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Title FACTORS INFLUENCING THE DEVELOPMENT OF ONION PINK ROOT DISEASE INCITED BY PYRENOCHAETA TERRESTRIS (HANSEN) GORENZ, WALKER, LARSON

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A study was conducted of the influence of various climatic and soil factors on the development of onion pink root disease and of the influences of temperature, light, pH, carbon and nitrogen sources, and vitamins on the growth in vitro of an Oregon isolate of the pink root fungus, Pyrenochaeta terrestris (Hansen) Gorenz, Walker, Larson.

Eleven onion lines were planted in eastern and western Oregon to determine whether the relative resistance to pink root among them would vary during the growing season and with different climatic conditions. Varietal resistance remained generally stable among the different lines.

Ten onion lines were grown in mucky peat and silty clay loam soils in the greenhouse to determine the influence of soil moisture and soil type on severity of pink root. Onions grown in soil held

at field capacity had less pink root than those in dryer soils. Pink root ratings were similar among onions grown in both soils.

Lanstan, Vorlex, Telone, Pictel, Morton Soil Drench, SD 345, chloropicrin, Mumfume, Phaltan, E. P. 230, and E. P. 201 were tested in the field for their effect on pink root. In some fields Vorlex, chloropicrin, Mumfume, E. P. 230, and E. P. 201 increased onion yields from 30 to 75 percent. None of these fumigants noticeably reduced pink root, however. Telone controlled stubby root nematode infection but did not reduce pink root.

On malt extract-yeast extract agar P. terrestris grew fastest at a temperature of 30 C, with the greatest increase in growth rate between 15 and 20 C. There was no growth at 5 C.

Continuous light, alternating darkness and light, and brief exposures to germicidal ultraviolet light (2,500 Å) did not noticeably affect the growth rate of the fungus.

Growth of P. terrestris increased the pH of glucose-asparagine and sucrose-potassium nitrate liquid media. On both media the fungus grew well over a pH range from 6 to above 8 but poorly at a pH of 4 or less.

Sorbose inhibited growth of P. terrestris. Maltose, galactose, glucose, fructose, sucrose, lactose, and starch in asparagine liquid and agar media each supported good growth of the fungus, as did glycine, potassium nitrate, and urea in glucose agar.

The addition of thiamine, biotin, inositol and pyridoxine to sucrose-asparagine agar did not noticeably affect P. terrestris growth.

Higher temperatures coincided with greater pink root infection in the field.

FACTORS INFLUENCING THE DEVELOPMENT OF ONION PINK ROOT DISEASE INCITED BY *PYRENOCHAETA TERRESTRIS* (HANSEN) GORENZ, WALKER, LARSON

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FACTORS INFLUENCING THE DEVELOPMENT OF ONION PINK ROOT DISEASE INCITED BY *PYRENOCHAETA TERRESTRIS* (HANSEN) GORENZ, WALKER, LARSON

INTRODUCTION

Onions are grown and consumed on a world-wide basis, and production is not greatly restricted by climate, soil or locality, as is the case with many agricultural crops. Pink root disease of onions, caused by *Pyrenochaeta terrestris* (Hansen) Gorenz, Walker, Larson, is also world-wide in occurrence.

The United States is the leading onion-producing country in the world. Egypt, Turkey and Japan each have more land in production of onions than the United States, but their yields are smaller (32, p. 1-2). In the United States the annual onion crop averages more than a million tons grown on approximately 100,000 acres (49, p. 74-75; 85, p. 1).

Some onions are grown in every state, but approximately 75 percent of the crop in the United States is grown in the northern states from Massachusetts to the Pacific coast (85, p. 1). Most of the crop is grown from seed sown directly in the field in early spring at the rate of three to four pounds per acre with no thinning. Both upland and muck soils are used.

Large, mild Sweet Spanish onions are grown on the irrigated

mineral soils of the western United States, chiefly in Colorado, Idaho, and Oregon. Hard, pungent storage types are grown in the muck soils of the northern and western states of New York, Michigan, Ohio, Indiana, Wisconsin, Minnesota, Oregon, and California.

Oregon produces approximately 11 percent of the annual United States crop and ranks sixth among states in the total production of onions. About 2,000 acres of muck soil are used for production of Danver onions at Lake Labish in Marion and Yamhill counties of western Oregon. Overhead sprinkler irrigation is used in some fields; in other fields no irrigation is used. An area of approximately 3,000 acres of furrow irrigated, mineral soil in Malheur County of eastern Oregon comprises the other major onion production region of the state. Primarily Yellow Sweet Spanish onions are grown there. Pink root disease is a problem of importance in both areas. The muck soil of western Oregon has been used for onion production without rotation with other crops since before the turn of the century. In eastern Oregon, onions generally are not grown for more than two or three years in succession. They are rotated with potatoes, sugar beets and other crops in an effort to control pink root and other diseases.

Onion varieties have been developed that have been described as being quite tolerant or resistant to P. terrestris. However, varieties that have been reported very resistant in one locality often

do not exhibit this same degree of resistance when grown in other localities or when grown in the same locality during successive years. It has puzzled workers that some of the onions of a given variety having the largest bulbs at harvest time have the least number of healthy roots and vice versa. Reasons for these inconsistencies are not well understood nor easily explained.

Some work has been done relating to the effects of light and various media on the sporulation of isolates of P. terrestris. Very little work, however, has been done on factors influencing the rate of growth of the fungus in vitro. Some workers have attempted to find the optimum pH and temperature for most rapid growth of some isolates, but nothing has been reported on the influence of light, varying carbon and nitrogen sources, and the absence or presence of vitamins in the substrate.

The major objectives of this study were to determine: (1) Whether the varietal resistance to pink root among several selected onion lines varies as onions mature or as they are grown under different conditions. (2) The influence of soil moisture on severity of pink root infection of onions. (3) Possible uses of chemical soil treatments for control of onion pink root. (4) Influences of temperature, light, pH, different carbon and nitrogen sources, and selected vitamins on the growth and sporulation of an Oregon isolate of P. terrestris.

(5) Factors which make pink root disease a greater problem in eastern Oregon onion fields than in western Oregon.

REVIEW OF LITERATURE

Organisms

Shortly after the turn of the century pink root disease of onions was found to be the cause of serious damage to onions in Texas (69) and Louisiana (13, p. 9). In 1915 Mally (70, p. 7), realizing the threat of the problem, began work in cooperation with the Texas Agricultural Experiment Station to uncover the cause of pink root disease. Taubenhaus and Johnson (69) were the first to report on pink root, when in 1917 they published a brief description of the disease, giving it the name "pink root" without speculation as to its cause. In 1918 and 1919 Taubenhaus (67, 68) gave more extensive descriptions of the disease, and in 1921 he and Mally (70) published the first treatise of experiments on causes and control of pink root. They presented evidence that the causal organism was Fusarium malli Taub.

In California Sideris (62) isolated and named four new species and two new varieties of Fusarium which he found associated with the disease. He concluded (63) that several species of Fusarium, especially Fusarium cromyophthoron Sid., caused pink root.

Hansen (17, 18), studying pink root of onions in California and Texas about the same time and shortly after Sideris, was unable to incite the disease with Fusarium cromyophthoron, F. malli, or any

of the ten other species, varieties, and strains of Fusarium which he tested. He found evidence that a species of Phoma was the true causal agent of pink root, and showed that species of Fusarium acted only as secondary parasites. In 1929 he (18) named the causal organism Phoma terrestris. In 1948 Gorenz, Walker, and Larson (16) changed the name to Pyrenochaeta terrestris after a careful morphological study of the fungus.

Davis and Henderson (10) found that Fusarium zonatum forma 1, which causes a semi-dry rot of onion bulbs in the field and storage would not attack the roots or bulbs of onion, except following injury or initial invasion by P. terrestris or some other pathogen.

Hess (21, p. 59-60) studied three isolates of Fusarium and 14 of P. terrestris from onion roots, and found all isolates capable of causing root disease of onion. The pathogenicity of mixtures of Fusarium and P. terrestris did not differ significantly from that of either fungus alone.

Kehr, O'Brien, and Davis (34) showed that resistance to P. terrestris alone is no assurance of resistance to Fusarium oxysporum f. sp. cepae and vice versa. The presence or absence of either pathogen did not modify the susceptibility to the other.

Although species of Fusarium have been shown (21, p. 28-43; 34; 70) to cause "pink root" symptoms without the presence of P. terrestris, most recent studies confine the term to the disease caused by P. terrestris.

Watson and Paden (88) discovered that the use of "sterile head set" bulbs to test the effects of P. terrestris may eliminate the effects of other pathogenic fungi and bacteria which are sometimes confused with symptoms caused by P. terrestris. Watson (87) has also developed a technique for rapid identification of P. terrestris. It consists of growing fungi on wheat straw, which is reddened by P. terrestris but usually not by other fungi.

Variation Among Isolates

The first to note variation among isolates of the fungus was Hansen (18). Gorenz, Larson, and Walker (15) later reported that isolates of P. terrestris from 14 different locations in 10 different states exhibited great variation in virulence, even among isolates from the same vicinity. They also found marked differences in rates of growth between isolates, especially at 28 C. Hess (21, p. 28-43) also found great diversity in pathogenicity among isolates from the same vicinity. Kulik and Tims (41) found extreme differences in pathogenicity and production of pycnidia among 91 mycelial isolates

of the fungus taken from a single field.

Variation Within Isolates

Gasiorkiewicz, et al. (14) induced variations of the fungus with nitrogen mustard. The majority of the mutants were less virulent than the untreated controls, yet some of the mutants coming from weak parental types showed increased pathogenicity.

Hansen (19) performed inoculation experiments on onion seedlings with variants obtained from single spores and found considerable variation in pathogenicity and culture color among the variants. Yet, the fungus remained constant when perpetuated by mycelial transfers, indicating that segregation occurred during pycnidium formation or spore maturation. He (loc cit., 20) concluded that the individual nuclei of multinucleate spores of the fungus might exhibit genetic variation. Thus the use of the single-spore method in obtaining pure cultures could prove confusing to one working with the fungus.

Occurrence

After the pink root disease was first described in Texas (69) Edgerton (13) mentioned that it had been known in Louisiana since 1909. In 1919 it was found in California (70, p. 5), and within the following four years was reported in Bermuda (12, p. 5), Quebec (11),

and Ontario (27). Pink root had also been found in Japan (12, p. 5), in Egypt and Spain (46), and several states of the United States (67, 83). In 1927 pink root was reported in the Union of South Africa (12, p. 6) and later was found to be widespread in its occurrence there. Recently it has been reported as a problem in Argentina (36) and as occurring extensively in Brazil (5). It is also found in Australia and the Netherlands (6, p. 397), and is undoubtedly a problem in other areas where onions are grown.

Crop Losses

In 1942 and 1943 Tims (74, 75) reported that pink root was the most serious disease affecting shallots in Louisiana. Howit (27) estimated that in 1922, in Ontario, pink root was responsible for a crop reduction of at least ten percent. Taubenhaus and Mally (70, p. 4) placed the loss in badly diseased fields in Texas prior to the introduction of resistant varieties, at 35 to 43 percent or more. Du Plessis (12, p. 7) in 1933 estimated losses in South Africa to be 20 to 30 percent, or even 50 percent when associated with other diseases. The disease was so severe in Bermuda during 1921 that it was considered a chief factor against the further production of onions there. However, these estimates probably include losses due to other organisms in conjunction with *P. terrestris*.

Sporulation

Hansen (18) reported good sporulation of P. terrestris on corn-meal agar but very poor sporulation on Czapek's, Conn's, Pfeffer's, and other synthetic media. Kulik and Tims (41) obtained limited pycnidial formation on beanpod agar but none on corn-meal agar or PDA (potato-dextrose agar).

Gasiorkiewiez et al. (14) observed pycnidia on onion roots in the field. They and Wilhelm (90) obtained sporulation of the fungus on surface sterilized roots in sand.

Garvajal (4) found that pycnidia formed readily when isolates of P. terrestris were grown on PDA at room temperature in subdued natural light. Hess, Vaughan, and Leach (21, p. 21-27; 22; 23; 43) induced sporulation by placing isolates of the fungus under near-ultraviolet radiation for 12 days.

Gasiorkiewicz et al. (14) found no correlation between sporulation and pathogenicity of P. terrestris isolates. Yet, the findings of Kulik and Tims (40, 41) indicated that there was an apparent correlation between the production of pycnidia by isolates in vitro and their pathogenicity on onion seedlings. However, pycnidia are not usually considered as being extensively involved in transfer of the fungus in the field (83).

Disease Rating

Gorenz, Larson, and Walker (15) divided disease symptoms into five classes: 0 = no infection; 25 = 1 to 25 percent infection of roots; 50 = 26 to 50 percent infection; 75 = 51 to 75 percent infection; 100 = 76 to 100 percent infection of roots. This system was also used by Kulik and Tims (41) and by Hess (21, 28-43).

In breeding work Davis (9) has used a more general system which is perhaps more useful for breeding purposes, especially if the rating is done by the same worker. He classed onion varieties or lines on the basis of their reaction to the pink root fungus as: very resistant, resistant, segregating, susceptible, or very susceptible. The term segregating is generally used to denote a wide range of resistance or susceptibility among different onions of the same small plot and seed lot.

Hosts

In a brief description of pink root disease in 1918, Taubenhaus (67, p. 292) reported that onion and its near relatives chive, shallot, garlic, and leek were susceptible to pink root; however, he found no infection of narcissus, tulip, funkia, iris, freesia, lily or calla lily (70, p. 6-7).

Hansen (18) isolated P. terrestris from cowpeas, lima beans,

and potatoes. In the Chicago area Thornberry and Anderson (72) found that pink root was a serious problem on tomatoes. Kreutzer (38) added barley, cane sorghum, cantaloupe, carrot, cauliflower, corn, cucumber, eggplant, millet, muskmelon, oats, pea, pepper, soybean, spinach, squash, and wheat to the list of hosts. However, he found certain varieties of leek, soybean, pinto bean, red clover, sweet clover, alfalfa, pepper, cabbage, parsnip, celery, sugar beet, lettuce, and tomato to be resistant to pink root.

Carvajal (4) obtained the fungus from sugar cane and sweet clover. Pig weed, crab grass, crow foot grass, and jungle rice were added to the list by Tims (78). Wilhelm (90) found that the fungus attacks hairy nightshade and strawberry. Sprague (64) found P. terrestris to be widespread as a minor parasite of cereals, many grasses, and various other plants in North Dakota and surrounding areas.

Hess (21, p. 51) isolated P. terrestris from all of the following 18 crop plants which he tested: Sweet Spanish onion, asparagus, bean, clover, rye grass, timothy, bent-grass, fescue, oats, cabbage, turnip, radish, muskmelon, sunflower, lettuce, beet, chard, and chrysanthemum. Undoubtedly the list of hosts not mentioned in the literature far exceeds those mentioned here.

Resistant Varieties

Taubenhaus and Mally (70, p. 6-7) found the varieties Yellow Dutch, Spanish, Strasburg, Australian Brown, Large Red Globe, Large Red Wethersfield, Large White Globe, White Portugal, and White Silverskin all highly susceptible in Texas, as were the "multiplier" varieties of onions. Extra Early Red was quite resistant, and the Bermuda varieties were moderately resistant to pink root. In California Porter and Jones (56) found Allium fistulosum L. (Nebuka type), leek, and chives to be extremely resistant; garlic, shallot, and most varieties of the common onion, including Australian Brown and Yellow Globe, were extremely susceptible, and the variety Sweet Spanish was moderately susceptible. Westcott (89, p. 314) reported that Sweet Spanish and Japanese types of onions were less susceptible than Danvers.

In 1939 (54, 55) a cooperative breeding program was established between the USDA and the Texas Agricultural Experiment Station; this has expanded to other states since (9, 51, 77). As an outcome, resistant short-day type onions have been developed through field selection and breeding. Perry and Jones (55) found Excel, L36, Eclipse, and L365 highly resistant in southern Texas. L281 W was somewhat less resistant yet produced good yields. The F_1 hybrids Excel (986) X L281 W, Excel (986) X L303, and Excel (986) X L365

were highly resistant; the Grano types were very susceptible; and Granex onions were intermediate in susceptibility.

Nichols, Larson, and Gabelman (51) in investigating the relative resistance of many of the commercial onion varieties and hybrids found the greatest resistance among the southern onion types.

The Nature of Resistance

Apparently pink root resistance is usually multigenic in onions since it is relatively unstable in a variable environment (84, p. 685). Resistance to pink root disease has been found (15) to vary with environmental conditions, inoculum load, and with different isolates of the fungus. Davis (9) and Hess (21, p. 60) found that some varieities that have been resistant to pink root when grown in the field in Texas have been susceptible when grown in Oregon. Other varieties have shown resistance during certain years, but when grown on the same ground during subsequent years have not exhibited the same resistance. This difference apparently is due to more than inoculum potential in the soil.

In some instances, however, resistance seems to be a one gene characteristic. Jones and Perry (33) in crossing the Bermuda-type onions Excel, Yellow Bermuda, Eclipse, and L365, which are very resistant to pink root, with Texas Early Grano 951 or San Joaquin, both of which are very susceptible, obtained a 3:1 ratio of

susceptibles to resistants in the F_2 generation. Nichols (50, 52) isolated several experimental inbred lines of onions which demonstrated a single recessive gene controlling pink root resistance but found evidence in other lines for additional genes controlling resistance.

Kreutzer (38) in describing the structure of the fungus and host tissue reported that hyphae entering the root grew through the cortical tissue. Invaded cells were plasmolyzed and the nuclei distorted. Adjacent cells showed similar, less severe injury. In the epidermal and cortical cells pycnidial primordia were formed. Struckmeyer et al. (65) in a comparative study of the host-parasite relations of the fungus and three varieties of onion found that the cell wall of the resistant varieties was a major factor in restricting penetration and subsequent infection. Resistance was expressed by the formation of a peg which consisted of a hyphal tip over which the host cell wall was stretched. The fungus appeared definitely retarded, and damage to the root was restricted.

Factors Influencing Disease Development

General Factors

Taubenhaus and Mally (70, p. 14-22) from field and laboratory observations credited the following factors as favoring pink root disease development on onions: (a) soil deficient in plant food, chiefly nitrogen and humus; (b) repeated cultivation of onions on the same land for a period of years without rotation with other crops; (c) alkaline soil; (d) transplanting of infected green onion sets; (e) a shock which will set back diseased onion plants (viz. sudden freezes or droughts); (f) poor leveling--sets growing in dry higher spots became more susceptible due to their weakened condition; (g) poor irrigation, especially immediately following the transplanting of young onion sets; (h) hot weather and high soil temperature; (i) nematodes which open the way for pink root infection by weakening the plants and making wounds in the onion roots; and (j) thrips acting upon the onions in a similar manner as nematodes. Lime or sulfur treatments of the soil as done by Taubenhaus and Mally (loc. cit. p. 29) had no effect in reducing pink root. Fertilizers (loc. cit. p. 28) tended to retard pink root development. They felt this was due to accelerated growth of the onions and more rapid formation of new roots.

Nichols (50, 52) felt that the fungus isolate, inoculum

concentration, moisture conditions, and seed quality all affected uniformity of infection and expression of disease symptoms in onion seedlings. Gorenz, Larson, and Walker (15) showed that the expression of onion resistance to P. terrestris was suppressed in in proportion to the virulence and concentration of the pathogen.

Temperature

Hansen (18) found the optimum temperature for infection of onion roots to be 26 C. Gorenz, Larson, and Walker (15) found maximum disease development in sand culture at 28 C.

Borgman (3) in finding that disease incidence in the field increased from 10.8 to 100 percent in four weeks, while soil temperature increased only gradually, concluded that soil temperature does not warrant the importance generally given it as a factor in aggravating pink root disease.

pH

As mentioned Taubenhaus and Mally (70, p. 10) felt that alkali in the soil decreased the resistance of onions to pink root. Gorenz, Larson, and Walker (15) found that disease development was not affected by a change in pH within the range of pH 4 to 8. Sideris (63) found that onions grew best in both water and soil cultures at pH values between 5.5 and 6.5. Values outside of this range

inhibited growth somewhat. Differences of temperature shifted the optimum pH for growth. He found that a slightly more acid reaction was more favorable for growth of onions during the summer months than in the winter months.

Factors Influencing Rate of Growth of P. terrestris

Moisture

Borgman (3) reported that the fungus was able to grow well over a wide range of available moisture or osmotic pressures.

Temperature

Hansen (18) using corn-meal agar found 26 C and Davis and Henderson (10) using PDA found 28 C to be the optimum temperature for growth of P. terrestris. Gorenz, Larson, and Walker (15) in studying 11 isolates from various parts of the United States found optimum temperature for growth of the isolates to be from 24 to 28 C on PDA.

pH

A pH range of 4.2 to 7.4 was reported by Davis and Henderson (10) to be favorable for growth of the fungus on PDA, with an optimum about 5.4 to 6.6. Gorenz, Larson, and Walker (15) found that

isolates grew well at all pH levels within the range of 4 to 8 when grown on a modified Hoagland's nutrient agar.

Relationship of Color to pH

Gorenz, Larson, and Walker (15) found that root color varied with onion variety and fungus isolate at each of the pH levels of 4, 6 and 8. The roots were darkest red at pH 8 and many infected roots were brownish at pH 4. Kreutzer (37) found that the color of diseased roots in a liquid changed from red at pH 5 to yellow brown at pH 4.5. By adding hydrochloric acid to an extract from potato-agar mats of P. terrestris he found a definite color change from pansy purple to yellow brown within the pH range of 7.00 to 7.86. The reverse color change occurred within the same pH range by adding sodium hydroxide.

Chemical Control

Kreutzer and Mantagne (39) reported 300 percent yield increases over control plots following injection applications of chlorobromopropene to the soil at the rate of 25 gallons per acre three weeks prior to planting. Using three different soils in the greenhouse and onion seedlings as test plants, Tims (79) obtained almost complete control of pink root with Vapam. Mylone also gave good control.

Kulik and Tims (40, 42) tested 54 fungicides and 29 chemotherapeutants in the laboratory and obtained highly significant results in effectiveness against P. terrestris with 25 of the fungicides and eight of the chemotherapeutants. However, field experiments using the most promising of the fungicides as measured by tests in sand cultures in the greenhouse, did not give conclusive results due to lack of sufficient disease development in the field. Tims (76) in treating shallot sets with various chemicals found that treatments which reduced pink root also caused severe injury to the plants.

Hess (21, p. 50-56) obtained significant yield increases and reduction of the incidence of pink root using Vapam, Mylone, and chloropicrin in the field. Tarped chloropicrin increased yields more than 50 percent.

In field trials yield increases have not always coincided with a decrease in incidence of pink root. Marlatt (47) found that Granex gave significantly higher yields of three inch and two to three inch onion bulbs despite their showing more susceptibility to pink root. In other trials with Lanstan (57), disease control as measured by visual ratings of roots has occurred without a corresponding yield increase.

FIELD AND GREENHOUSE TRIALS

General Materials, Methods and Conditions

Onion Lines

Fourteen onion lines were used in field and greenhouse trials (Table 1). The first seven lines were obtained from the Plant Industry Station, Beltsville, Maryland. Line 8 came from an onion grower at Lake Labish, Oregon, and lines 9 and 10 from an onion grower in Malheur County, Oregon. The last four lines came from the Oregon State University Vegetable Crops Farm east of Corvallis, Oregon.

Soils

Lake Labish Semiahmoo (80) black mucky peat and Malheur County silty clay loam soils were used in greenhouse trials (Table 2).

Chemicals

All of the chemicals used in field soil fungicide and fumigation trials were liquid formulations except for Phaltan, which was a granular material (Table 3).

Table 1. Source and previous pink root resistance ratings of onion lines used in field and greenhouse trials in Malheur County and at Corvallis, Oregon.

Line No.	Line	Source	Pink Root Resistance*
1	PI 219754 Allium fistulosum	B 171-182 Beltsville 1962	nearly immune
2	Ia 2997 B prr (Ore) (Tex)	Ore 36 LC 5 Beltsville 1962	highly resistant
3	Ia 13 B prr (Tex) (Ore)	Inc 164 sc 14 Ames 1961	highly resistant
4	B 2473 B prr (Tex)	Inc 142 LC 3 Ames 1961	moderately resistant
5	B 2264 B prr (Tex)	Gr 478 LC 4 Beltsville 1960	moderately resistant
6	Red Globe	s 36 sc 16 Parma 1960	highly susceptible
7	Ia 4408 B	Obs 808 sc 78 Ames 1961	highly susceptible
8	Danver	Lake Labish	moderately resistant
9	Yellow Sweet Spanish	Malheur County	moderately resistant
10	Southport White Globe	Malheur County	susceptible
11	OKD-2	Selected from Oregon Danvers	moderately resistant
12	OKD-3	Selected from Oregon Danvers	moderately resistant
13	OSU-13-3	Oregon Danver, Yellow Sweet Spanish, Australian Brown, and an USDA hybrid all open pollinated together	moderately resistant
14	OSU-5-2	Oregon Danver, Yellow Sweet Spanish, Australian Brown, and an USDA hybrid all open pollinated together	resistant

*The first ten ratings are taken from previous USDA ratings (8). and the last four from variety field plot ratings at Corvallis.

Table 2. An analysis of Lake Labish and Malheur County, Oregon soils used in greenhouse trials.

Measurement	Soil	
	Lake Labish	Malheur County
Type	Semiahmoo black mucky peat	Silty clay loam
Mineral content*		
Phosphorus	48 ppm	46 ppm
Potassium/100 g	2.38 me	1.38 me
Calcium/100 g	47.0 me	16.3 me
Magnesium/100 g	5.8 me	8.0 me
Moisture holding capacity@ (percent moisture/dry weight)		
0.1 Atm	103.47%	49.73%
0.5 Atm	85.37%	22.10%
1.0 Atm	80.74%	20.74%
2.0 Atm	73.31%	18.86%
5.0 Atm	72.48%	16.86%
15.0 Atm	70.18%	13.28%
Mechanical analysis#		
Sand (>50 μ)		38.0%
Course silt (20 to 50 μ)		19.4%
Fine silt (2 to 20 μ)		19.2%
Clay (<2 μ)		23.4%
pH	4.9	7.9

*Determined by the methods of Alban and Kellogg (1).

@Determined following the procedures outlined by Richards (58, 59, 60).

#Determined following the procedures of Kilmer and Alexander (35).

Table 3. Source and active ingredients of chemicals used in field soil fungicide and fumigation trials at Corvallis, Lake Labish, and Malheur County, Oregon.

Trade Name	Manufacturer or Distributor	Active Ingredients
Lanstan	Niagara	45% 1-chloro-2-nitropropane
Vorlex	Morton	20% methyl isothiocyanate; 80% mixture of dichloropropanes and dichloropropenes
Telone	Dow	mixture of dichloropropanes and dichloropropenes (90 to 93% 1, 3-dichloropropene)
Pictel	Maclean	trichloronitromethane; 1, 3-dichloropropene
Soil Drench	Morton	2. 2% methylmercury dicyandiamide (1. 5% mercury equivalent)
SD 345	Shell	3, 3-diacetoxy-1-propene
Chloropicrin	Maclean	99% trichloronitromethane
Mumfume	Maclean	67% trichloronitromethane 33% methyl bromide
Phaltan	Chevron*	6% n-trichloromethyl-thiophthalmide
E. P. 201	Morton	65% mixture of dichloropropanes and dichloropropenes; 20% methyl isothiocyanate; 15% trichloronitromethane
E. P. 230	Morton	15% methyl isothiocyanate 15% trichloronitromethane

*Formerly California Chemical Company.

Chemical Application

Some chemicals were applied as fumigants in the fall and others as granular or liquid formulations with spring planting.

During the fall of 1962 in Malheur County and at Lake Labish, the fumigants were applied at a depth of eight inches using a "V" blade injector (30, 53). The treatments in Malheur County were sealed with a Maclean tarp layer (Figure 1), using one mil polyethylene film. At Lake Labish the treatments were followed by a tractor-drawn roller in place of tarp.

In the 1963 Malheur County field test, fumigants were applied with a chisel injector. The chisels were spaced one foot apart and the fumigant injected at a depth of eight inches, except where otherwise specified. There were both tarped and non-tarped treatments.

All spring treatments were applied in the furrow with onion seed as it was planted.

Disease Rating

Disease ratings were made according to the system employed by Gorenz, Larson, and Walker (15). Visual fungus and nematode infection ratings were made from approximately 25 onions pulled at random from each plot and the onions were rated individually for the percent of roots infected by the pink root fungus Pyrenochaeta

Figure 1. Fall fumigation using a Maclean tarp layer.

terrestris (Figure 2) and the percent infected by a stubby root nematode Trichodorus allius Jensen (29)(Figure 3).

Yield and Grade Data

In 1963 yield data were obtained at harvest time by weighing the onions from sample areas within different plots. In 1964 the entire yield from each plot was determined from the number of stubs (approximately 50 lb. sacks) harvested. Grade data were taken from the entire yield on one field and from ten stubs from each plot on the other field in 1964.

Field Temperatures

Average air temperatures in the eastern Oregon onion growing area during June, July, and August ranged from five to eight Fahrenheit degrees above average air temperatures in the western Oregon area (Figure 4 and Table 4). Average air temperatures during the summer at Corvallis varied less than one degree from those at the Lake Labish area (81). Average soil temperatures wherever available at all soil depths from 2 to 20 inches were just slightly less than average air temperatures for the same areas (24, 81, 82, 91).

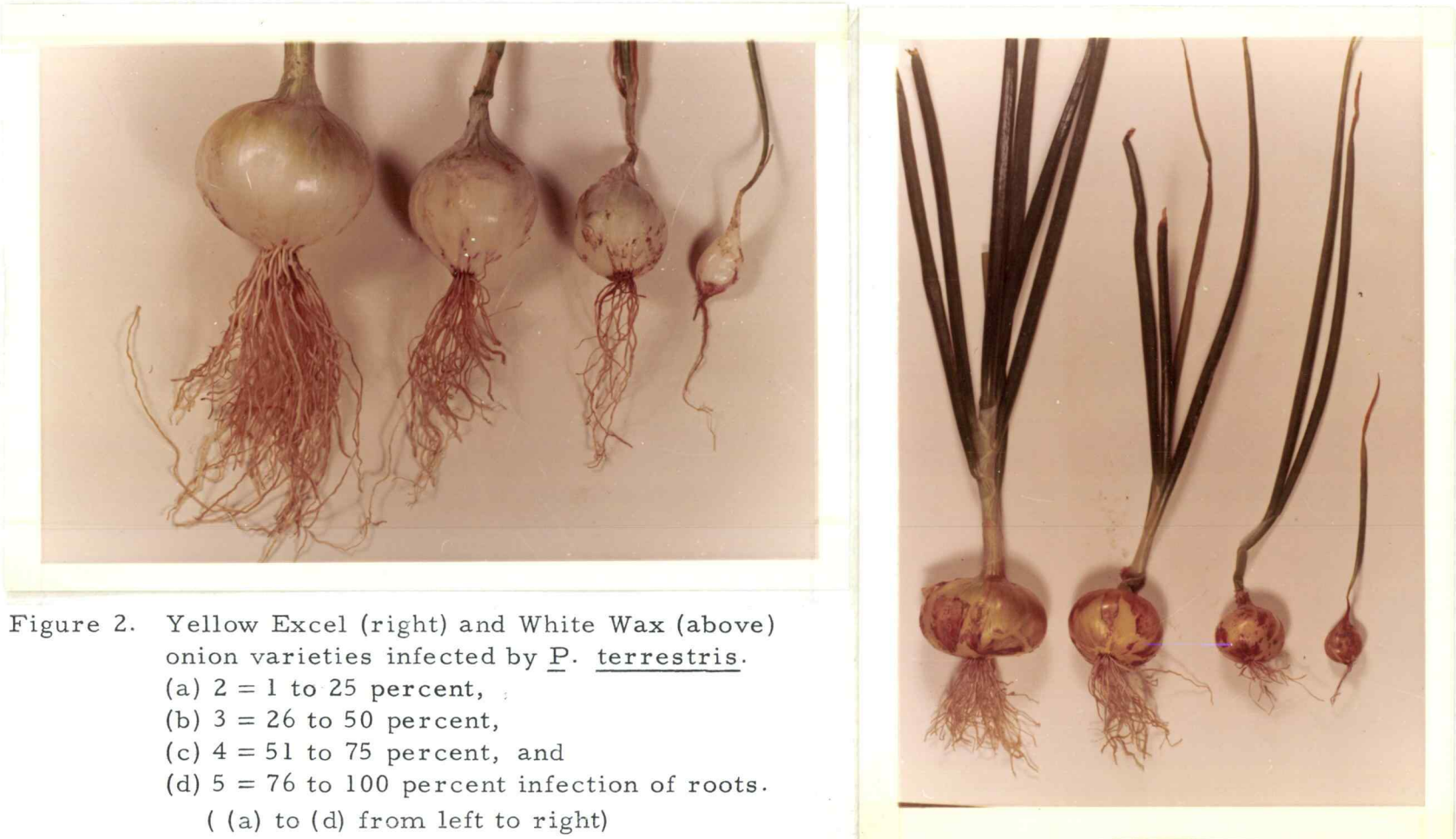

Figure 2. Yellow Excel (right) and White Wax (above) onion varieties infected by P. terrestris.
(a) 2 = 1 to 25 percent,
(b) 3 = 26 to 50 percent,
(c) 4 = 51 to 75 percent, and
(d) 5 = 76 to 100 percent infection of roots.
((a) to (d) from left to right)

Figure 3. Danver onions infected by a stubby root nematode, Trichodorus allius.
1 = no infection, 2 = 1 to 25 percent infection, 3 = 26 to 50 percent infection, 4 = 51 to 75 percent infection, 5 = 76 to 100 percent infection of roots. (1 to 5 from left to right)

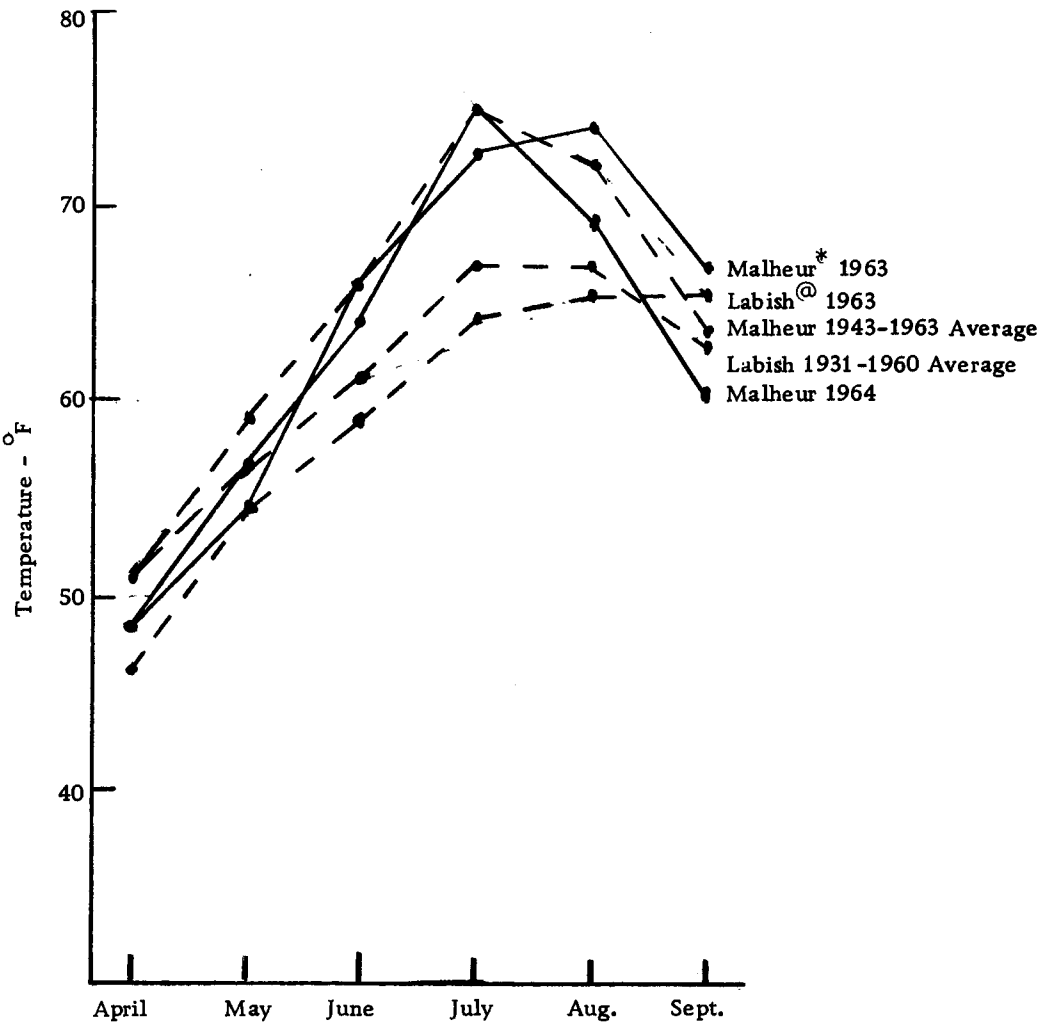

Figure 4. A comparison of average air temperatures during the growing season at the two major commercial Oregon onion growing areas.

*Readings from Malheur Experiment Station (25, 26, 81).

@Readings from Salem, Oregon (81, 82).

Table 4. Air temperature comparisons among western and eastern Oregon commercial onion growing areas and experimental plot areas.

Yearly Condition	Lake Labish* 1963	Cor-vallis@ 1963	Malheur County# 1963	1964	1959-1964 Average
Hottest temperature F	96	94	100	100	104
Days 100 F or above	0	0	1	1	8
Days 90 to 99 F	9	6	45	43	43

*Readings from Salem, Oregon (81 and 82).

@Readings from Oregon State University (81).

#Readings from Malheur Experiment Station (25, 26, 81).

Varietal Resistance

To determine if resistance among certain onion lines would remain relative constant throughout the growing season variety plots were established near Corvallis and at the Malheur Experiment Station in Malheur County. During the spring of 1963 at the Oregon State University Vegetable Crops Farm east of Corvallis, 11 onion lines were planted in a field infested with the pink root fungus. Pyrenochaeta terrestris cultures grown for two weeks on autoclaved oats were also added to the soil with the onion seed.

The onions were planted in nine-foot single-row plots at the rate of 20 seeds per foot of row (Figure 5). A similar set of plots was planted at the Malheur Experiment Station. At each location there were four replicated plots of six of the onion lines and one plot of the other five lines.

At intervals throughout the summer, onions from each plot were pulled and rated for degree of pink root infection (Table 5). The comparative resistance or susceptibility of any particular onion line in relation to the other lines did not vary appreciably throughout the growing season or between fields (Table 5; Figures 6-8).

Figure 5. Onion variety plots near Corvallis, Oregon, used to compare different onion lines for resistance to Pyrenochaeta terrestris.

Table 5. Pink root resistance of 11 onion lines grown near Corvallis and at the Malheur Experiment Station, Malheur County, Oregon.

	Malheur County					Corvallis			
Line	July 2	July 25	Aug. 14	Sept. 7	Avg	July 23	Aug. 22	Sept. 19	Avg
1*	1.0@	2.0	2.0	2.0	1.7	-	2.0	2.0	-
3*	1.1	2.0	2.0	2.1	1.8	1.0	2.0	3.4	2.1
14	1.6	2.0	2.7	3.0	2.3	1.7	2.0	2.6	2.1
2*	1.3	2.2	2.0	3.4	2.2	1.9	2.2	3.1	2.4
13	1.6	2.7	2.9	3.5	2.7	1.5	2.1	3.7	2.4
12	1.2	2.6	3.5	4.0	2.8	1.8	2.1	3.3	2.4
9	1.8	3.4	3.5	3.7	3.1	2.2	2.3	2.5	2.3
11	1.5	2.9	3.1	4.3	3.0	1.8	2.2	3.3	2.4
6*	1.8	3.1	4.3	5.0	3.6	1.9	2.0	4.0	2.6
10	2.0	4.0	4.4	4.8	3.8	1.8	2.1	3.5	2.5
7*	2.8	3.7	4.4	4.7	3.9	1.8	2.1	3.7	2.5
Average	1.6	2.8	3.2	3.7	2.8	1.7	2.1	3.2	2.4

*Only one plot at each field.

@1 = disease free; 2 = 1 to 25 percent root infection; 3 = 26 to 50 percent infection; 4 = 51 to 75 percent infection; 5 = 76 to 100 percent infection. Ratings are an average of all of the onions pulled in all of the plots.

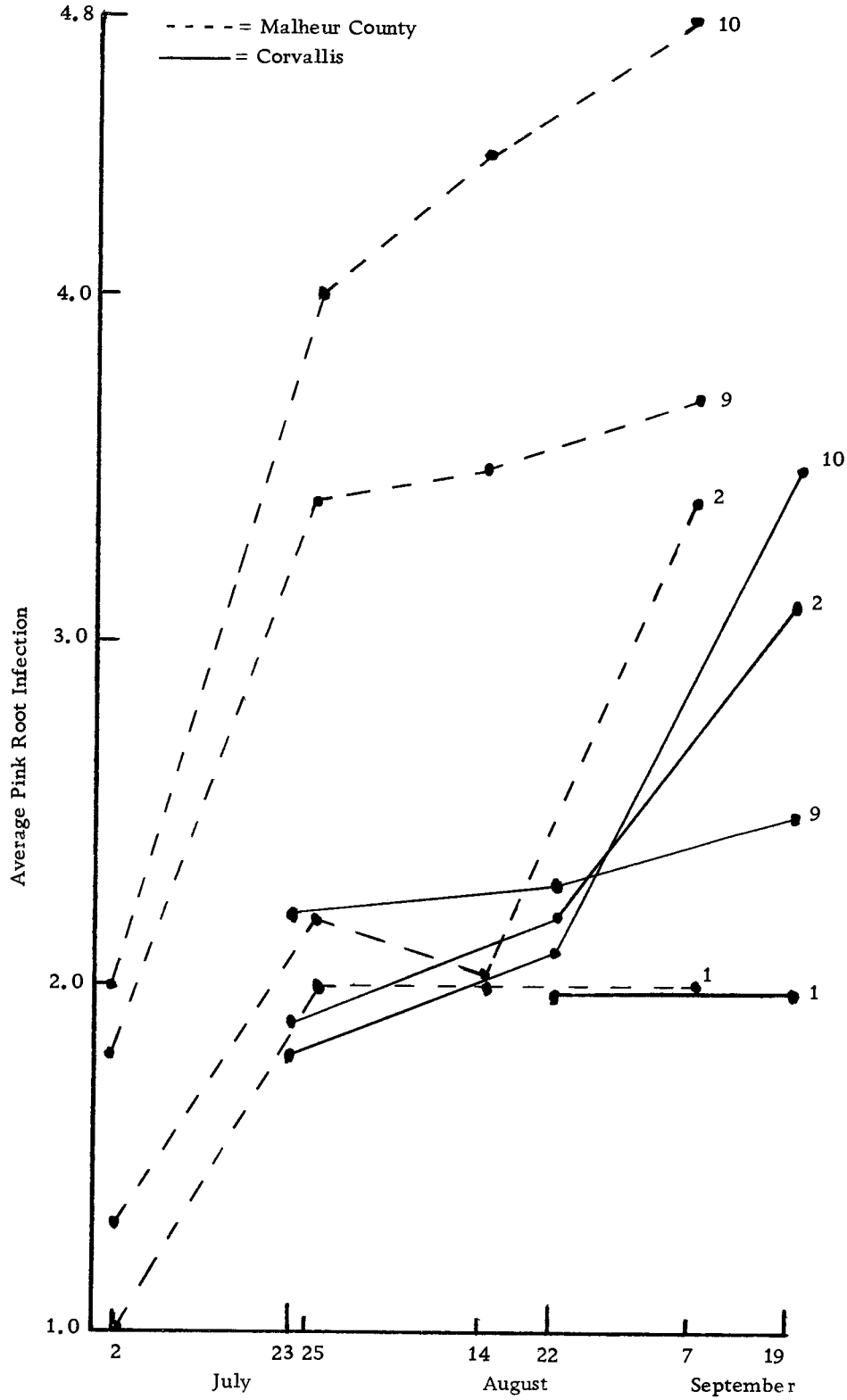

Figure 6. Pink root resistance of onion lines 1, 2, 9, and 10, grown near Corvallis and at the Malheur Experiment Station, Oregon.

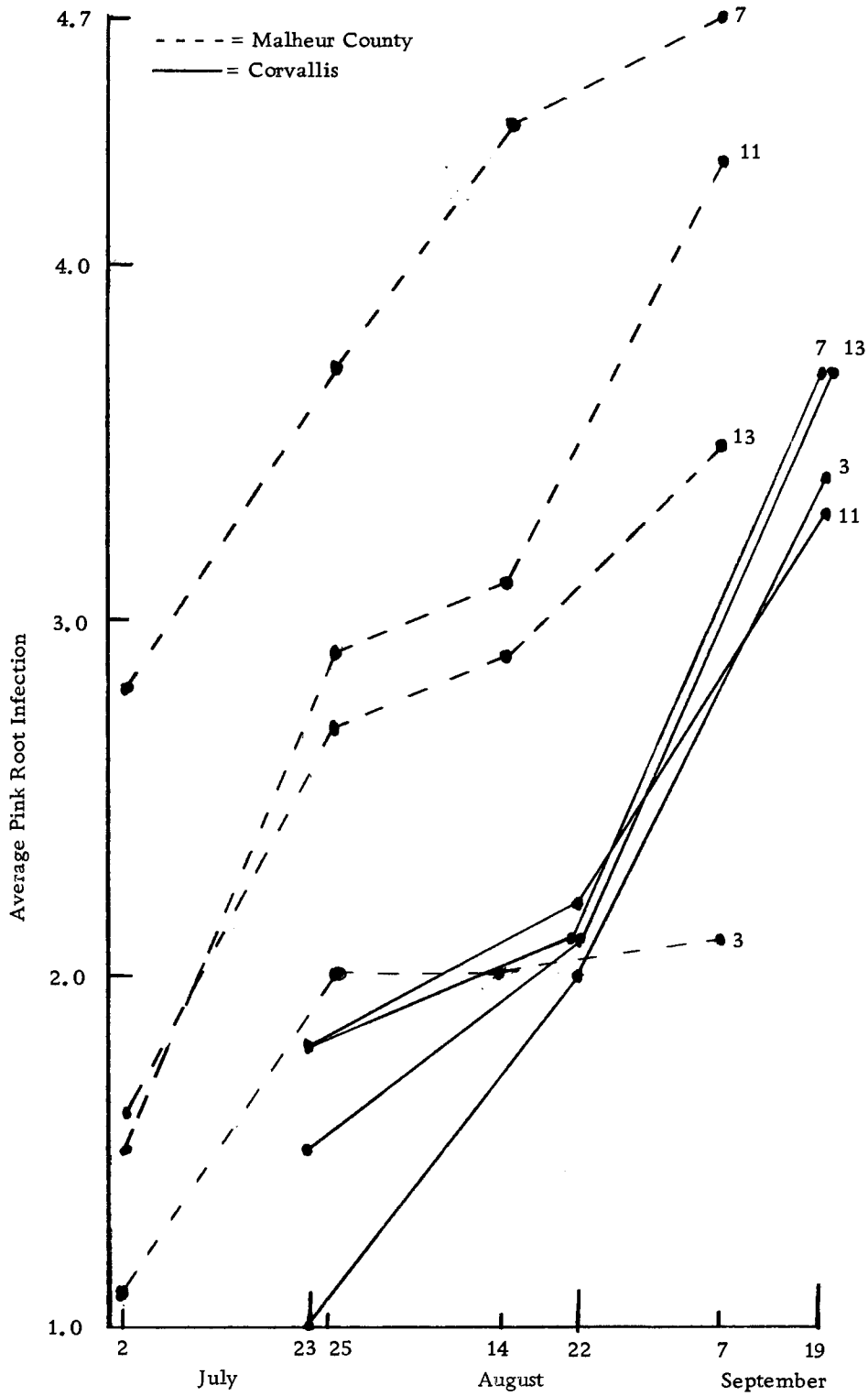

Figure 7. Pink root resistance of onion lines 3, 13, 11, and 7, grown near Corvallis and at the Malheur Experiment Station, Oregon.

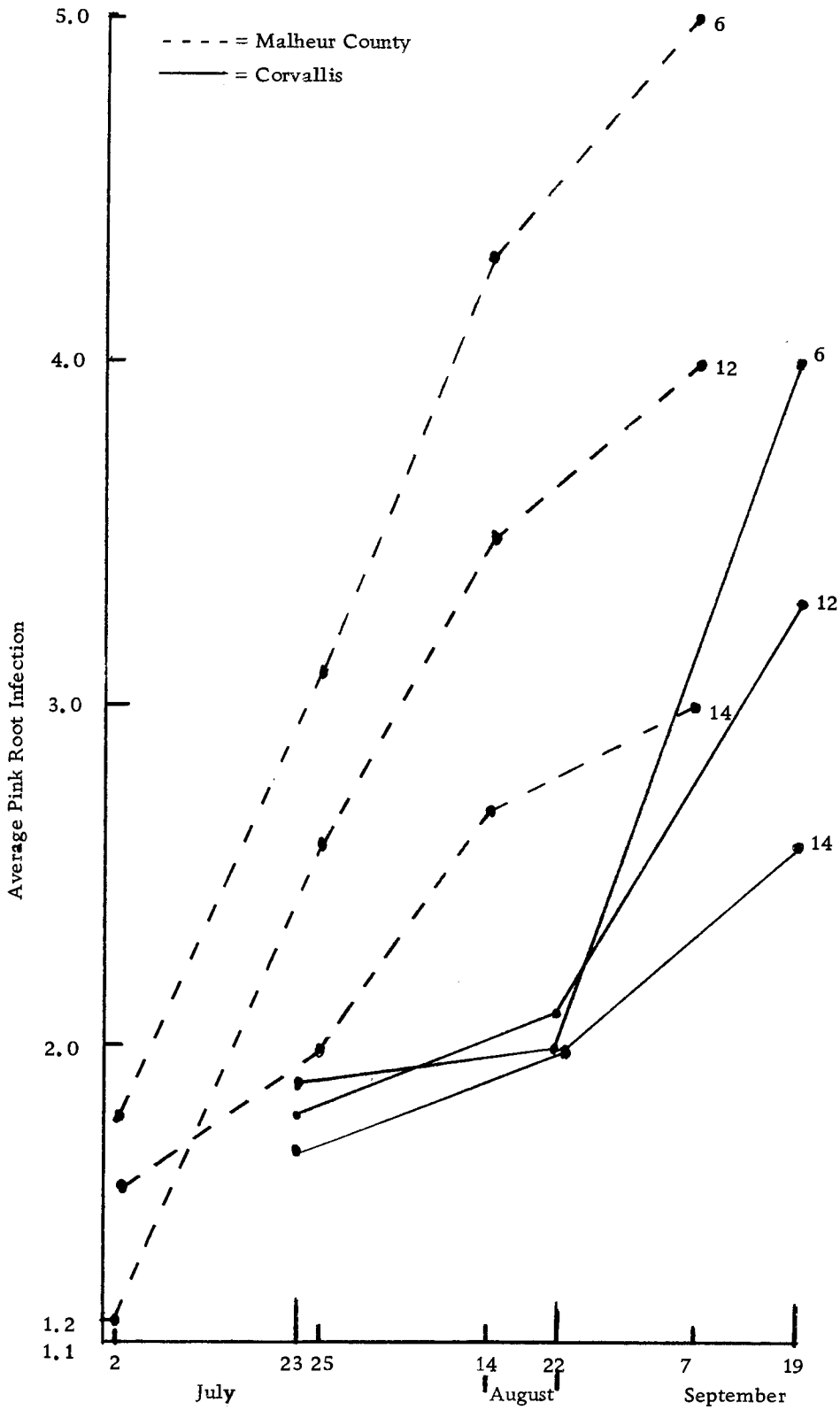

Figure 8. Pink root resistance of onion lines 14, 12, and 6, grown near Corvallis and at the Malheur Experiment Station, Oregon.

Greenhouse Soil Moisture and Soil Type Study

To determine the effects of soil moisture and soil type on severity of pink root infection, ten onion lines were planted in no. 10 cans filled with soil from Lake Labish and Malheur County. Half of the cans filled with each of the two soils were autoclaved at five psi for 12 hours before planting. Each of the cans was planted with 30 seeds, five each of six lines, and water was added to bring the soil to field capacity. After planting, one-third of the cans were allowed to dry to the wilting point of the soil before each watering back to field capacity. Another third were allowed to dry to a weight midway between field capacity and the wilting point before each watering back to field capacity. The remaining third of the cans, which had holes punched at the base, were placed in trays kept filled with water.

Each combination of treatments was replicated with nine cans of Malheur County soil and 18 cans of Lake Labish soil. The onions were grown in a temperature-controlled greenhouse from the summer of 1963 to the early spring of 1964. Air temperature within the greenhouse generally ranged from 55 F during the early morning to 90 F during the afternoon, as recorded by a thermograph. Average air temperature was about 70 F and average soil temperature slightly less.

During the early spring the onions were harvested and rated for severity of pink root (Table 6). Those receiving the least frequent watering had the poorest growth and the greatest amount of pink root, and those kept at field capacity had the best growth and the least amount of pink root. The Malheur soil treatments had slightly less average infection than the Lake Labish soil treatments. Onions grown in autoclaved soil had no pink root infection, but overall onion growth was not noticeably better than that of onions grown in non-autoclaved soil.

Field Soil Fungicide and Fumigation Trials

Corvallis

Lanstan trials were conducted at the Oregon State University Vegetable Crops Farm on a field heavily infested with P. terrestris. During the spring of 1964, Lanstan was applied with the seed of four onion varieties at the rates of two and four lb. active ingredients per acre. The liquid Lanstan was applied by gravity flow through a small tube running from a quart jar strapped to the arms of a small hand operated belt planter (Figure 9). Chemical dosage was controlled by dilution of the Lanstan.

The onion lines Yellow Sweet Spanish (line 9), OSU-13-3 (line 13), Danver (line 8), and Southport White Globe (line 10) were

Table 6. The influence of soil type and soil moisture on pink root resistance of ten onion lines grown in a greenhouse at Oregon State University, Corvallis, Oregon.

	Malheur Soil				Labish Soil				Average			
Line	WP*	½FC@	FC#	Avg	WP	½FC	FC	Avg	WP	½FC	FC	Avg
1	4.0$	3.2	1.5	2.9	3.3	2.6	2.1	2.7	3.7	2.9	1.8	2.8
3	3.6	4.6	2.0	3.4	3.9	3.3	2.6	3.3	3.8	3.9	2.3	3.4
14	3.8	4.5	1.5	3.3	4.4	3.6	3.2	3.8	4.1	4.1	2.4	3.5
2	4.0	4.2	1.0	3.1	4.7	4.0	3.0	4.0	4.4	4.1	2.0	3.5
4	4.0	3.9	2.2	3.4	4.0	3.8	3.3	3.7	4.0	3.9	2.8	3.5
9	3.3	3.5	1.8	2.9	4.8	4.2	3.3	4.1	4.1	3.8	2.6	3.5
12	4.0	4.2	1.8	3.3	4.6	4.3	2.8	3.8	4.3	4.3	2.3	3.6
5	4.0	3.0	2.0	3.0	4.5	4.3	3.6	4.1	4.3	4.3	2.8	3.6
11	4.0	3.8	2.2	3.3	4.6	4.4	3.4	4.2	4.3	4.1	2.8	3.7
10	4.0	4.0	2.7	3.6	4.8	4.0	3.7	4.2	4.4	4.0	3.2	3.9
Average	3.9	3.9	1.9	3.2	4.4	3.8	3.1	3.8	4.1	3.9	2.5	3.5

*Soil was allowed to dry to the wilting point before watering to field capacity.

@Soil was allowed to dry to midway between field capacity and the wilting point before watering to field capacity.

#Soil continuously held at field capacity.

$1 = disease free; 2 = 1 to 25 percent root infection; 3 = 26 to 50 percent infection; 4 = 51 to 75 percent infection; 5 = 76 to 100 percent infection. Ratings are an average of all onions of a particular line subjected to a given treatment.

Figure 9. Hand operated belt planter used to apply liquid Lanstan with onion seed.

Figure 10. Front row of Danver onions infected by a stubby root nematode, Trichodorus allius.

planted at the rate of 20 seeds per foot of row in 25-foot single-row plots replicated five times.

On June 1 each of the plots was given a rating for onion stand. The same thing was done in September prior to harvesting the onions. At harvest the roots were also rated for amount of pink root infection (Table 7). Both dosages of Lanstan were phytotoxic to the onions especially the four lb. rate. There was a slight reduction of pink root infection of three of the four onion lines treated with Lanstan; however, the phytotoxicity of Lanstan at these rates cut yields drastically.

Lake Labish

Fumigation and fungicide trials were conducted at the Art Rasmussen farm adjacent to Labish Center on a field with a history of pink root and serious stubby root nematode infection (28, 29, 30, 31). Plots were treated with Lanstan, Pictel, and Telone in the fall of 1962. The following spring Morton Soil Drench and Shell 345 were applied as in-the-furrow treatments at planting time. Pink root and nematode ratings and nematode assays were made throughout the summer (Table 8). Soil samples for nematode assays were taken from the surface to a depth of nine inches. Nematodes from pint soil samples were extracted using an adaptation by Thorne (70, p. 49) of the Baermann (2) principle. None of the treatments had any

Table 7. Influence of Lanstan on growth and pink root infection of four onion lines grown near Corvallis, Oregon, 1964.

Line	Lanstan Lb. Active/A.	June Stand	September Stand	September Pink Root
9	0	1.0*	1.0	3.0@
	2	3.6	2.4	3.4
	4	4.4	4.4	3.3
	Avg 0-4	3.0	2.6	3.2
13	0	1.0	1.0	4.0
	2	3.0	1.8	3.2
	4	4.0	2.8	3.4
	Avg 0-4	2.7	1.9	3.5
8	0	2.0	1.4	4.6
	2	3.0	1.4	4.0
	4	4.0	3.6	3.0
	Avg 0-4	3.0	2.1	3.9
10	0	1.0	1.0	4.8
	2	4.0	2.6	4.0
	4	4.0	4.0	4.0
	Avg 0-4	3.0	2.5	4.3

*1 = excellent, thick stand; 2 = fair stand; 3 = sparse stand; 4 = very sparse stand; 5 = no onions.

@1 = disease free; 2 = 1 to 25 percent root infection; 3 = 26 to 50 percent infection; 4 = 51 to 75 percent infection; 5 = 76 to 100 percent infection.

Table 8. Effect of chemical treatments of the soil on nematode population of the soil and on nematode infection, pink root infection and yields of Danver onions at Lake Labish, Oregon.

Treatment	June Nematode No.@	Average Infection* 9 July Nematode	9 July Fungus	29 July Nematode	29 July Fungus	20 Aug. Nematode	20 Aug. Fungus	Tons/A. Yield
Check	>100	1.5	1.4	2.5	2.1	1.5	2.2	27.71
Pictel	10-100	1.1	1.4	1.6	2.1	1.0	2.2	33.58
Lanstan	>100	1.4	1.2	2.5	2.0	1.5	2.2	24.45
Check	>100	3.4	1.7	-	-	4.9	2.9	18.72
Telone 35 Gal/A.	<10	1.0	1.5	-	-	-	-	31.78
Telone 52.5 Gal/A.	<10	-	-	1.0	2.1	-	-	24.29
Telone 70 Gal/A.	<10	1.0	1.1	1.0	2.0	1.0	2.9	29.99
Soil Drench below seed + Telone 70 Gal/A.		1.1	1.5	1.0	2.0	1.0	2.3	25.59
Soil Drench with seed + Telone 70 Gal/A.		1.1	1.5	1.0	2.1	1.0	2.3	28.20
SD 345 below seed		2.1	1.4	2.7	2.0	2.1	2.5	20.38
SD 345 with seed		2.1	1.3	3.1	2.2	1.5	2.7	19.52

*Ratings are based on the percent of roots infected by the pink root fungus Pyrenochaeta terrestris and a stubby root nematode Trichodorus allius. 1 = no infection; 2 = 1 to 25 percent infection; 3 = 26 to 50 percent infection; 4 = 51 to 75 percent infection; 5 = 76 to 100 percent infection.

@Relative number of nematodes of all species obtained per pint of soil. The number of T. allius averaged one in fifteen or seven percent of the total.

noticeable effect in reducing the amount of pink root infection. Telone gave a very appreciable nematode control and increased onion yields. Greatest increases in yields were from plots with the lowest population of stubby root nematodes as measured by both nematode disease ratings and actual nematode counts. There was no decernible relationship between amount of pink root and nematode infection.

Malheur County

Plots were established on the Earl Winegar farm south of Ontario and adjacent to Cairo Junction on a field heavily infested with P. terrestris. During the spring of 1963 granular phaltan was applied in-the-furrow with onion seed on replicated, previously non-treated plots and on plots fumigated with tarped Mumfume the previous fall at the rate of 140 lb. per acre.

Pink root disease ratings were made throughout the summer. There was no noticeable difference in amount of root infection among onions from different treatments (Table 9). However, Mumfume treatments gave significant increases in yields of from 43 to 46 percent Yellow Sweet Spanish onions and 78 percent Southport White Globe onions. During the fall of 1963 two fields with a history of pink root were fumigated with chloropicrin, Pictel, Vorlex, E. P. 201, and E. P. 230. One field was on the Kayno Saito farm

Table 9. Effect of chemical treatments of the soil on pink root infection and onion yields at the Cairo Junction Earl Winegar farm, Malheur County, Oregon.

	Yellow Sweet Spanish Onions					Southport White Globe Onions				
	Pink Root Infection					Pink Root Infection				
Treatment	2 July	14 Aug.	6 Sept.	Avg.	Yield Tons/A.	2 July	14 Aug.	6 Sept.	Avg.	Yield Tons/A.
Check	2.7*	3.0	4.0	3.2	40.26	2.6	4.2	4.9	3.9	13.20
Phaltan 50 Lb./A.	2.5	3.1	4.1	3.2	35.21	2.7	4.0	4.9	3.9	13.04
Phaltan 65 Lb./A.	2.2	3.4	4.0	3.2	35.58	-	-	-	-	-
Mumfume@	2.8	2.9	4.0	3.2	51.02	1.9	3.3	4.8	3.3	23.47
Mumefume + Phaltan 50 Lb./A.	2.0	3.0	4.0	3.0	47.91	2.1	2.9	4.6	3.2	20.38
Mumefume + Phaltan 65 Lb./A.	2.7	3.5	4.1	3.4	43.68	-	-	-	-	-
Check	-	-	-	-	38.74	-	-	-	-	-
Mumfume	-	-	-	-	56.27	-	-	-	-	-
L.S.D. 5%					3.97					

*1 = disease free; 2 = 1 to 25 percent root infection; 3 = 26 to 50 percent infection; 4 = 51 to 75 percent infection; 5 = 76 to 100 percent infection.

@Each Mumfume treatment was applied 140 lb. per acre and tarped.

north of Nyssa and the other on the Mas Yano farm on the Oregon Slope about ten miles north of Ontario. The ground of the first field was well cultivated prior to fumigation while the second field was quite dry and had many hard clods when fumigated.

The following spring both fields were planted in Yellow Sweet Spanish onions; however, the onion seed in the field near Nyssa was planted slightly thicker than is normally done. The onions on the Oregon Slope field got a poor start due to inadequate irrigation and apparently an overdose of cyanide spray weed killer. Both fields were hit by a brief, strong wind and rain storm (26, p. 14) on July 29. This storm was probably more severe on the Oregon Slope where many onion tops were knocked to the ground. However, onions growing in the fumigated plots withstood the storm much better than those in non-treated plots (Figures 11 and 12).

At the Oregon Slope field yields from plots fumigated with E. P. 201 and E. P. 230 averaged 50 percent more than the non-treated plots (Table 10). At the field near Nyssa there was no apparent difference among treatments in either onion appearance or yields (Table 11).

Figure 11. Aerial view of a fumigated onion field on the Mas Yano farm following a severe windstorm on the Oregon Slope north of Ontario, Oregon.

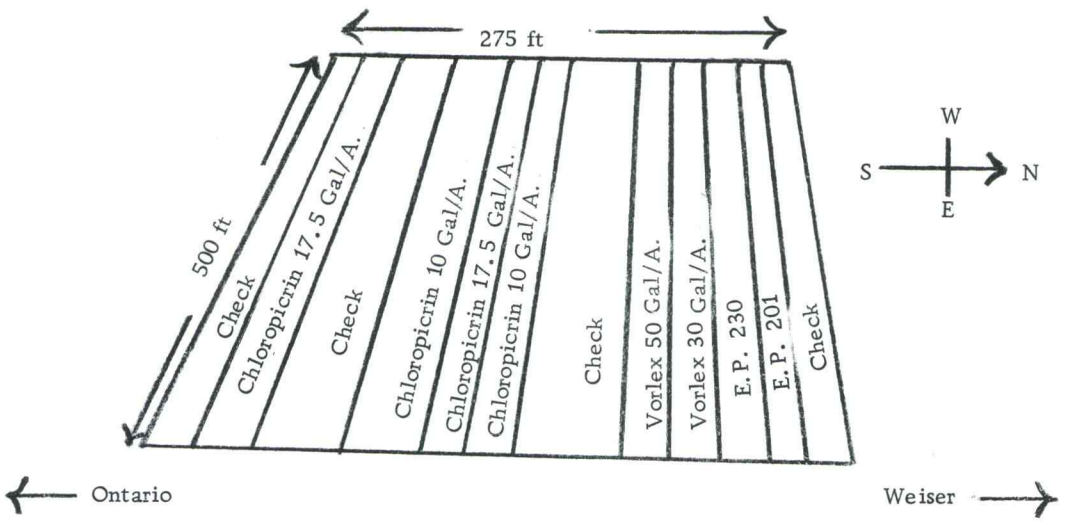

Figure 12. Plot diagram of the Oregon Slope fumigation plots.

Table 10. Effect of soil fumigation treatments on onion yields at the Mas Yano farm on the Oregon Slope north of Ontario, Oregon.

Treatment	Average Yield in Tons/A.	Percent 3+ inch Onions
Check	17.5	63
Chloropicrin 17.5 Gal/A. tarped	21.5	91
Chloropicrin 10 Gal/A. tarped	24.5	83
Vorlex 50 Gal/A.	24.2	83
Vorlex 30 Gal/A.	24.8	83
E. P. 230 30 Gal/A.	27.0	80
E. P. 201 30 Gal/A.	27.5	84
Average of all treatments excluding checks	24.9	84

Table 11. Effect of soil fumigation treatments on Yellow Sweet Spanish onion yields at the Kayno Saito farm north of Nyssa, Oregon.

Treatment	Average Yield in Tons/A.	Percent 3+ inch Onions
Check	27.5	44
Chloropicrin 20 Gal/A.	25.8	-
Chloropicrin 17.5 Gal/A. tarped	32.3	53
Chloropicrin 10 Gal/A. tarped	29.7	55
Vorlex 32 Gal/A.	21.7	-
Vorlex 3 in. depth 32 Gal/A.	20.3	-
Vorlex 20 Gal/A.	29.0	-
Vorlex 3 in. depth 20 Gal/A.	28.9	-
E. P. 230 30 Gal/A.	26.3	33
E. P. 201 30 Gal/A.	27.8	56
Pictel 400 Lb./A.	27.8	50
Average of all treatments exculding checks	27.0	49

FUNGUS PHYSIOLOGY

General Materials and Methods

Fungus Isolates

Isolates of Pyrenochaeta terrestris were obtained from pieces of infected onion roots which were immersed in a one percent sodium hypochlorite solution for two minutes then plated on potato dextrose agar (PDA). To minimize mutation these isolates were preserved in cold storage in soil tubes (48). Prior to use in growth experiments the fungus isolates were recultured on PDA plates or tubes.

Isolates L-5-10 and C-44-1 were obtained from onion fields at Lake Labish and Malheur County, respectively. In greenhouse tests using the onion varieties: Y28, 951, Southport White Globe, and Yellow Sweet Spanish, Hess (21, p. 32) rated C-44-1 most pathogenic and L-5-10 sixth when compared with 12 other isolates of P. terrestris from these same two major onion growing areas. Isolate L-5-10 was used throughout the physiology experiments. Isolate C-44-1 was used only in the vitamin experiment.

Media

PDA was made by mixing 17 g of agar, 22 g of dehydrated powdered potatoes, and 20 g of dextrose in one liter of distilled

water, and autoclaving at 15 psi for 20 minutes. In some instances the broth obtained from cooking 200 g of peeled, sliced potatoes in 500 ml of water for 40 minutes in an autoclave was substituted for the 22 g of dehydrated potatoes.

Malt extract yeast extract agar was made using 20 g of malt extract, 2 g of yeast extract, 20 g of agar and one liter of distilled water.

Media for the carbon source tests consisted of the following:

Glucose	10.0 g
Asparagine	2.0 g
KH_2PO_4	1.0 g
$MgSO_4 \cdot 7H_2O$	0.5 g
Fe^{+++}	0.2 mg
Zn^{++}	0.2 mg
Mn^{++}	0.1 mg
Biotin	5.0 g
Thiamine	100.0 g
Distilled water	1.0 liter
Agar	20.0 g

All other asparagine media used had the same basal composition with different carbon sources substituted for glucose. The iron, zinc, and manganese were supplied from a solution of ferric nitrate, zinc sulfate heptahydrate, manganese sulfate tetrahydrate, and sufficient sulfuric acid to give a clear solution. To minimize hydrolysis each carbon source was autoclaved separately and added to the medium.

Chemicals of cp grade were used. The media were adjusted to pH 6 by adding either concentrated sodium hydroxide or concentrated hydrochloric acid before autoclaving. Liquid media were

prepared in the same manner without agar.

Media for nitrogen source tests were prepared identically to the glucose-asparagine medium except for the substitution of other nitrogen sources for asparagine.

Media for pH tests had the same basal composition using glucose and asparagine as the carbon and nitrogen sources in one medium and sucrose and potassium nitrate in the other. The pH of each medium was adjusted with sodium hydroxide or hydrochloric acid before autoclaving, but the "initial pH" was determined after autoclaving, from representative flasks of each group. No buffer was used.

Growth Determinations

Inoculations were made by transferring a small piece of mycelium from a one week old culture of P. terrestris grown on PDA at room temperature to the center of a 90 mm pyrex Petri dish containing 15 ml of agar medium, or to a 125 ml pyrex Erlenmeyer flask containing 15 ml of liquid medium. Unless otherwise stated cultures in the growth experiments were grown in a dark cabinet. Temperature in the cabinet, as measured by a thermograph, fluctuated between 23 and 26 C.

Linear growth of P. terrestris was outlined on the bottom of Petri dishes with a marked pencil and colony diameter was measured

with a ruler. Flask cultures were collected on a weighed glass filter paper using a Buchner funnel. The filter paper containing the fungus was placed in a drying oven at 100 C for two days, removed to a desiccator for one day, then weighed on a Mettler balance to determine the dry weight of the fungus.

Temperature

Effects of temperature on growth and sporulation of P. terrestris isolate L-5-10 were studied on malt extract-yeast extract agar. Cultures were incubated for four weeks at 5, 10, 15, 20, 25, and 30 C in the dark. Three plates were incubated at each temperature and linear growth was measured periodically.

Very little growth of the fungus took place below 15 and none at 5 C (Figure 13). The greatest growth was at 30 C. There was no observable sporulation.

Light

Effects of light on growth and sporulation of P. terrestris were studied on malt extract-yeast extract and sucrose-asparagine agars. The four following light treatments were imposed on isolate L-5-10: continuous total darkness, continuous light, alternating darkness and light (exposed to light from 6 AM to 6 PM daily), and alternating darkness and light with a two-minute exposure to

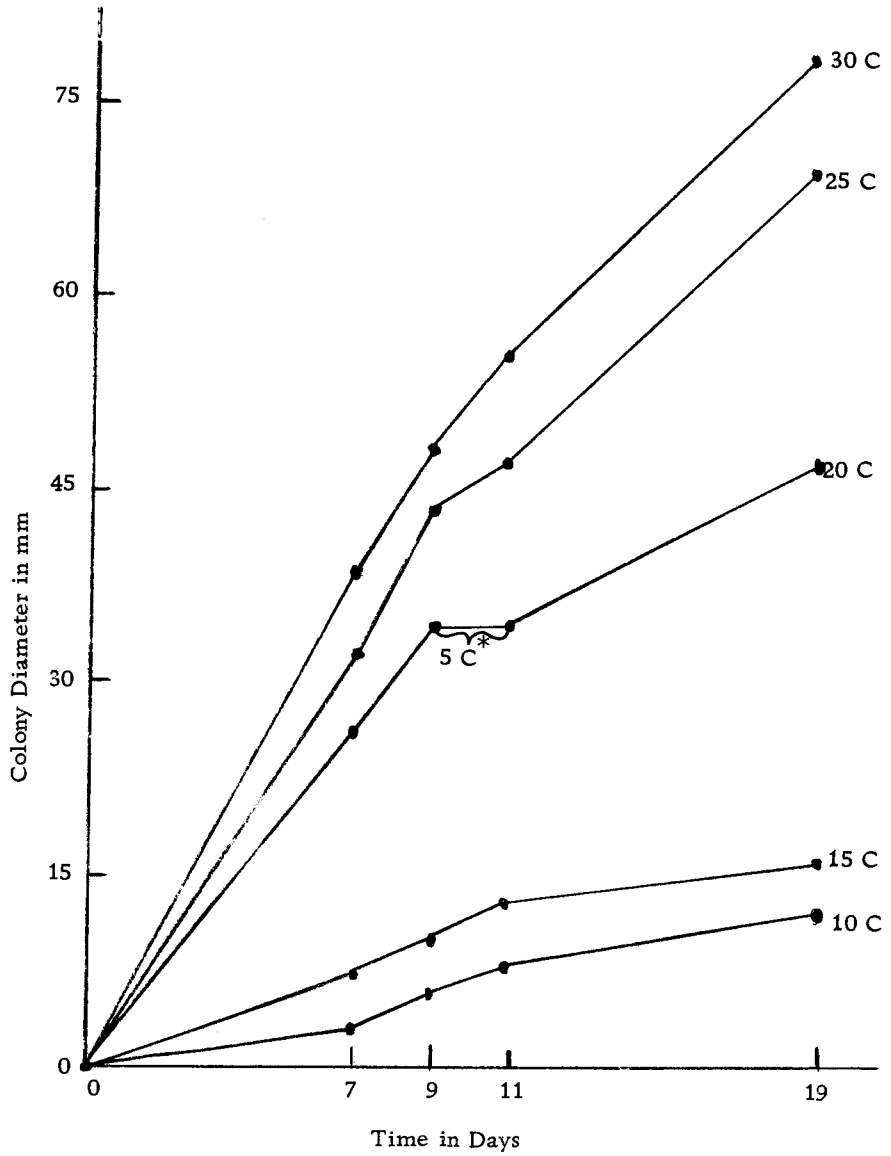

Figure 13. Influence of temperature on linear growth of Pyrenochaeta terrestris isolate L-5-10 on malt extract-yeast extract agar.

*After nine days at 20 C these cultures were inadvertently grown at 5 C for two days and then returned to 20 C.

germicidal ultraviolet light (2,500 Å) at the end of five days and again two days later.

Illumination was provided by indirect daylight and four 40-watt fluorescent lights placed three feet above the plates. The exposure to ultraviolet light was done at a distance of approximately eight inches with the lids of the plates removed. Measurements of cultures grown in the dark were made using a 20-watt red lamp. The colony diameters of three replications of each treatment were measured periodically over a period of three weeks while the fungus grew at room temperature which fluctuated between 20 and 25 C as measured by a thermograph.

The different light exposure treatments had no consistent effect in changing the rate of growth of the fungus (Table 12). The fungus grew slightly faster on the malt extract-yeast extract agar only for the first few days after which time it grew somewhat slower than on the sucrose-asparagine agar, especially when exposed to continuous light. None of the treatments induced sporulation during the three week period.

pH

The effect of pH on P. terrestris growth and the effect of the growth of P. terrestris on pH was studied using isolate L-5-10 and glucose-asparagine and sucrose-nitrate media adjusted to initial

Table 12. Influence of light on growth of Pyrenochaeta terrestris isolate L-5-10 on sucrose-asparagine and malt extract-yeast extract agar.

	Continuous Light		Alternating Light-Dark		Alternating Light-Dark+UV		Continuous Dark	
Days	S-A*	M-Y@	S-A	M-Y	S-A	M-Y	S-A	M-Y
4	15#	17	15	15	16	17	15	20
7	33	29	29	28	28	25	-	-
9	50	36	-	-	-	-	-	-
11	65	42	48	48	48	38	-	-
14	79	52	64	65	61	48	-	-
19	90+	61	-	-	90+	66+	-	-
21	90+	64	87+	86+	-	-	90+	69+

*Sucrose-asparagine agar.

@Malt extract-yeast extract agar.

#Colony diameter in mm. Average of three replications.

pH values of 3, 4, 6, and 8. In order to follow the effect of fungus growth on the pH of the media no buffer system was used. This also eliminated the effects that different buffer systems might have had in supplying additional nutrients for growth. Two cultures at each of the four initial pH values were harvested at the end of 8, 11, 13, and 16 days.

In practically all instances the pH of the medium increased with growth of the fungus (Table 13 and Figure 14). The fungus grew very well on media with intial pH values of 6 and 8 (Figure 15). Growth was very slow on media with a pH of 3 or 4. There was a definite color change of the fungus from a yellowish brown to red as the pH of the cultures increased from below pH 5 to above pH 5. As a whole the fungus grew faster on the glucose-asparagine media (Figure 15). None of the cultures produced spores.

Carbon Sources

Effects of nine different carbon sources on growth and sporulation of P. terrestris isolate L-5-10 were evaluated using both liquid and agar cultures. Three replicates of each treatment were used. Linear growth on the agar plates was measured periodically and the liquid cultures were harvested after 18 days' incubation.

The fungus grew well on all of the carbon sources except sorbose and carbon deficient media (Table 14 and Figure 16).

Table 13. Relation between pH and growth of Pyrenochaeta terrestris isolate L-5-10 on glucose-asparagine and sucrose-potassium nitrate media.

Days	Measurement	Initial pH Value 3 G-A*	3 S-N@	4 G-A	4 S-N	6 G-A	6 S-N	8 G-A	8 S-N	Average G-A	Average S-N
8	Wt#	18.3$	12.4	16.5	18.2	36.7	30.5	40.7	14.1	28.1	18.8
	pH	3.0	2.9	4.9	5.8	5.6	6.8	7.6	7.8	5.3	5.8
11	Wt	19.7	11.4	56.2	19.8	56.1	39.2	59.7	56.5	47.9	31.7
	pH	3.6	3.4	6.6	6.8	6.6	7.9	7.7	8.3	6.1	6.6
13	Wt	34.5	5.5	63.9	43.0	39.6	34.2	49.5	59.1	46.9	35.3
	pH	4.2	3.2	6.9	8.0	6.3	7.6	8.4	8.6	6.5	6.8
16	Wt	68.4	34.2	71.6	53.2	56.8	61.9	64.1	57.1	65.2	51.6
	pH	5.4	6.7	6.2	8.3	6.9	8.1	8.3	8.8	6.7	8.0
Avg	Wt	35.2	15.9	52.1	33.6	47.3	41.5	53.5	46.7		
	pH	4.1	4.1	6.2	7.2	6.4	7.6	8.0	8.4		

*Glucose-asparagine medium.

@Sucrose-potassium nitrate medium.

#Dry weight in mg.

$Average of two replications.

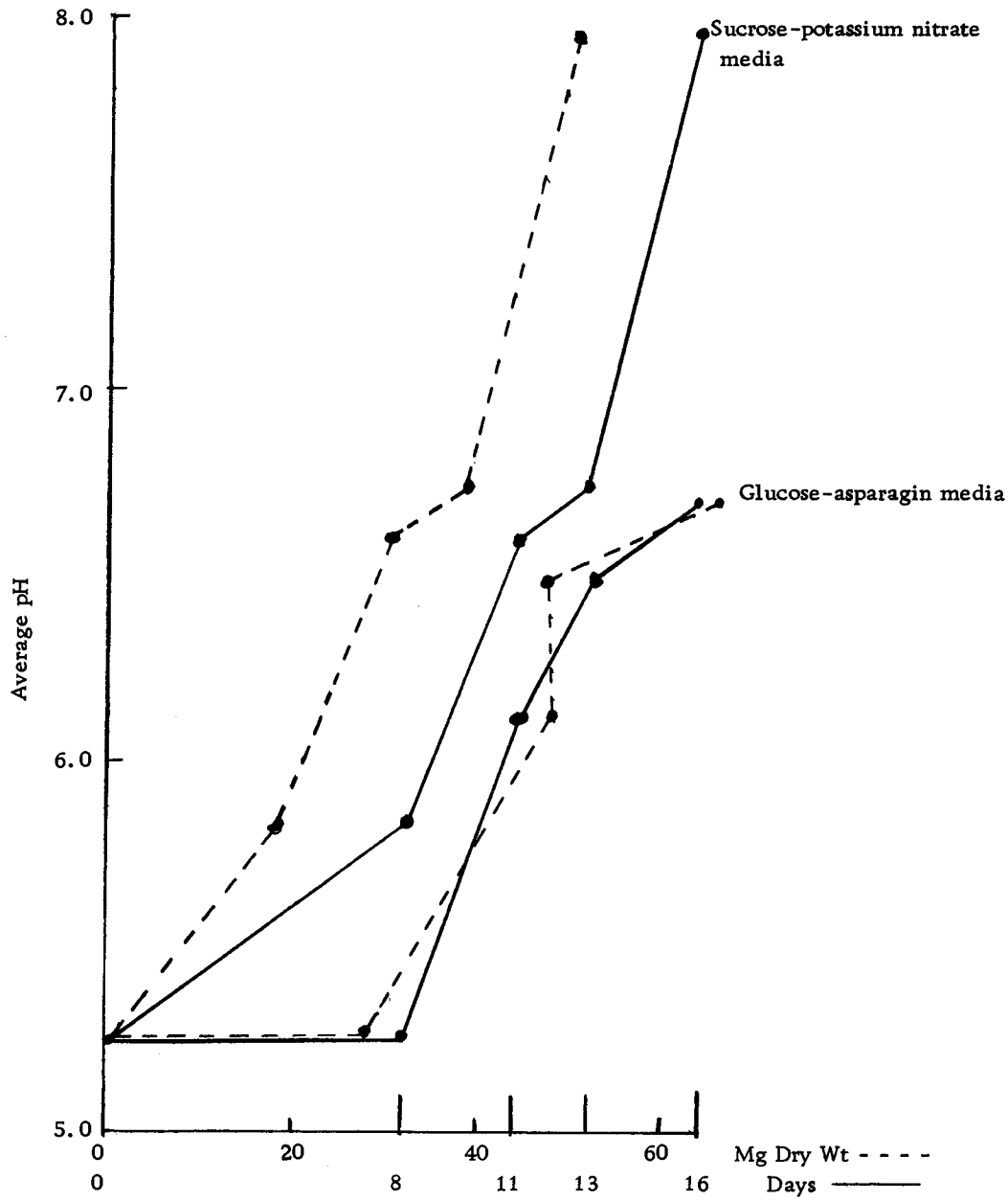

Figure 14. Influence of Pyrenochaeta terrestris isolate L-5-10 on the pH of glucose-asparagin and sucrose-potassium nitrate media.

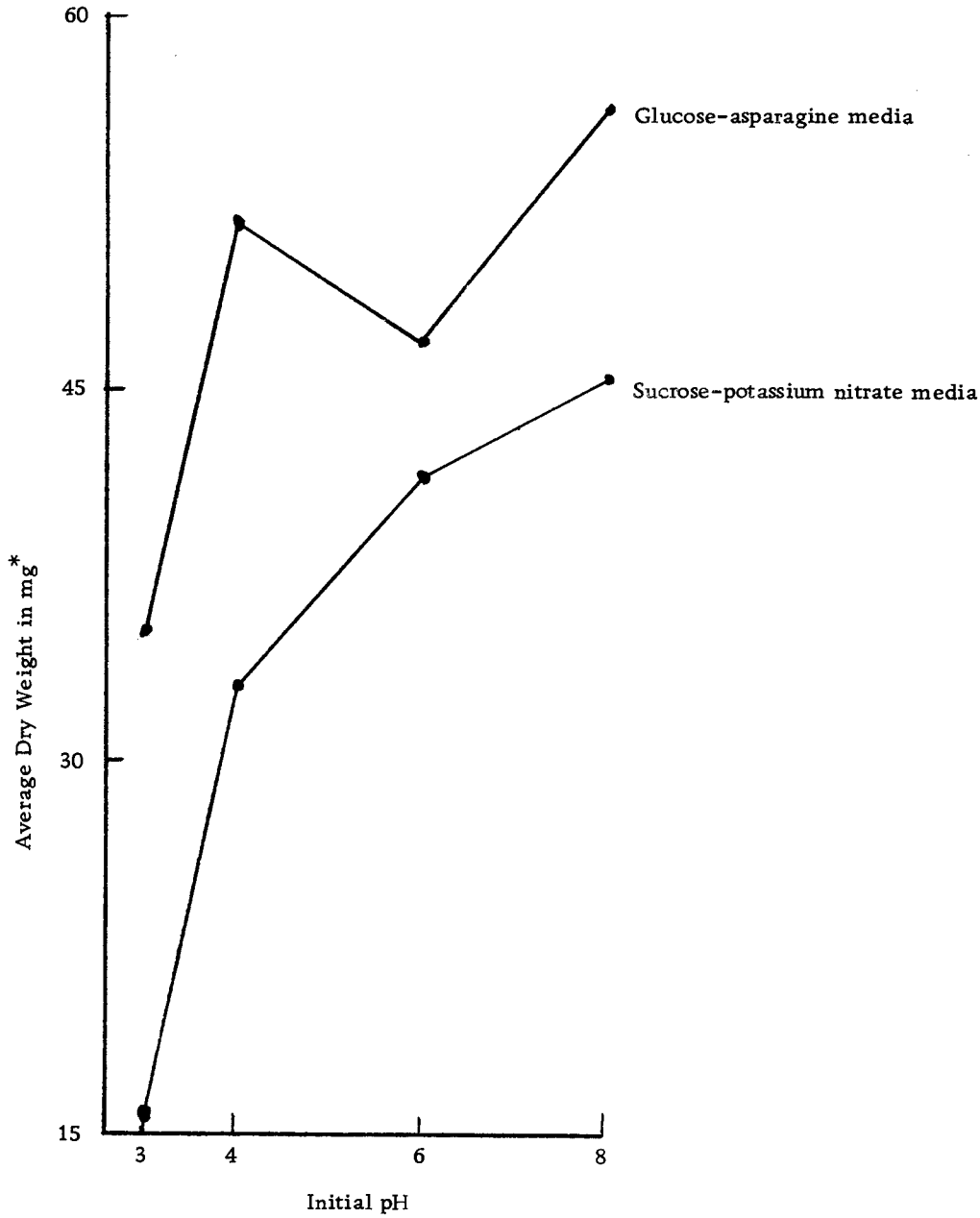

Figure 15. Influence of pH on growth of Pyrenochaeta terrestris isolate L-5-10 on glucose-asparagine and sucrose-potassium nitrate media.

*Average of four harvests--8, 11, 13, and 16 days' growth.

Table 14. Influence of carbon source on growth of Pyrenochaeta terrestris isolate L-5-10 on asparagine media.

Carbon Source	Linear Growth* 4 Days	7 Days	12 Days	21 Days	Dry Wt@ 18 Days
None	14#	34	47	57	6.7
Sorbose	3	4	9	19	6.7
Maltose	14	38	71	90+	44.1
Galactose	13	27	58	90+	45.6
Glucose	11	34	67	90+	46.5
Fructose	15	32	59	90+	46.8
Sucrose	15	36	64	90+	46.9
Lactose	14	31	57	90+	49.1
Starch	16	34	57	87+	60.8
Malt extract-yeast extract	20	36	57	72	114.7

*Colony diameter in mm.

@Dry weight in mg.

#Average of three replications.

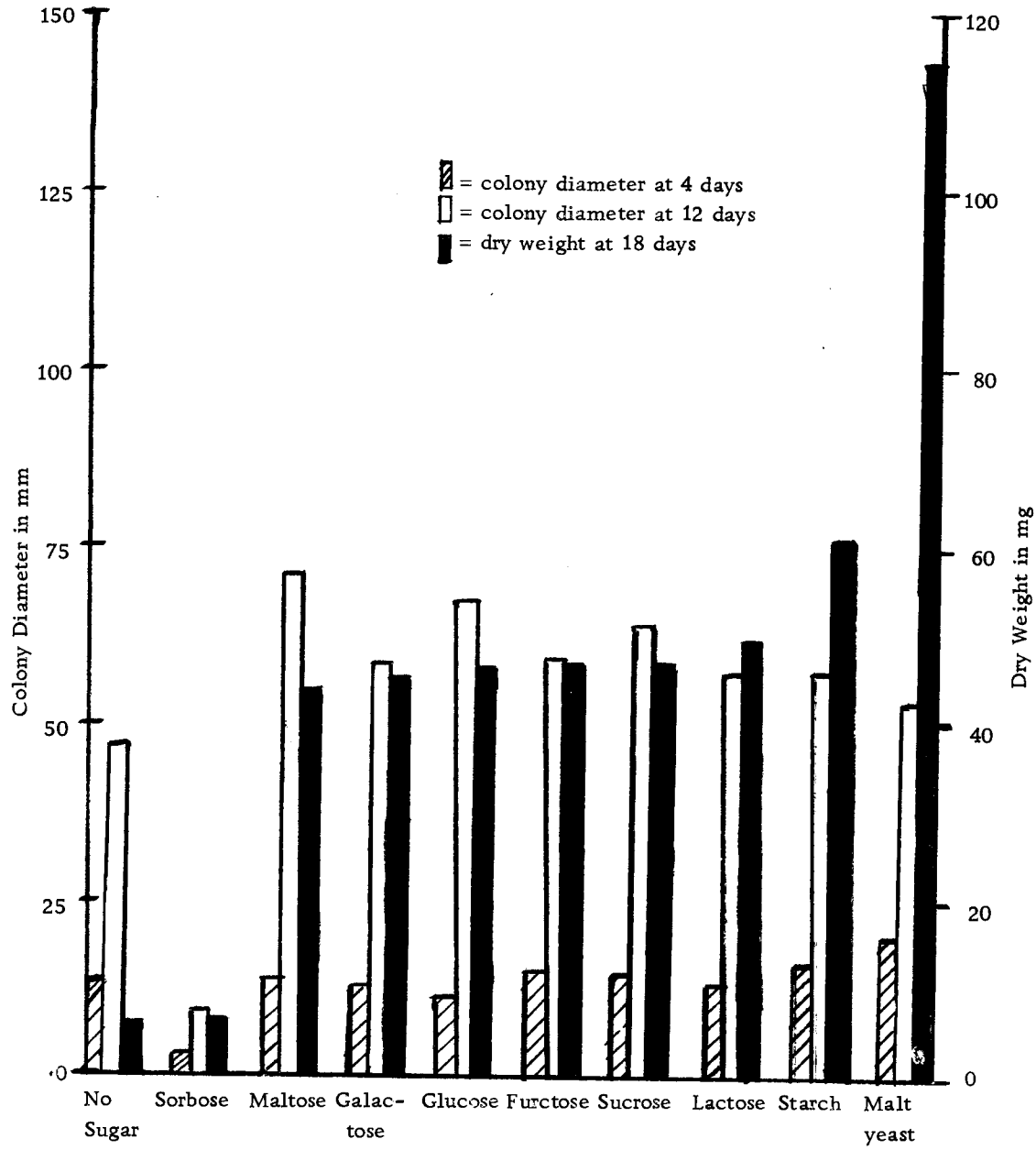

Figure 16. Influence of carbon source on growth of Pyrenochaeta terrestris isolate L-5-10 on asparagine media.

The isolate increased in dry weight by a little more than two times when grown on malt extract-yeast extract medium as compared to growth on asparagine media supplemented with maltose, fructose, galactose, sucrose, starch, or glucose. Although the growth during the first week on the carbon deficient agar medium was comparable in length to that on the other agar media, it was extremely sparse as compared to the other cultures. Linear growth of the isolate on malt extract-yeast extract agar exceeded growth on the other media for the first few days only. After one week the linear growth on carbon deficient and on malt extract-yeast extract agars began to lag behind other cultures. Sporulation did not occur on any of the media. Pigment produced by each culture was distinctive and characteristic of the particular substrate used (Figure 17).

Nitrogen Sources

Agar media were used to study effects of nine different nitrogen sources on growth and sporulation of P. terrestris isolate L-5-10.

The pH of the glucose media after autoclaving was recorded as follows:

glutamic acid	3.3
caesein hydrolysate	3.7
asparagine	5.3
ammonium sulfate	5.4
potassium nitrate	5.5
ammonium tartrate	5.6
no nitrogen	5.6
glycine	5.6
urea	6.7

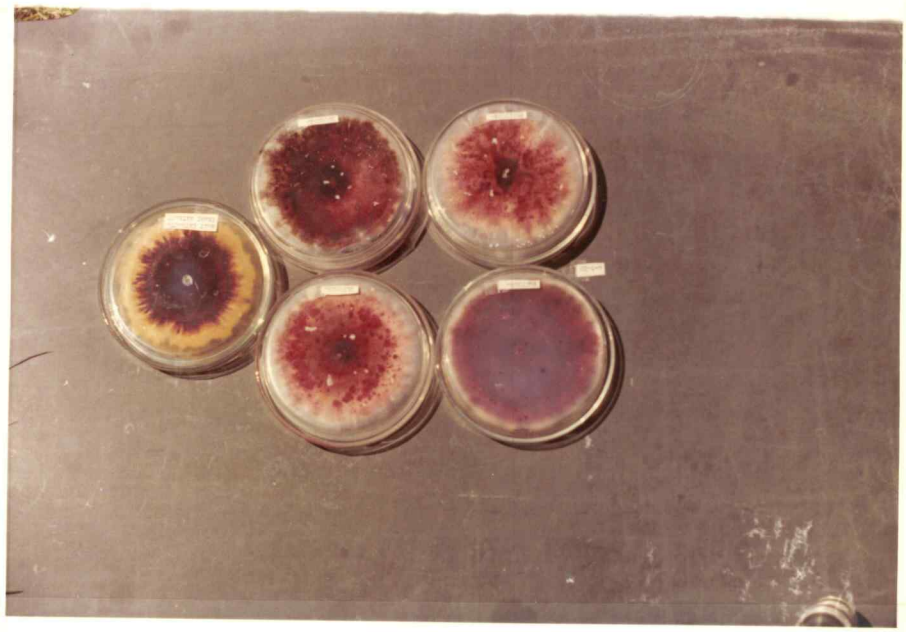

Figure 17. Pigment produced by Pyrenochaeta terrestris isolate L-5-10 on malt extract-yeast extract agar and on asparagine agar supplemented with sucrose, fructose, maltose, and glucose (clockwise from left).

Linear growth of the isolate was recorded during a 16 day incubation period using three replications of each medium. The fungus grew fastest on the medium supplemented with glycine with the growth on potassium nitrate, urea, and asparagine slightly slower (Figure 18). Growth was slowest on casein hydrolysate and glutamic acid media, possibly due to the low pH of these media. The isolate grew very rapidly during the first few days on the malt extract-yeast extract agar, but linear growth was quite slow after that time.

Again a pigment distinctive and characteristic for each substrate was produced (Figure 19), and none of the cultures sporulated.

Vitamin Requirements

The ability of P. terrestris to grow without thiamine, biotin, inositol, and pyridoxine in its substrate was tested using 100 ml test tube slants containing sucrose-asparagine agar minus various of these vitamins. Difco purified agar was used. Treatments consisted of: no vitamins; thiamine (100 μg per liter); biotin (5 μg per liter); biotin plus thiamine; thiamine, biotin, inositol (5 μg per liter), and pyridoxine (100 μg per liter). In addition to P. terrestris isolates L-5-10 and C-44-1, four fungi with known vitamin requirements were used as checks to assure that "vitamin free" agar was truly vitamin free.

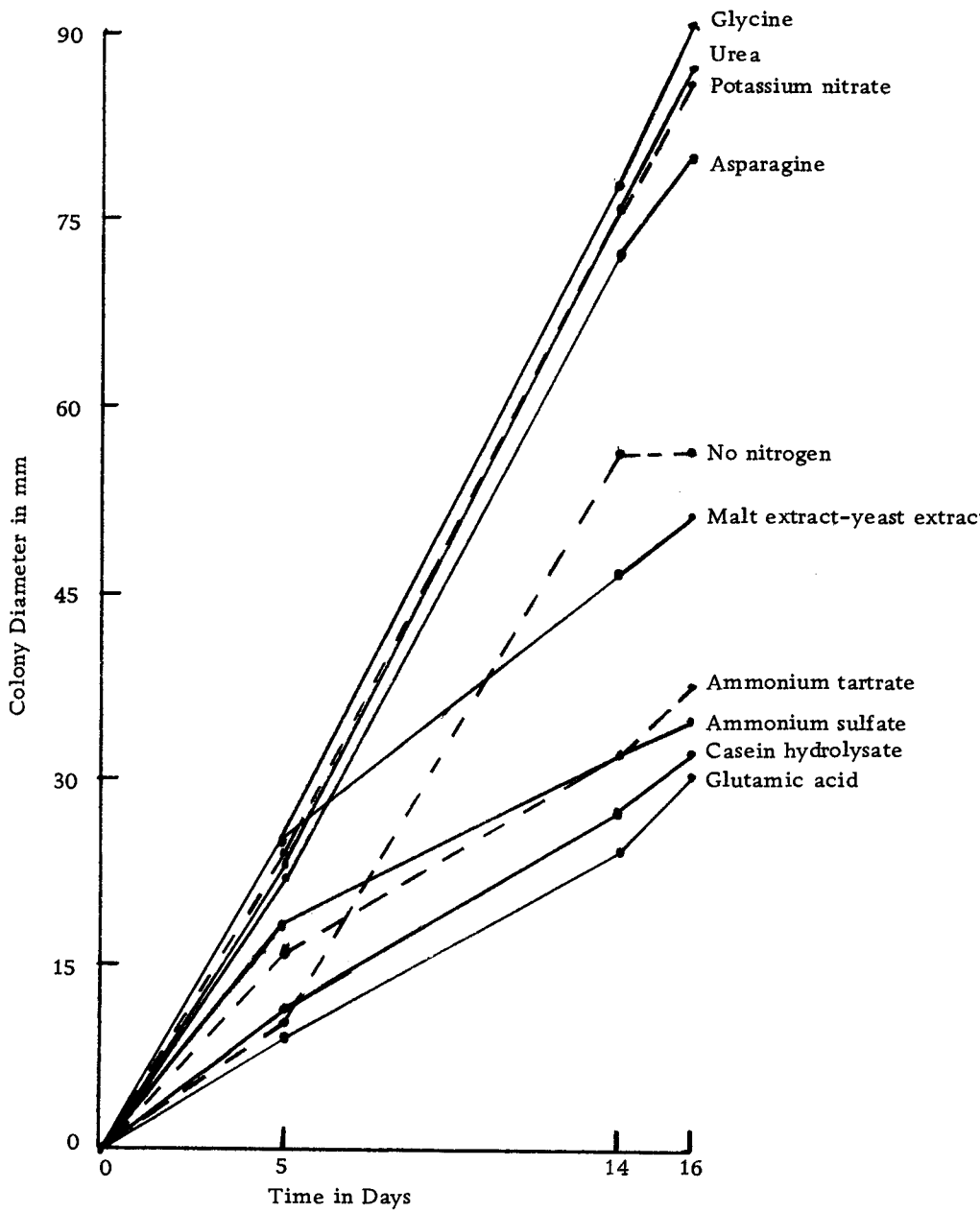

Figure 18. Influence of nitrogen source on linear growth of Pyrenochaeta terrestris isolate L-5-10 on glucose agar.

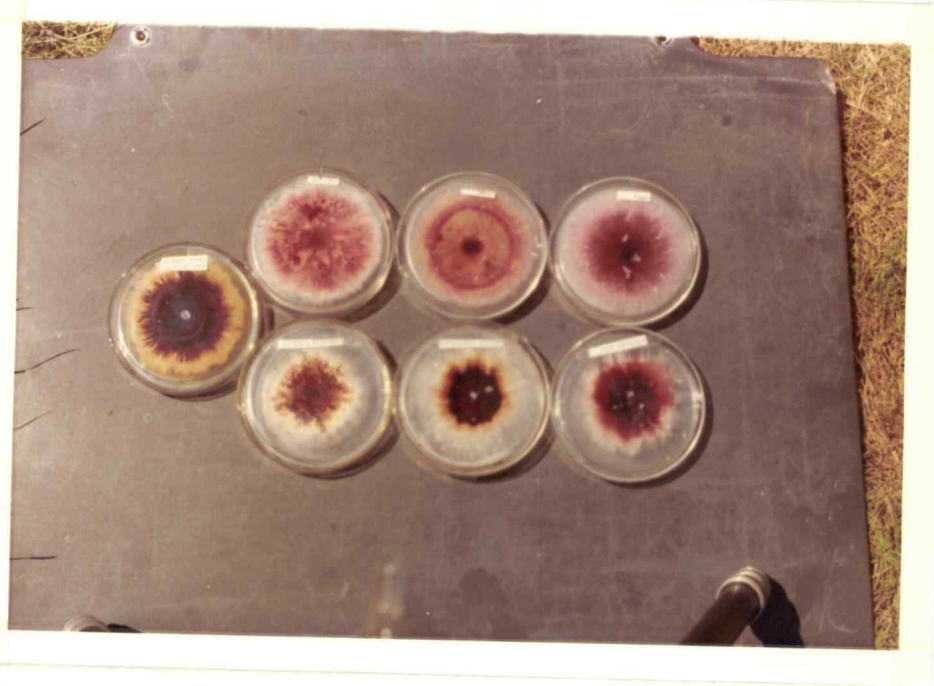

Figure 19. Pigment produced by Pyrenochaeta terrestris isolate L-5-10 on malt extract-yeast extract agar and on glucose agar supplemented with glycine, urea, potassium nitrate, glutamic acid, casein hydrolysate, and ammonium tartrate agar (clockwise from left).

Glomerella cingulata and Monilinia fructicola, both known to grow well without these vitamins (44, p. 172), grew equally well on all five media. Sordaria fimicola, known to require biotin for good growth (loc. cit., p. 173, 175, 178; 45), grew very poorly on both media that did not contain biotin but grew well on the other media. Phycomyces blakesleanus, known to require thiamine for good growth (44, p. 172-174, 177-178; 61, p. 101-112), grew poorly on both media that did not contain thiamine but grew well on the other media. Both isolates of P. terrestris grew equally well on all five media.

DISCUSSION AND CONCLUSIONS

Varietal Resistance

In general varietal resistance among 11 onion lines grown in both eatern and western Oregon remained relatively constant throughout the growing season, showing that normal seasonal changes during the growing season did not tend to change the resistance of one line as compared with another. Throughout the summer, line 1 (Allium fistulosum) consistently exhibited the greatest pink root resistance, whereas lines 6 (Red Globe), 7 (4408 B), and 10 (Southport White Globe) quite consistently were the most susceptible to pink root.

Differences in soil and climatic conditions between the Malheur Experiment Station in eastern Oregon and the Oregon State University Horticulture Farm in western Oregon likewise had no appreciable effect upon comparative resistance to pink root among the onion lines. When eight of these same lines plus two others were subjected to three different soil moisture levels in the greenhouse, the comparative resistance among lines agreed very closely with that of the field trials in eastern and western Oregon using the same lines. However, there were a few exceptions to this general stability of varietal resistance, the most notable of which was that of line 9 (Yellow Sweet Spanish) the primary commercial onion

variety grown in eastern Oregon. As a whole it was intermediate in resistance. However, during the earlier ratings in western Oregon it showed the least resistance of all of the lines, yet was rated quite resistant during the earliest rating in eastern Oregon, and most resistant when grown in the dryest Malheur County soil in the greenhouse. The overall ratings of the USDA lines coincided with previous general ratings by other workers (8).

Some workers have rated onions for pink root resistance in greenhouse tests using young seedlings. Others have rated them at harvest or just prior to harvest. However, onions generally have not been rated throughout the growing season to determine whether comparative resistance among different varieties grown under the same conditions remains constant throughout the growing season. These overall results indicate that disease ratings among lines might be made at any time during the growing season and confirm the validity of pink root rating methods commonly used.

Soil Moisture

Onions grown in soil held at field capacity had less pink root infection than those grown under dryer conditions. This was true for both Labish and Malheur County soils, but it was especially evident for the Malheur County soil.

Frequent field irrigation may tend to reduce severity of pink

root infection especially in Malheur County where average temperatures are higher than in western Oregon and where more frequent irrigation is essential to keep soil moisture high. These results indicate that frequent irrigation especially during warm weather may help to thwart severe pink root infection by increasing onion resistance and by lowering soil temperature somewhat.

Chemical Control

Lanstan applied with the seed at rates of two and four lb. active material per acre reduced pink root infection of three of the four onion lines tested, but the phytotoxicity of the chemical cut yields substantially beyond the beneficial effects of pink root reduction.

Pictel, Lanstan, Telone, Soil Drench, and SD 345 used at Lake Labish, western Oregon had no noticeable effect in controlling pink root disease, although Telone served as an excellent control of nematodes. Since pink root was equally prevalent in plots that were practically free of nematodes and those with high nematode populations, nematode infection did not appreciably increase susceptibility of the Danver onions to pink root.

Granular Phaltan applied with the seed on a field south of Ontario at Cairo Junction, Malheur County, Oregon did not increase onion yields. Mumfume applied 140 lb. per acre as a fall tarped

fumigant on the same field increased Southport White Globe onion yields by more than 75 percent and Yellow Sweet Spanish yields by 45 percent. If these increases can be attributed to pink root control, it seems logical that Southport White Globe yield increases would be greater than Yellow Sweet Spanish yield increases. The former was shown to be more susceptible to pink root infection, and control of the disease should be more evident where the disease is more severe. However, none of the Mumfume or Phaltan treatments had any noticeable effect in reducing pink root infection as measured by visual ratings of onion roots throughout the growing season. Apparently fumigation treatments had a beneficial effect other than that of reducing soil infestation by Pyrenochaeta terrestris. Soil fumigation treatments may have controlled other organisms which were prohibiting optimum onion growth. There is also the possibility that fumigation increased the availability of various nutrients which stimulate onion growth, or changed the soil makeup in some other beneficial way.

On an Oregon Slope field north of Ontario, Malheur County, fumigation treatments with chloropicrin, Vorlex, E. P. 230, and E. P. 201 increased Yellow Sweet Spanish onion yields. Increases ranged from 30 percent with chloropicrin to 60 percent with E. P. 201. The onions on this field received adverse treatment due to inadequate irrigation during the early summer, an overdose of

cyanide spray weed killer, and a brief but strong wind and rain storm.

The same chemical treatments on another field near Nyssa, Malheur County, Oregon during the same year did not give yield increases. However, the onions grown on this field did not receive the same adverse treatment. All per acre yields including those from check plots were comparable to the highest yields from the treated plots on the Oregon Slope field. The adverse growing conditions on the Oregon Slope field enlarged differences between treated and untreated plots.

At present, yield increases that are not consistent enough to be depended upon from field to field or year to year do not offset fumigation costs. However, if consistent yield increases for more than one year without additional fumigation could be shown, it might be economically practical to use these chemicals on land used for onion production.

Temperature

There was no growth of the Lake Labish *P. terrestris* isolate L-5-10 on malt extract-yeast extract agar at 5 C and very little growth below 15 C. The greatest increase in growth rate took place between 15 and 20 C, and greatest growth was at 30 C. This was similar to findings of other workers using other isolates of

P. terrestris on PDA (10, 15) and corn-meal agar (18).

A comparative analysis of air and soil temperatures between eastern and western Oregon onion growing areas shows that higher temperatures in eastern Oregon have consistently been closer to that for rapid growth of P. terrestris. During the latter part of the summer disease incidence in the field increased rapidly while air and soil temperatures increased only gradually. Borgman (3), finding similar field conditions, concluded that soil temperature does not warrant the importance generally given it as a contributor to pink root development. However, the fact that P. terrestris growth in vitro increased rapidly with an increase of only five degrees in temperature from 15 to 20 C, might possibly help explain a rapid increase in disease incidence with only a gradual increase in air and soil temperatures. Temperature appears to be a very important factor in influencing the rate of disease development.

Light

Different light exposure treatments including continuous total darkness, continuous light, alternating darkness and light, and brief exposures to germicidal ultraviolet light (2,500 Å), had no consistent effect in changing the rate of growth of P. terrestris, nor in inducing sporulation on sucrose-asparagine or malt extract-yeast extract agar. It seems unlikely that light is an important factor in pink root

development in the field.

pH

Over a 16 day period of supporting growth of P. terrestris the average pH of glucose-asparagine and sucrose-potassium nitrate liquid media with initial pH values of 3, 4, 6, and 8 increased. The pH of the sucrose-potassium nitrate media increased more rapidly than that of the glucose-asparagine media probably because potassium-nitrate is the salt of a strong base. Therefore, the pH of the media would tend to increase rapidly with fungus utilization of the nitrate ions, which in turn would be replaced by hydroxyl ions.

Growth of the fungus was very slow at a pH of 4 or less, but it grew very well on media with intial pH values of 6 and 8. These pH values were similar to or slightly higher than optimum initial pH values found by other workers (10, 15) using other isolates of P. terrestris on various agar media. However, if the fungus tended to raise the pH of those agar media as it did the two liquid media tested here, the true optimum pH for growth of the fungus would be higher than that indicated by the intial pH values of those media.

Growth of the fungus was slightly faster on the glucose-asparagine liquid media than on the sucrose-potassium nitrate media even though the average pH of the former at harvest was slightly

lower. This can not be explained by the ability of the fungus to utilize one sugar or nitrogen source better than the other. According to the carbon source experiment the fungus was able to utilize glucose and sucrose equally well, and according to the nitrogen source experiment the same was true for asparagine and potassium nitrate.

Carbon Sources

The fungus grew equally well on seven of the nine carbon sources tested using both liquid and agar media. Sorbose on both liquid and agar media was inhibitory to growth of the fungus, as it is for many other fungi (7, p. 9-10, 62-63; 44 p. 122; 66). Linear growth followed the same pattern among different media as total growth of the fungus except on the carbon deficient media and the malt extract-yeast extract media. On the carbon deficient agar medium linear diameter growth of the colonies for the first week was camparable to that of growth on the other agar media; however, it was extremely sparse in comparison to the other agar cultures and lagged behind other cultures after the first week.

Total growth of the fungus was more than twice as great on the malt extract-yeast extract medium than on each of the sugar-asparagine media and almost twice as great on the starch-asparagine medium. Linear growth of the fungus on malt extract-yeast extract

agar excelled that on the other media for a few days after which time it began to lag behind other cultures. Apparently this was due to staling products produced by growth of the fungus on the malt extract-yeast extract agar.

The ability of the fungus to grow well on such a wide variety of media seems to help explain the fact that it is such a good soil saprophyte and is prevalent in a wide variety and range of soils.

Nitrogen Sources

The fungus grew very well on glucose media supplemented with glycine, nitrate, urea, and asparagine. Growth was poor on glucose-glutamic acid and glucose-casein hydrolysate media, but this was probably due, at least in part, to the low intial pH values of these media which were 3.3 and 3.7, respectively. Growth was also very poor on glucose-ammonium tartrate and glucose-ammonium sulfate media. This could have been due to a partial inability of the fungus to utilize ammonium nitrogen, but this seems very improbable since the fungus was able to utilize very well nitrate nitrogen from sucrose-nitrate and glucose-nitrate media. More probably the poor growth of the fungus on these two media was due to a lowering of the pH values of these media as a result of fungus utilization of the ammonium ions. This would explain decline of growth with time. It would also explain the more rapid

decline of growth on the glucose-ammonium sulfate agar than on the glucose-ammonium tartrate agar medium. Since ammonium sulfate is the salt of a stronger acid than is ammonium tartrate, the medium would become acidic more rapidly with growth of the fungus and utilization of the ammonium ions than would be the case with ammonium tartrate.

The nitrogen deficient cultures behaved similarly to the carbon deficient cultures, producing sparse, rapid growth for the first few days, after which time growth ceased. Growth on the malt extract-yeast extract agar again was rapid for only the first few days, then lagged behind other cultures. This was apparent in all the other growth experiments in which malt extract-yeast extract agar was employed.

Vitamin Requirements

The Lake Labish *P. terrestris* isolate L-5-10 and a Malheur County isolate C-44-1 both grew equally well with or without thiamine, biotin, inositol, and pyridoxine in their substrates, indicating that the isolates either do not need these vitamins for metabolism or are capable of synthesizing them from sucrose-asparagine agar in sufficient quantities to meet their needs. This too should be a characteristic favoring fungus growth as a soil saprophyte.

Aggravating Field Factors

Possible explanations for greater pink root infection of onions grown in Malheur County, eastern Oregon than at Lake Labish, western Oregon include: (1) P. terrestris grows best in a slightly basic substrate corresponding to Malheur County soil, whereas onions grow best in a slightly acidic soil (63) corresponding more nearly to that of Lake Labish. (2) Malheur County soil may be infested with greater numbers and/or more virulent forms of P. terrestris and other disease organisms especially Fusarium spp. (21, p. 28-43; 34; 70). (3) Danver onions grown at Lake Labish may be more resistant to P. terrestris than are the Yellow Sweet Spanish onions grown in Malheur County. (4) Climatic conditions including higher air and soil temperatures during the growing season in Malheur County, especially when irrigation is inadequate, may promote infection by stimulating P. terrestris growth, and inhibiting onion growth when soil is dry.

The greenhouse study involving soils from both areas did not support either of the first two explanations or any other explanation based on soil conditions apart from temperature and moisture since the onions grown in the Labish soil had just as much or more pink root infection as those grown in the Malheur County soil under the same climatic conditions. Resistance studies both in the greenhouse

and in the field did not support the third explanation since Danver onions were as susceptible or even more susceptible to pink root than Yellow Sweet Spanish onions grown under the same conditions.

In light of the fact that eastern Oregon consistently has higher air and soil temperatures, more nearly those for optimum growth of the fungus, than does western Oregon it seems reasonable that the fourth explanation may be important in explaining the greater disease problem apparent in eastern Oregon.

SUMMARY

1. Varietal resistance to pink root disease among onion lines grown in the field in eastern and western Oregon and in the greenhouse generally remained comparatively constant throughout the growing season and among different growing conditions.
2. Onions grown in the greenhouse in wet soil had less pink root than those grown in dryer soils.
3. Fumigants increased Yellow Sweet Spanish onion yields from 30 to 60 percent without noticeably decreasing pink root. However, these same fumigants did not increase yields in other fields where pink root was present.
4. Mumfume applied 140 lb. per acre as a fall tarped fumigant increased Southport White Globe onion yields by more than 75 percent and Yellow Sweet Spanish yields by 45 percent without noticeably decreasing pink root.
5. Fumigation which controlled stubby root nematode infection did not reduce pink root.
6. Greatest growth of a Pyrenochaeta terrestris Oregon isolate on malt extract-yeast extract agar was at 30 C. It did not grow at 5 C, and the greatest increase in growth rate took place between 15 and 20 C.

7. Light exposure treatments including continuous total darkness, continuous light, alternating darkness and light, and brief exposures to germicidal ultraviolet light (2,500 Å), did not affect the rate of growth nor induce sporulation of the fungus on sucrose-asparagine or malt extract-yeast extract agar.

8. The pH of glucose-asparagine and sucrose-nitrate liquid media increased with P. terrestris growth on them; the pH of the latter increased more rapidly.

9. The fungus grew well over a pH range from 6 to 8 on glucose-asparagine and sucrose-nitrate liquid media, but very poorly at a pH of 4 or less.

10. Maltose, galactose, glucose, fructose, sucrose, lactose, and starch all served as good carbon sources for P. terrestris growth on asparagine media. Sorbose inhibited growth of the fungus.

11. Glycine, potassium nitrate, urea, and asparagine all served as good nitrogen sources for fungus growth on glucose agar.

12. The addition of thiamine, biotin, inositol, and pyridoxine to sucrose-asparagine agar did not noticeably affect growth of P. terrestris.

13. None of the treatments used in any of the cultural studies of P. terrestris induced sporulation of the fungus.

14. Air and soil temperatures during the growing season are higher and more nearly those for optimum growth of P. terrestris in the eastern Oregon onion growing area than in western Oregon where pink root disease is not as serious a problem.

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