in Maine, potatoes should be fertilized for optimum yield and a reasonable specific gravity and early blight should be controlled by properly timed applications of fungicides during the growing season. In addition, the practice of killing the vines before harvest, coupled with raking and burning the vines after harvest, should contribute to the control of early blight by reducing the over-wintering population of highly pathogenic primary inoculum.

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