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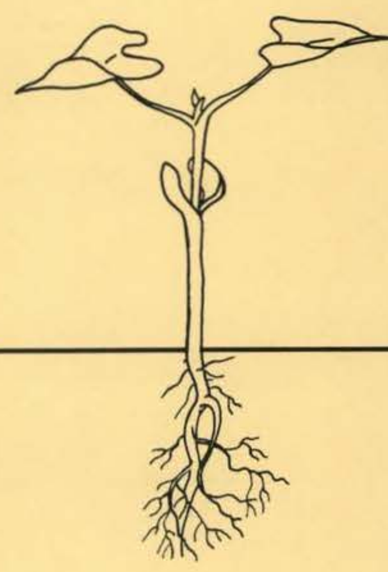

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The Epidemiology and Control Of Halo Blight in Idaho

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Introduction

Halo blight of beans, *Phaseolus vulgaris* L., incited by *Pseudomonas phaseolicola* (Burk.) Dows., was first described by Burkholder (1) in 1926. Due to its seed-borne nature, halo blight was quickly recognized as a serious threat to bean production throughout the world. Loss in some instances was limited to the death of a few plants; in others, all plants in a field were destroyed. In cases where the affected plants served as inoculum loci, secondary spread and subsequent pod lesion development destroyed the economic value of the crop. Such losses were important to the welfare of the nation since the bean (both as fresh pod and as dry edible seed) furnishes a large portion of the food to all income levels of the society. Consequently, disease control procedures became essential for continued production of this vegetable as a food source.

A review of literature to 1957 by Zaumeyer and Thomas (20) indicated that early control measures, using various copper compounds and antibiotic foliage sprays, were of some value in containing the secondary spread of halo blight. Practical control of halo blight was not accomplished until the introduction of disease-free seed. However, halo blight did reappear in the semi-arid West during the period of 1963 to 1967 and challenged this time-honored control procedure. Immediate steps were taken to develop control procedures for this blight, and to critically study the epidemiological factors that led to the development and spread of the disease.

A study of the epidemiology and subsequent control of a plant disease usually requires years of concentrated research by many scientists. Often the time from the onset of a disease until final control measures are discovered and successfully applied exceeds the professional life of individual researchers. However, this was not the case with halo blight in Idaho. The epiphytotic became apparent from 1961 to 1963 with increasing occurrence until it peaked in 1965. Control measures were initiated in 1964 and expanded until 1968 when halo blight appeared to be eradicated.

During 1968 halo blight was not observed in any bean field in Idaho. A trained group of 19 inspectors continuously inspected bean fields in 1968 from germination in the first week of June until all seed was harvested in early October. They did not detect a single bacterial blight infected plant. When one considers that in 1965 more than 5,000 acres of beans were infested, and that four years later this disease was apparently eradicated, the results of this concentrated control program are truly impressive.

The interaction of the pathogen-host-vector-environment relation was critically important in this epidemiological study. The importance of these interrelating factors to disease development and control are reported here.

History of Bean Seed Production in Idaho

Beans have been grown in Idaho since the development of our agriculture. Most bean varieties grown during the early 1900's were dry edible types, such as Lady Washington, Great Northern, and Red Mexican. This group of beans was grown in non-irrigated dryland farming areas of northern Idaho as recently as 1950. Since yield per acre was improved considerably with irrigation, dry edible bean culture became concentrated in southern Idaho, where today more than 130,000 acres are grown annually.

Between 1935 and 1940 vegetable seed companies interested in snap bean seed production moved part or all of their bean seed divisions to the western states. Some of these companies had plant facilities in Powell, Wyoming; Greeley, Colorado; and Twin Falls, Idaho. Personal interviews with representatives from Asgrow Seed Company, Gallatin Valley Seed Company, Keystone Seed Company, and Rogers Brothers Seed Company revealed that bean seed production in each location continued until about 1945 when repeated occurrence of halo blight and other bacterial diseases forced them to abandon their Wyoming and Colorado locations.

In the years before 1945, seed from blighted fields was sent to Idaho, planted usually for three consecutive years, and then returned presumably halo blight-free to the Wyoming-Colorado areas for increase and marketing. This seed remained relatively halo blight-free for a few years, but when recontaminated, the entire cycle had to be repeated. Finally, because of the constant threat of halo and other blights, the companies closed their Wyoming-Colorado operations and by 1945 had transferred seed production to Idaho. Depending on the market for snap bean seed, the acreage in Idaho has ranged from 15,000 to 35,000 acres per year.

The history of seed production in Idaho has been closely associated with climatological factors such as rainfall, temperature, and relative humidity. Southern Idaho's semi-arid environment is highly favorable for producing bean seed, snap as well as dry edible types. To a great extent this also holds true for the other vegetable seeds for which Idaho is famous. Of course, the major irrigation projects of southern Idaho make production possible, but it was this semi-arid environment of Idaho that originally attracted seed culture.

In speaking of the "semi-arid" West, the lack of, or perhaps minimal rainfall, is foremost in mind. The meaning and importance of "semi-arid" is well illustrated by comparing the summer rainfall in the western city of Twin Falls, Idaho, (8) to that of the mid-western city of Castalia, Ohio, (4) during the months of June, July and August. Average rainfall from 1935 to 1965 in Twin Falls during this 92-day period was 35 mm (1.4 inches); in Castalia, the average from 1955 to 1965 for the same 92-day period was 267 mm (10.7 inches). Monthly precipitation in Twin Falls during June, July and August was 24, 5, and 6 mm (0.9, 0.2, and 0.2 inches), respectively; in Castalia, 92, 96, and 78 mm (3.7, 3.8, and 3.1 inches). This extremely low rainfall in Twin Falls, and the abundant water from irrigation projects was and still is the principal reason for this region's success in vegetable seed production.

Summer air temperatures in these two communities, surprisingly enough, do not differ greatly — particularly the average maximum records. Castalia recorded 28, 30, and 29°C during June, July and August, respectively; Twin Falls averaged 27, 33, and 30°C for this same period. The nights are generally cooler in the intermountain regions, however. The average minimums for the summer months in Castalia are 15, 17, and 16°C; Twin Falls averages are 11, 12, and 10°C.

A summary of the environment during the summer months for Twin Falls is shown in Figure 5. This should give some idea of the environment found in the semi-arid West and how this environment is interrelated to the seed industry.

Development of Halo Blight in 1963

Halo blight was identified in southern Idaho in 1963 by Dr. L. L. Dean on plants taken from a few fields of snap beans. That halo blight occurred the two previous years in this area was probable, but either this knowledge was not made public or its presence actually remained undetected. The latter seems more plausible since the last known occurrence of this disease was about 1954. Many seed company fieldmen had never seen halo blight; consequently a few plants might have gone unnoticed.

Following detection of the disease in 1963, a large-scale search for diseased plants was started by many seed companies. The results of this search were not made public. Therefore, we had very limited data on halo blight occurrence and its spread at this early date. From the general occurrence of halo blight the following two years we feel that many snap bean seed companies and companies producing kidney and cranberry beans had plantings during 1963 which contained halo blighted plants. A report indicated that halo blight was common and widespread in Wisconsin during 1964 (16). Many of the bean varieties listed in this report are commonly grown for seed in Idaho.

Factors Contributing To Halo Blight Incidence

Before 1963, halo blight, although not unknown in Idaho, had not been considered a threat to the bean seed industry. Bean seed grown for three consecutive years was, in fact, considered free of seed-borne bacterial pathogens. This factor contributed greatly to the growth and economic success of the Idaho bean seed industry. Discovery of a number of bean fields infested with bacterial blight caused great concern in Idaho, forcing immediate steps toward developing a control program. In retrospect, we now believe that occurrence of the disease was influenced by two major factors: (A) introduction of substantial quantities of contaminated seed, and (B) climatological factors. In addition, a combination of these factors occurring over a prolonged period of years would increase the probability of greater disease incidence.

Introduction of Contaminated Bean Seed

Bean seed harvested from halo blight infected plants will often spawn infected plants when replanted. If this seed is planted in areas of heavy rainfall accompanied by wind, disease spread can be rapid. In exceptional cases, disease will spread through an entire field, rendering the crop a total loss. This was the character of the seed industry in the middle west and eastern United States during the late 1920's.

The practice of using a three-year planting schedule in Idaho has been used by foreign and domestic seed companies as well as state and federal agencies for the past 30 years. The success of this procedure is self-evident: most of the major bean seed companies producing snap bean seed and many companies producing dry edible bean seed center their bean seed production in Idaho. During the 1963-1967 halo blight epidemic, 51 snap and 7 dry edible bean varieties were found to be infested. Development of this disease has resulted in restricting introduction of contaminated bean seed into Idaho. All seed introduced must be certified free of halo blight, common blight, bacterial wilt and other regulated pathogens and must be laboratory tested and field inspected by the Idaho State Department of Agriculture.

During the past 20 to 30 years some bean varieties have been altered to incorporate physical characteristics as well as disease resistance. Types of dry edible beans grown in Idaho have remained relatively stable but snap bean varieties have undergone frequent changes.

Idaho has produced Red Mexican, Pinto, and Great Northern beans for many years and they have been improved to include virus resistance. Pinto bean production became important with the introduction of curly top and mosaic resistant Pinto UI-111 in 1944. Somewhat later, production of Pinks expanded. These dry edible types as a group are not easily infected by the halo blight pathogen. Red Mexican UI-3 and UI-34 varieties are considered to be resistant to race 1 of the pathogen (18).

Idaho is an important source of Red Kidney seed, and to a lesser extent Cranberry seed. These two dry edible types are easily infected. Bacterial spread within the field occurs readily once the pathogen is present. Until recently few changes or improvements had been made among them. Redkote, a new Red Kidney type developed in New York, is reported to be tolerant to some isolates of halo blight.*

Snap beans in Idaho are produced almost exclusively for seed. Varieties of snap beans grown before 1955 generally matured seed in approximately 95 days from seeding. Continued varietal development has resulted in slower maturing varieties requiring as long a season as 115 days for seed production. Coyne and Schuster (5) said that all *P. vulgaris* lines which had a high level of blight tolerance were also late in flowering and pod maturity although they proposed that late maturity is not always associated with blight tolerance. In addition, horticultural characteristics such as slow seed development, low fiber, and white seed coat have been increasingly emphasized. Many recent varieties have been produced utilizing the halo blight susceptible germplasm typified by the Tendercrop types.

Common Red Kidney and Cranberry dry edibles appear to react to halo blight similarly to the highly susceptible snap bean types. Susceptibility, tolerance, and resistance to halo blight thus seem more closely associated with specific genes than with maturity or morphology factors, since all snap bean types and Common Red Kidney react similarly to halo blight, yet are quite opposite in regard to meatiness of the pod, pod fiber, and speed of seed development. Furthermore, certain of the varieties in the Bush Blue Lake class do not express the usual symptoms of halo blight even when they are infected. The Bush Blue Lake as a class is low in fiber, has meaty pods, and is relatively slow in rate of seed development.

Control procedures that involve symptom diagnosis may be challenged with the advent of tolerant varieties. Coyne et al. (7) noted that inoculated tolerant plants can contain fairly high bacterial populations without showing symptoms, and that vegetative plants exhibited higher levels of tolerance and lower bacterial populations than did plants in the pod stage. Demands by the processor and those of seedsmen may cause some conflict in resistant lines. For example, Hill et al. (12) said that three

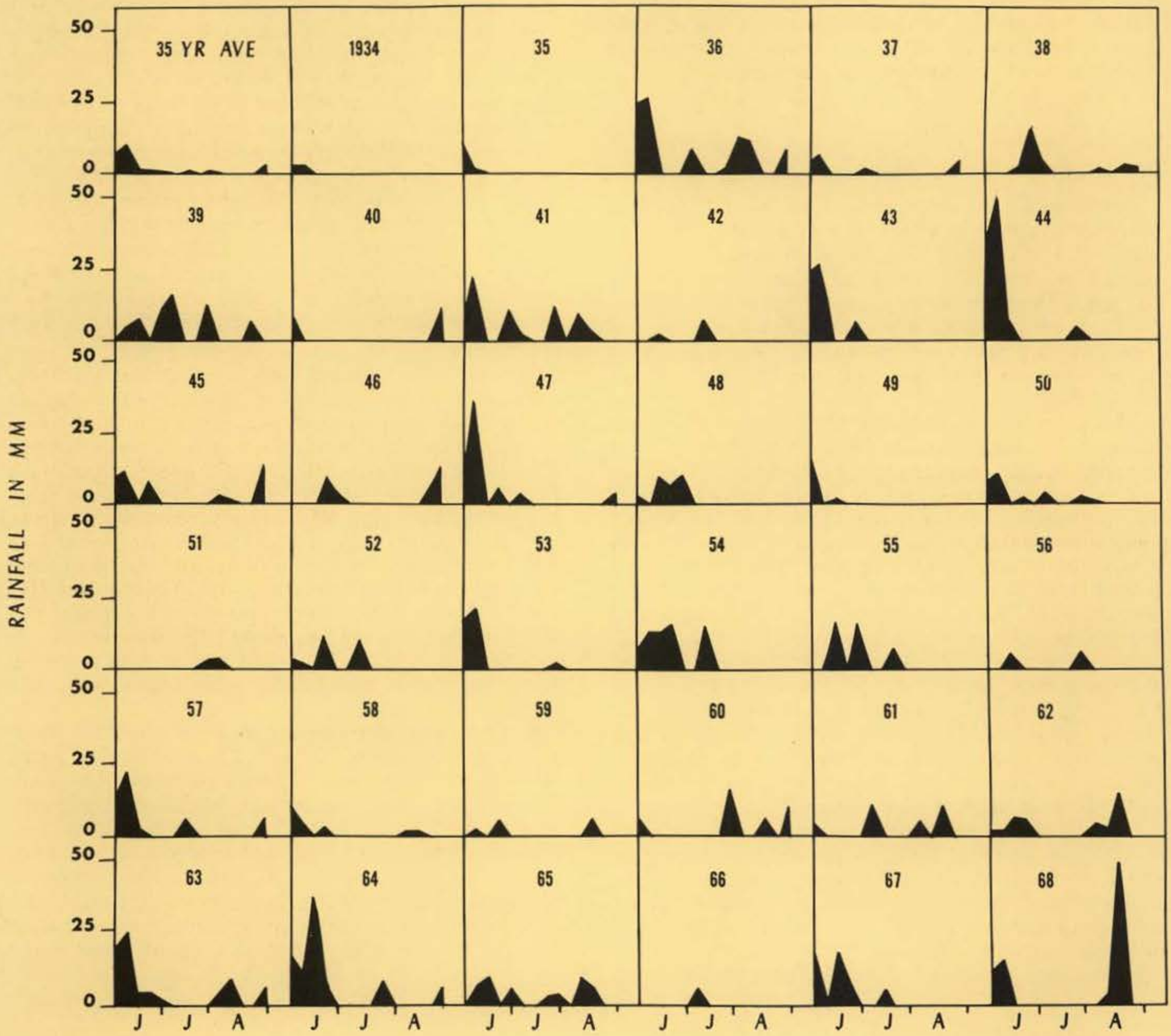
* Personal correspondence with Dr. John Natti.

different genes each separately control the expression of halo blight reaction in different plant parts. In a separate report, Coyne and Schuster (6) stated that large populations of *X. phaseoli*, *P. phaseolicola* and *C. flaccumfaciens* bacteria develop in tolerant lines and this occurs even when the leaves are inoculated with low cell concentrations. This has serious implications for the breeders and seed producers of tolerant cultivars. Wellhausen (19) and Lincoln (13) found that the virulence of a bacterial population increased through mutation and selection during passage through a tolerant host. Thus, in order to reduce the possibility of breakdown or tolerance due to the emergence of more virulent strains and races, seed of tolerant varieties should be saved from plants which are free of bacteria.

Climatological Factors: Rainfall Frequency

Splashing rain or hail accompanied by cooler air appears to be a primary vector in the spread of *P. phaseolicola* from one susceptible bean plant to another. Of course man himself is probably the greatest source of disease spread as a result of his

Fig. 1. Rainfall pattern in millimeters over 35 years for the months of June, July and August, Twin Falls weather station. The figure at upper left shows the 35-year rainfall average.



frequent activity in the field. One should not discount the effect of wind-blown sand or other abrasive particles, but in the semi-arid west these conditions are usually accompanied by hot winds and are perhaps less important in disease spread.

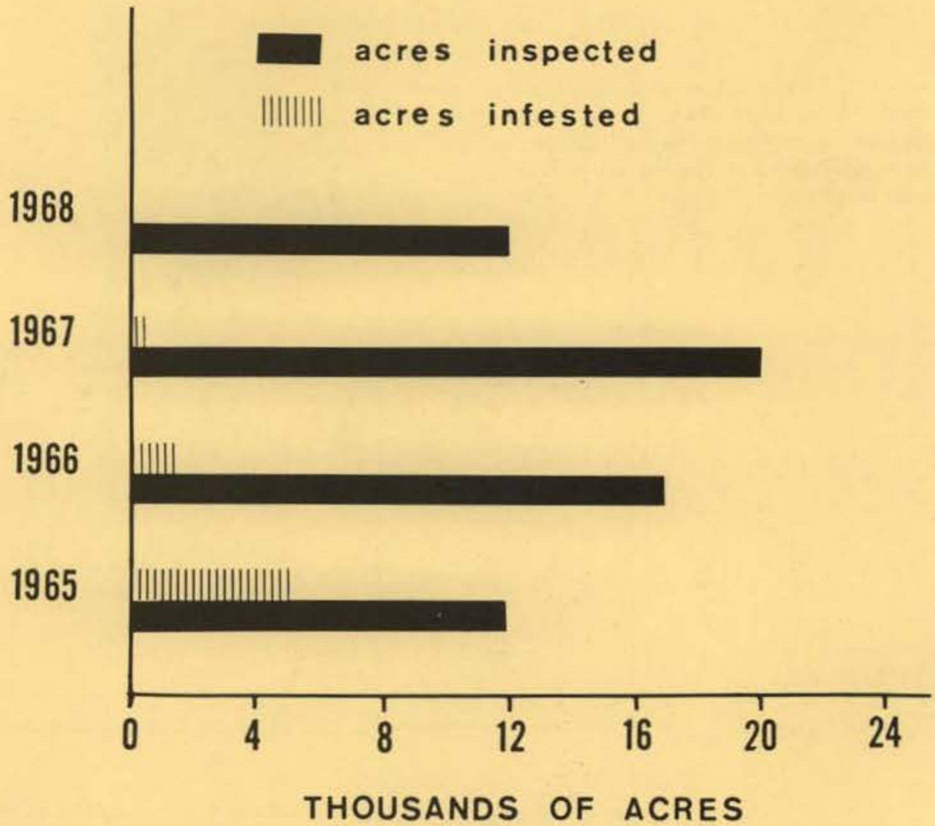
The typical weather pattern in southern Idaho during the June, July, and August growing period has been rain during the first two weeks of June followed by a 10-to 13-week period of hot, dry weather with possible showers the last week of August. The pattern is illustrated graphically by 35-year averages in the top left corner, Fig. 1. Average rainfall for June is 10 mm (0.25). During the following weeks if rain occurred, the quantity was often as little as 2.5 mm (0.1 inches). Variations have occurred during the past 35 years when precipitation was much less than average — as in 1934, 1935, etc., and when it was much greater than the 35-year average, as in 1936, 1939, 1941, 1954, etc. The latter variation from the norm appears to have been significant, particularly during the period from 1960 to 1965.

Personal interviews with representatives from four bean seed companies, plus personal observation, confirmed the occurrence of halo blight during past years in Idaho. These representatives were in general agreement that halo blight occurred during years which had abnormally wet, cool weather. However, since most wet, cool years were followed by dry, hot summers, halo blight never became a serious problem in Idaho.

This was true until 1960. Frequent rains, and in some areas hail, occurred often during the following 6 years. At no time did the total rainfall during a week's period approach that found in the midwestern or eastern United States. It occurred as light rains or cloudbursts lasting but a few minutes. Although the rainfall average for 1960 to 1965 did increase to 29 mm (1.1 inches), above the 35-year average of 22 mm (0.88 inches), the development of foliar diseases such as halo blight was probably influenced more by frequency than by quantity of rainfall.

Summer rains in southern Idaho occur in at least two forms: (1) gentle precipitation occurring intermittently over a week to 10 days, but not continuously; and (2) violent thunderstorms accompanied by winds and sometimes hail with a duration of minutes. The latter can cause some leaf damage to bean plants. If infection foci are present, this increases the probability of disease spread. Massive spread of halo blight has been observed following such storms. However, in the absence of the pathogen, only simple mechanical damage occurred. For example, in 1949 rain occurred 5 times during the summer (Fig. 1). Three of these recorded rainfalls were in quantities less than 2.5 mm (0.1 inches) and were probably short duration summer

Fig. 2. Progressive decrease in acreage infested with halo blight compared to acres inspected in Idaho, 1965 to 1968.



thunderstorms. Our records do not indicate that halo blight occurred during this period. With the apparent absence of the pathogen, rainfall in any form, even the potentially damaging thunderstorm, could not play a part in disease spread.

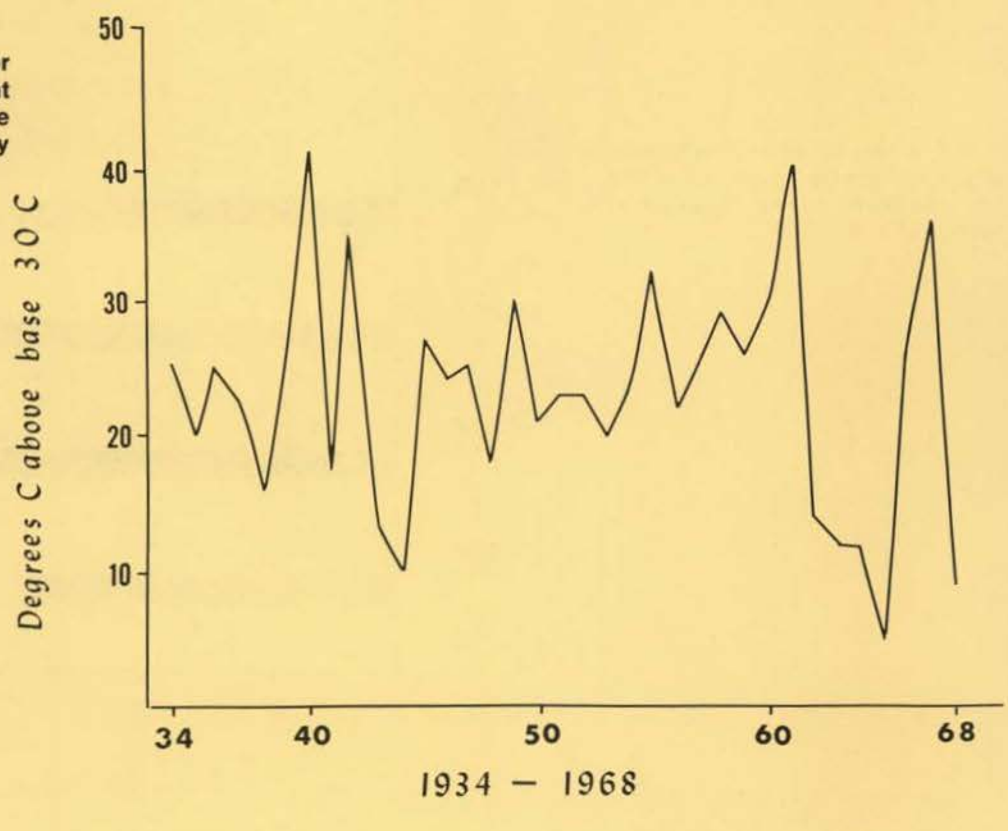
Climatological Factors: Temperature Variations

According to Patel (15) the infection process and subsequent disease development are reduced under the influence of large diurnal temperature fluctuations. For example, he reported that the "halo" development on infected plants was smaller on plants subjected to day temperature of 28°C followed by a 16°C night temperature. This factor might have contributed to halo blight development under Idaho field conditions, particularly in 1962 and 1965 when the number of weeks with average weekly maximum above 30°C is markedly fewer than in the preceding years (Fig. 3). The data in Fig. 3 were compiled by adding the number of degrees above a base of 30°C for each week during June, July, and August. For example, if the weekly average maximum was 34°C, the 4 degrees were added to the total figure for these months. In 1940, a year with high weekly maximum temperatures, the total accumulation of degrees above base 30 was 41 compared to only 5 for 1964, a year of low weekly average maximum temperatures.

Severity of halo blight symptom development may have been frequently equated with disease incidence and hence numbers of bacteria and rate of multiplication of the pathogen. This may have given rise to the idea that halo blight is a cool weather disease. The pathogen may in fact, however, flourish at temperatures above those optimum for severe symptom development. Goss (9), Carpenter (3), and Skoog (17) stated that the typical halo symptom is noted chiefly at 20°C and below. Occasionally a slight halo is present at 24°C. At 28 to 32°C no halo symptoms are noted but infection points are greater in number than at lower temperatures; the spots are small and somewhat inconspicuous.

One of the characters of semi-arid Idaho is that if any one year had excessive rainfall and was cool, the following year often had low rainfall and was hot. The assumption that the rainy, cool climate would be conducive to halo blight symptom development but the hot, dry environment the following year would be unsuitable is based on seed production success. In most instances, environmental conditions unfavorable to halo blight expression and spread usually occurred in 2 or 3 year sequences. This anti-pathogen environment did not occur from 1962 to 1965, appearing to result in conditions favorable to disease spread during this 4-year period (Figs. 1 and 3). Starting in 1963, efforts by individuals and organizations toward disease control, enhanced by a shift in climatic condi-

Fig. 3. Temperature variations for Twin Falls, 1934-1968. Each point equals the number of degrees above or below base 30 C during June, July and August.



tions back to the hot, dry growing season in 1966 (Fig. 3) resulted in apparent control of halo blight in 1968, even though climatic conditions favorable to disease spread reoccurred in 1967 and 1968.

Climatological Factors: Relative Humidity

The influence of relative humidity on the infection process can be significant in certain host-pathogen relationships. Just how important this factor is with a bacterial disease such as halo blight is unknown. Since *P. phaseolicola* can initiate infection through stomatal openings (20) the influence of relative humidity to microclimate of the leaves is possibly more important than previously realized. We have seen exudate from the hydathodes of bean leaves that also exhibited the toxin and necrosis associated with halo blight infection. In addition, free moisture occurs where two leaves touch even when the relative humidity of the air is minimal.

One characteristic of the semi-arid West is extremes in percent relative humidity during the day-night cycle. As illustrated in Fig. 4, the summer maximums range between 70 and 80%, but summer minimums during the same period are only 25 to 30%. Prolonged periods of high relative humidity are rare in the summer. Although not frequent, relative humidity as low as 6% is not unknown. Naturally, relative humidity of 100% occurs a few times each year.

During the 14 years 1955 to 1968, the average maximum relative humidity at Twin Falls ranged from 71 to 83%, and the average minimum from 23 to 27% (Fig. 4). The diurnal fluctuation in percent relative humidity to such lows might account for the lack of many foliar plant diseases common to the midwest. Fig. 5 summarizes the typical climatological pattern of southern Idaho during these summer growing months.

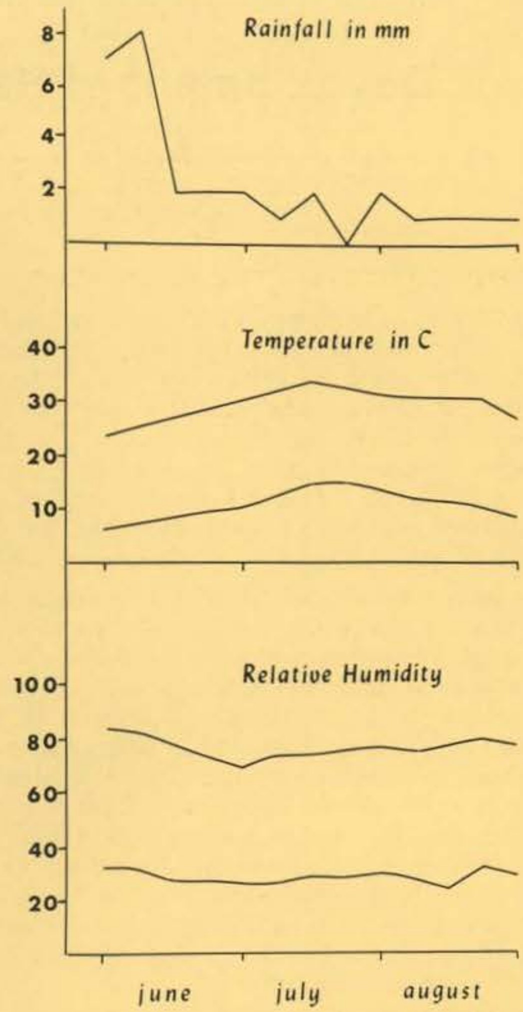


Fig. 5. Average rainfall, temperature and relative humidity during June, July and August at Twin Falls for 30-year period ending 1968.

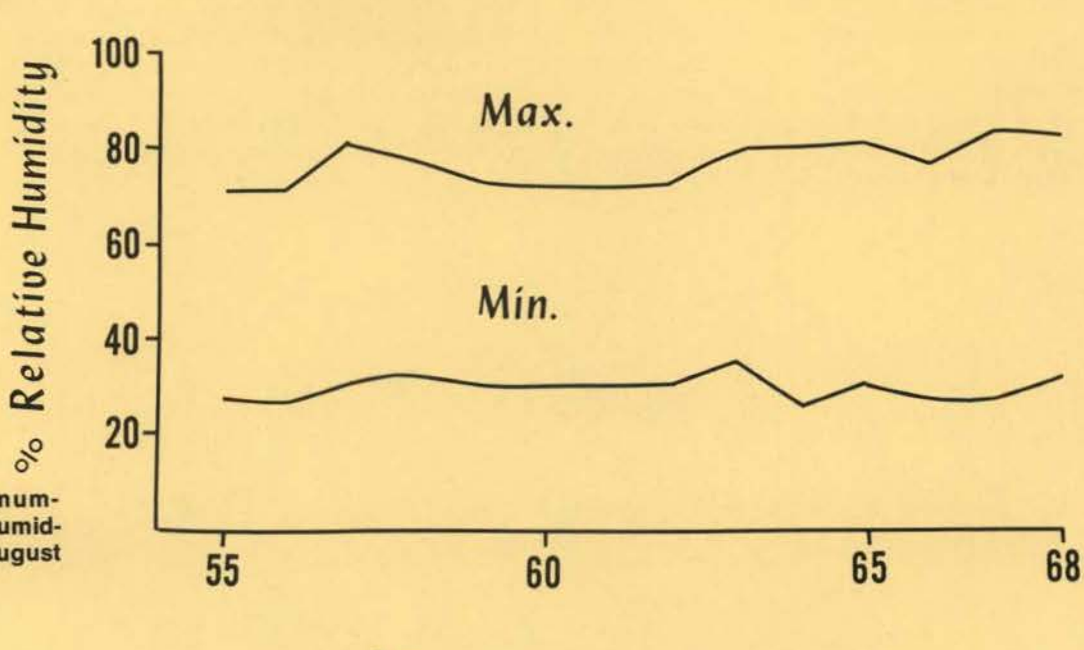


Fig. 4. Average minimum-maximum percent relative humidity during June, July and August at Twin Falls, 1955-1968.

Development of Halo Blight Control Program

Field Inspection and State Regulation

In 1963 halo blight appeared in scattered fields of beans, particularly snap beans, and as a result became the individual concern of various bean seed companies. Following the practice used in years past, individual companies inspected their own plantings. Fields with just a few plants infected were rogued but the crop was not destroyed. Disease control was strictly voluntary according to the decisions of each company.

The number of fields with halo blight was greater in 1963 than in the preceeding 20 years and caused considerable concern among both the growers and the seed companies. In February 1964, the State Commissioner of Agriculture at the request of the bean industry called a series of meetings throughout the bean growing sections of Idaho to develop a bacterial blight control program. These meetings resulted in the development of a voluntary control program whereby each company would be responsible for inspecting and condemning their own bean fields found to contain halo blighted bean plants. The results of this voluntary program were found to be less than satisfactory.

During the fall of 1964, at the request of both growers and industry, the State Department of Agriculture established a formal control order concerning inspection and destruction of blighted fields. Clyde Butcher, a plant pathologist, was hired by the State Department of Agriculture to inspect all field plantings of beans to be harvested and used as seed. If halo blight was found, the grower was required to destroy the field by plowing within 5 days after detection, weather conditions permitting. During 1965, over 5,600 acres of beans were found infested with halo blight (Fig. 2). Reports showing progress in halo blight control have been published (2).

Seed Testing

More often than not, halo blight symptoms on the plants of susceptible varieties are self-evident and disease identification or confirmation in the laboratory is not necessary. Symptoms on some dry, edible varieties are manifested as vague nonspecific blemishes that are similar to those induced by other pathological or physiological or even mechanical causes. Identification and removal of all infected seed cannot be accomplished visually. Parker and Dean (14) reported that some seed infected with halo blight fluoresced when viewed under ultraviolet light. They stated that although bean seed fluoresce for numerous other reasons, selection of seed under ultraviolet light tended to concentrate seed most likely to be internally infected with the pathogen. Although this procedure cannot be used to eliminate contaminated seed from a seed lot, it can be very useful in a sample selection.

Pathogen identification often required 14 to 21 days because the suspected seed had to be planted to allow identifiable symptoms to develop on the resulting plants. Refinements developed at the University of Idaho shortened this procedure to about 3 days by use of serological techniques (10). Actually, in the first instance disease symptoms were identified; with the serological adaptation the pathogen was identified. Identification of the bacterial pathogen isolated from fresh or dried plant material was first tested serologically and later, if needed, a more detailed study of the cultural, physiological and pathological characteristics was made (11). Individuals or companies may now have seed samples tested at the State Health Laboratory under the auspices of the State Department of Agriculture. This test involves serological and cultural examination, and in most instances host inoculations.

Summary and Conclusion

Halo blight has come and gone, or at least we hope it is gone. The control program and practices developed during the past few years should remove this disease as a serious threat to the bean seed industry of the west.

Indiscriminate introduction of bean seed into Idaho has slowed if not stopped altogether. Evidence cited by Butcher et al. (2) shows that if the sources of halo blight are absent, irregularities in the weather such as extended rainy periods do not pose a threat. Varietal differences in even the disease tolerant types will likewise be no problem provided they are introduced into the seed growing areas free of disease and remain so during production periods.

Actually none of the problems that faced the bean seed industry during the past 30 years relative to halo blight need be of concern if the entire bean seed industry remains alert and maintains current regulations. Strict enforcement of the rules and regulations devised by the seed industry and enforced by the Idaho State Department of Agriculture will ensure continual success in bean seed production and marketing. High quality Idaho bean seed, free of disease, will always be a prime attraction to customers all over the world.

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