FUNGICIDAL CONTROL OF

ERYSIPHE BETAE (VAN.) WELT.

By

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ERYSIPHE BETAE (VAN.) WELT.

MINASSIAN

AN ABSTRACT OF THE THESIS OF

Vahé Minassian for M.S. in Plant Pathology

Title: Fungicidal control of Erysiphe betae (Van.) Welt.

Field experiments and green house and laboratory tests were conducted in studying the powdery mildew of beets Erysiphe betae (Van.) Welt. and its chemical control. The disease did not affect the yield of the seed but it reduced significantly the yield of roots, tops and sugar. The sugar percentage of the roots and the dry matter, protein, fat, fiber and ash content of the foliage were not affected.

Sulfur and Karathane proved to be the most desirable fungicides, followed by Morestan. Coprantol was inferior to the first three and Melprex was the poorest. Highly significant increases in the yield of roots, tops and sugar (31.7 percent, 64.2 percent, and 31.7 percent, respectively) were obtained by fungicidal treatment.

It appears that only 3 to 4 spray applications, starting in June and at monthly intervals, gave the most economical returns.

Erysiphe betae (Van.) Welt. was found to be pathogenic only on Beta spp. when different species of Chenopodiaceae, Polygonaceae and Papilionaceae were inoculated.

Spore germination tests showed that although germination takes place at low relative humidities, even at 0 percent R.H., germination of conidia increases with increasing R.H. The highest germination percentage was obtained at 100 percent R.H.

Tests for ascospore germination in vitro were unsuccessful. Ascospores failed to infect beet seedlings.

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I. INTRODUCTION

Sugar beets supply more than one-third of the world's sugar and are the main source of sugar in areas too cold to grow sugar cane.

Sugar beets were first introduced into Lebanon in 1947 (63, p. 1). Since 1958, when the first sugar beet factory was established in South East Beqa'a near Anjar, beet production has increased from 3,000 tons grown on 1,300 dunums to around 80,000 tons grown on about 18,000 dunums in 1966[1].

Experimental yields of as high as 600 kg of seed per dunum and 10 tons of roots per dunum with a sugar content of 18.8 percent were obtained at the Agricultural Research and Education Center (AREC) of the American University of Beirut (AUB) (12, p. 23; 63, p. 12). However, the yields obtained by farmers are generally low, 2 to 4 tons per dunum, probably due to lack of knowledge concerning cultural and fertilization practices, and disease control.

With the expansion of the acreage and increase in the intensity of production diseases become prevalent and severe. Epiphytotics may develop under conditions favorable for the spread of the pathogen.

Studies of sugar beet diseases in Lebanon have shown that the powdery mildew, Erysiphe betae (Van) Welt., is by far the most serious (59).

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1. Personal communication from responsible personnel at the sugar beet factory in Beqa'a, Lebanon.

Other diseases occurring sporadically are: beet rust, Uromyces betae (Pers.) Lev. and beet mosaic, caused by Beet Mosaic Virus or Cucumber Mosaic Virus. Leaf spot, Cercospora beticola Sacc. is found mainly along the coastal plains (59).

Powdery mildew of beets and its chemical control, were studied with the following objectives:

1. to observe the spread of the disease throughout the growing season,

2. to evaluate the effect of the disease on the yield of seed and roots,

3. to investigate the comparative effectiveness of different chemicals for the control of the disease,

4. to develop an economical spraying schedule,

5. to survey the host range of the pathogen,

6. to study the germination of spores of the pathogen in vitro,

7. to study the role of the perfect stage of the pathogen for its overwintering and dissemination.

It was believed that the information obtained from this investigation would be helpful in the economical control of the disease.

II. REVIEW OF LITERATURE

Geographic Distribution of the Pathogen

Powdery mildew of beets has been reported, so far, from Europe, North America and Asia. It was observed for the first time in Czechoslovakia by Vanha in 1903 (58). Later the disease was reported from many other European countries, namely, France (15, 20, 28), Russia (30, 37, 41, 47, 52, 67), Spain (2, 19), Germany (33, 39, 57) Switzerland (47), England (3, 29, 42), Belgium (16), Austria (26, 60), Italy (8, 10), and most recently from Denmark (5).

In the United States it was recorded by Yarwood (64) in California and Carsner (11) in Washington and Oregon.

In Asiatic Russia the disease has been reported from different regions (24, 38, 43, 45, 69). Recently the pathogen was found in countries of the Middle East. Goffart (23), Golovin (24) and Bachthaler (6) reported it from Turkey. Viennot-Bourgin (56) found it in Iran. Rayss (49) and Nevo (40) observed it in Israel. Weltzien (58) described it in Lebanon.

Economic Importance

The disease appears to be occasionally important in Europe. No serious damage has been caused by the disease in France (20). In Spain it is also considered a minor disease of beets (19), and it is

not serious in England either (35, p. 144). In Russia, however, it is widespread and has very dangerous potentialities as emphasized by Mouravieff (37).

Although in North America and Europe the disease appears to be insignificant (with the exception of Russia), it is the most important disease on sugar beets in Lebanon (59).

There are few reports on the effect of the disease on seed yield. Recently Christias (12) found that the disease did not affect the yield of seed. Many authors have reported losses of 12 to 20 percent in root yield (12, 26, 43, 67, 68).

Taxonomy

Most of the reports mentioned the Oidium stage, i.e., the imperfect stage of the fungus while a few reported the perfect stage. The taxonomy of the pathogen presented many difficulties due to the scant information regarding its perfect (cleistothecial) stage.

In naming the causal organism some used the name Oidium and others made use of already published nomenclature of the perfect stage; namely, Microsphaera betae; Erysiphe communis and; Erysiphe polygoni. Recently the fungus was renamed by Weltzien (58) as Erysiphe betae (Van.) Welt.

Biology

Little information is available on the biology of the fungus and its ascospores (sexual spores). Germination of the conidia (asexual spores) on glass slides at different relative humidities has

been studied to a limited extent (12, 65, 66). Christias (12, pp. 55-58) found the highest germination percentage (57.6 percent) to occur at 33 percent R.H. and 30°C, and the lowest (0.9 percent) at 0 percent R.H. and 30°C. High percentage germination was obtained with conidia of Erysiphe betae (Van.) Welt. by Zaracovitis. Percent germination was found to increase with increasing R.H. (65, pp. 83, 85). At 0 percent R.H. a maximum of 64 percent germination was recorded after 6 hours. At 100 percent R.H. after 24 hours incubation a maximum of 91 percent germination was recorded.

The host range studies of the fungus has been limited in extent (12, pp. 40-55). Its main host appears to be the cultivated beet, Beta vulgaris L., although a few varieties have been reported to show some resistance (9, 12, 13, 67). The fungus was also found on Beta maritima L. plants in France (14) and Italy (10).

Disease Cycle and Environal Relations

The cleistothecial stage of the pathogen has been reported from Europe (5, 29, 37, 39, 60) and the Middle East (49, 58, 59). Erysiphe betae (Van.) Welt., like most powdery mildews, is inactive during the winter. There are no reports on the role of its cleistothecia in the life cycle of the pathogen. Overwintering by cleistothecia and/or infection by ascospores have been reported in a few powdery mildews on other hosts (18, 22, 25, 27, 32, 46, 50, 61). The pathogen Erysiphe betae (Van.) Welt., may be perpetuated from year to year on wild beet plants (10, 15).

Control

Chemical: Klika (31), Polevoi (43), Trofiments (55), and Christias (12) controlled the disease by sulfur vaporization and spray applications. Trofiment (55) obtained better control of the disease by spraying with one percent colloidal sulfur or lime sulfur at 800 l per ha than by dusting with milled sulfur at 15 kg per ha.. Neuwirth (39) and Haudiquet (28) used bordeaux mixture and other copper products. Graf and Wenzl (26) successfully controlled the disease by three applications of copper oxychloride (W.P.) sprays at a rate of 1.7 kg of copper in 400 l per ha. Christias (12, pp. 28-30) also controlled the disease successfully using 0.3 percent copper oxychloride (Coprantol) or 0.05 percent Karathane (W.P.) sprays. Bongiovanni (8) found that three bi-weekly Karathane applications at a rate of 0.15 kg per ha were superior to an equal number of triphenyltin acetate application at the rate of 0.3 kg per ha. Solel (54) reported that Brestan (W.P.) (60 percent triphenyltin acetate + 20 percent maneb) at 600 gm per ha reduced infection from 1.7 to 0.2 on a scale of 0 to 4. Krexner (33) observed that Brestan favored infection and Brestan plus Karathane did not control the disease. Christias (12, pp. 28-30) reported that 0.2 percent Morestan (W.P.) sprays controlled the disease. Dekker (17) reported that kinetin inhibited the development of the fungus. Seed treatment with 2,4-D, heteroauxin, gibberellin and succinic acid lowered infection from 59 percent to 46.5 to 42.5 percent (48).

Resistant varieties: Shevchenko (52, 53) described methods of

selection for resistance and listed the most resistant strains. Polevoi and Chebolda (45) made selections of the resistant varieties in the irrigated areas of Central Asia and Kazakhstan. Polevoi (44) found that the variety F986 was highly resistant to the disease, and, under conditions of natural infection, yielded 6 to 18 percent more sugar than M_2, the local variety. Zhukova (67) reported that the variety Kirgizskaya 018 was the most resistant of all the varieties tested in the irrigated areas of Southern Ukraine. Other resistant varieties listed were: Frunzenskaya 986, Kirgiskaya 055, Yaltushkovskaya odnosemyannaya and Belotserkovskaya odnosemyannaya (67).

III. MATERIALS AND METHODS

Field Experiments

Field experiments on powdery mildew of sugar beets Erysiphe betae (Van.) Welt. were conducted in 1963-1964 and 1966 at the Agricultural Research and Education Center (AREC) located in the North Central Beqa'a Plain at an elevation of 995 m. The summers are hot and dry with little precipitation. The winters are cold with non-uniform rainfall distribution. Average temperatures, rainfall and relative humidity at the AREC for the years 1964 and 1966 are shown in Table 1.

For seed-bed preparation the land was disk plowed, harrowed and smoothened. Twenty kg P_2O_5 in the form of superphosphate (18.5 percent P_2O_5) and 12 kg N as ammonium sulfonitrate (26.0 percent N) per dunum[1] were applied to the experimental plots. The fertilizers were broadcasted and disked into the soil before planting. Later in the season 2 additional N side-dressings at the rate of 4 kg N per dunum were applied.

Seeds of sugar beet, Beta vulgaris L., were planted with a "Planet Junior". At the 4-leaf stage plants were thinned to a distance of 20 to 25 cm in the row. Weeding was done by hoes whenever necessary. Plots consisting of 4 rows, 5 m long were irrigated weekly.

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1. Dunum = 1000 square meters.

Fungicide sprays were applied by means of a knapsack sprayer. The plants were sprayed to run-off. For this purpose 2,500 l per ha or 3.5 l per plot of each fungicide preparation was used. Spray applications were started as soon as the disease was observed in the field. The sprays were applied every other week. Observations were made and data collected at biweekly intervals alternating with the sprays.

Data on infection were collected as follows: The leaves of all plants within each row were examined and the number of infected plants per row was recorded. A disease index (21) was calculated for each plot by dividing the sum of counts from the 2 middle rows per plot by that of the plot with the smallest sum of counts, i.e.,

$$D.I._x = \frac{\sum T_x}{\sum t_{min}}$$

Where:

$D.I._x$ = Disease index for plot x

$\sum T_x$ = Sum of counts from 2 middle rows of plot x

$\sum t_{min}$ = Sum of counts from 2 middle rows of the least infected plot

The yield data were obtained by harvesting 4 m from the 2 middle rows per plot.

Data were statistically analysed using the appropriate methods for the different designs as suggested by LeClerg et al. (34, pp.50-51, 137-146, 152-156, 184-190).

Sugar beet seed production experiments: Two experiments, using the winter

annual method of seed production, were carried out simultaneously during the period from September 1963 to July 1964 to determine the effect of the disease on seed production and efficacy of different treatments in the control of the disease.

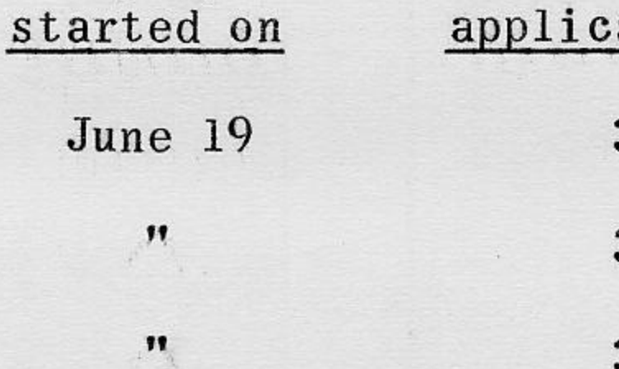
Experimental design: The experimental design for both experiments was a 4 x 4 Latin Square. Plots consisted of 4 rows, 5 m long and 75 cm apart. Seeds of the variety Pedigree E were planted on September 13, 1963. The seeds in one corner (15 m^2) of the field did not germinate due to failure of the irrigation system, and the rows were replanted on October 13, 1963.

Treatments: In the first experiment the treatments were as follows:

Treatment No.	Chemical	Conc. %	Spray started on	Total No. of applications
1	Karathane[1]	0.05	June 19	3
2	Morestan[2]	0.20	"	3
3	Melprex[3]	0.05	"	3
4	Check	-	-	-

1. 2,4-Dinitro -6- (2-Octyl) Phenylcrotonate $H_3C-HC=CH-COO-C_6H_2(NO_2)_2(CH(CH_3)-C_6H_{13})$

2. 6-Methyl-2,3- quinoxaline-dithiol cyclic carbonate



3. N-Dodecylguanidine acetate $C_{12}H_{25}-NH-C(=NH)-NH_2.CH_2-COOH$

In the second experiment the treatments consisted of 3 different concentrations of coprantol[1].

Treatment No.	Chemical Conc.	Spray started on	Total No. of applications
1	0.075	June 19	3
2	0.15	"	3
3	0.30	"	3
4	Check	"	-

Harvesting and recording data on seed yield and quality: The seeds were harvested on July 20, 1964. The seed stalks were cut with a sharp pruning shear to minimize shaking and shattering and were placed in sacs and hung in the open air to dry. A month later the seeds were threshed by means of a threshing machine. The seeds were separated from the chaff by sieving and then weighed. Germination tests were run in the laboratory at the American University of Beirut (AUB). A sample of 250 seeds from each plot were observed under the binocular to ascertain the percentage of seeds carrying cleistothecia.

Sugar beet root production experiment:

Experimental design: A randomized complete block design with 4 replications was used. The plots consisted of 4 rows, 5 m long and 50 cm apart. Seeds of the variety Kleinwanzleben N were planted on April 10, 1964.

Treatments: Six treatments, each replicated 4 times, were

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1. Copper oxychloride $3\ Cu(OH)_2 . CuCl_2$

distributed at random within each replication. The different treatments are shown in the following table.

Treatment	Concentration %	Spray Started	Spray Ended	Total No. of applications
Sulfur	0.50	July 16	Oct. 22	8
Karathane	0.05	"	"	8
Morestan	0.30	"	"	8
Coprantol	0.20	"	"	8
Melprex	0.05	"	"	8
Check	-	-	-	-

Beets were harvested on October 30, 1964. The roots and tops were weighed separately. A sample of 8 quarters of tops from the 2 middle rows per plot was secured for moisture, dry matter, protein, fiber, fat, and ash determination.

After recording the weight of roots, 4 beets representative of the size range of each lot were taken in tagged sacs to the laboratory for sucrose analysis. The percentage of sucrose was determined according to the method suggested by the AOAC (1, pp.420-421).

Spraying schedule experiment: In this experiment a randomized complete block design was used. Seeds of the variety Kleinwanzleben N were planted on March 23, 1966. The plants were inoculated with conidia of Erysiphe betae (Van.) Welt. in mid-June, in order to get a uniform spread of the disease and develop a high intensity of infection. Inoculation was done by touching infected leaves against the foliage of beet plants.

Treatments: The following 9 spray schedules, using 0.5 percent sulfur (W.P.), were investigated.

Treatment	Spray Started	Spray Ended	Interval (weeks)	Total No. of application
1	July 8	Aug. 19	2	4
2	"	Sept. 30	4	4
3	"	"	2	7
4	"	Sept. 2	4	3
5	"	Sept. 16	2	6
6	July 22	"	4	3
7	"	Sept. 30	2	6
8	Aug. 5	Sept. 30	2	5
9	Aug. 19	"	2	4
10	Check (no spray)	-	-	-

Method of recording disease index: A modification of the method described for the previous experiments (page 9) was used in that the number of infected plants per row was recorded in 3 categories of infection intensity. The extent of infection was expressed as percentage of infected leaves per plant. Infections of 0 to 30 percent were designated arbitrarily as slight, 31 to 70 percent as medium, and above 70 percent as severe.

Greenhouse Host Range Experiments

One month old seedlings of 34 plant species or varieties (Table 10)planted in flats in greenhouse at the AREC and AUB, were tested for susceptibility to Erysiphe betae (Van.) Welt. The seedlings were inoculated by shaking infected beet leaves or potted plants over them. Sugar beet seedlings were used as checks. The symptom development of the disease on the different species was recorded.

Conidia Germination Tests

Conidia germination tests were carried out in the laboratory at AUB. Ordinary microscope slides were washed in 50 percent alcohol and wiped with a cloth to remove inert particles in order to prevent condensation of free moisture on the glass surface at very high relative humidity levels. The conidia were detached and collected by vigorously shaking infected leaves over the glass slides placed at the bottom of a plastic container 20x20x10 cm. In order to reduce variation in germination and to obtain reproducible results only 24-hour old conidia were used. For this purpose the plants were shaken every day to prevent accumulation of old and shrivelled spores. The slides bearing conidia were incubated singly in air-tight Zwolfer chambers (2.5 cm deep and 8 cm in diameter) set at different relative humidity levels. The following saturated salt solutions were used to provide the various R.H. levels (62).

Salt	Concentration g/100 g water	R.H. % 25°C	R.H. % 30°C
Phosphorus pentoxide P_2O_5	dry	0.0	0.0
Magnesium chloride $MgCl_2.6H_2O$	240.0	32.5	32.5
Magnesium nitrate $Mg(NO_3)_2.6H_2O$	250.0	53.0	52.0
Sodium chloride NaCl	36.3	75.5	75.5
Distilled water H_2O	-	100.0	100.0

The slides were held in a horizontal position on 2 pieces of glass tube, supported just above the surface of the salt solution. One set of chambers was kept in the light and another in darkness. The percent germination of conidia was determined 24 hours after incubation. Each test was replicated 7 times. Five hundred spores were counted on each slide.

Ascospore Germination and Infection Tests

Leaf samples carrying mature cleistothecia of Erysiphe betae (Van.) Welt. with well-formed asci and ascospores were collected from the field in November 1964.

Ascospore germination tests: Cleistothecia mounted in water on glass slides were crushed by gently pressing with a needle on the cover glass, and the exposed asci and ascospores were studied in hanging drop slides. Slides were kept at room temperature and were observed daily for 4 days.

Infection tests: Young seedlings of sugar beets grown in the laboratory under artificial light were inoculated after the 2 to 4 leaf stage.

Lamp chimneys plugged with cotton at the top were used as coverings to prevent external infection. One to three seedlings were grown under each glass chimney. Seedlings were repeatedly inoculated using 3 different methods as described below:

a. Intact cleistothecia on leaf pieces were placed in contact with the seedlings.

b. Whole cleistothecia scraped from the surface of infected leaves were transferred and smeared onto the under side of filter paper covers replacing the cotton plugs on the top of the glass chimneys. The filter papers were sprinkled periodically with water in order to provide suitable moisture conditions for the release of ascospores and for infection.

c. Mature cleistothecia were mounted in water on glass slides and were crushed by gently pressing with a needle on the cover glass. The exposed asci and ascospores were subsequently smeared on the leaves.

The first inoculation was made on December 15, 1964. After 2 months of inoculation the glass chimneys were removed because of growth and high transpiration rate of the plants. The exposed plants were thereafter inoculated several times using the methods a and c described above.

Table 1. Average monthly temperature, rainfall and relative humidity at the AREC for the years 1964 and 1966.

Months	Rainfall mm		Temperature °C		R.H. %	
	1964	1966	1964	1966	1964	1966
January	60.6	70.9	0.6	5.7	73.7	75.2
February	183.8	68.7	3.7	6.4	75.6	72.5
March	52.8	96.7	9.0	7.0	72.2	67.9
April	13.9	0.0	9.6	11.7	66.6	62.1
May	23.7	2.6	12.8	14.5	61.7	57.9
June	0.0	0.0	20.2	19.7	61.5	53.3
July	0.0	0.0	23.1	22.8	53.3	53.1
August	0.0	0.0	23.2	23.7	54.3	53.5
September	0.0	0.9	20.2	20.2	58.8	62.1
October	0.0	28.0	17.8	16.1	41.9	64.1
November	167.2	11.0	12.4	14.1	54.3	63.1
December	22.1	187.8	6.8	7.3	54.5	75.4

IV. RESULTS AND DISCUSSION

Sugar Beet Seed Production Experiments

Trials with Karathane, Morestan and Melprex: The first sign of disease development in 1964 was observed on June 12 on about one percent of plants. By June 19 over 50 percent of the plants were infected, by the end of June infection was about 70 percent and by July 14 it was 80 percent. Favorable conditions for the rapid spread of the disease started in June when 70 percent of the plants got infected within 3 weeks. As shown in Table 1 mean temperatures of 20.2 to 23.1°C and mean relative humidities of 61.5 to 53.3 percent prevailed during the months of June and July. In July cleistothecia were formed mostly on the lower leaves, and were present on the seed also[1].

Effect of treatments on disease incidence: The number of infected plants was not reduced appreciably by the sprays applied on June 19, July 3 and July 17. However, it was observed that the intensity of infection was much lower in the treated plants.

Effect of treatments on seed yield and quality: The yield data presented in Table 2 show that the disease did not affect the seed production. The seed yield varied from 209.0 kg per dunum[2] (Melprex treatment) to 277.0 kg per dunum (Check), but this difference is not statistically significant.

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1. Appendix A, Plate 1.
2. Dunum = 1000 square meters.

In the Beqa'a Plain sugar beets grown for seed production are planted in September and harvested in mid-July the following year. By the end of May the plants have all bolted and attained full development.

During this period, November to April, the environmental conditions are unfavorable for the establishment of the pathogen in the plants (Table 1). The disease, although it may appear in the field as early as April, becomes serious only in June (Page 18, Figures 1 and 3) by which time the plants are fully grown with well-developed roots. Any damage to the foliage as a result of disease or otherwise is not serious because the plants have adequate root reserves and stored energy for producing seed.

The germination percentage of the seeds ranged from 88.7 (Karathane treatment) to 92.5 (Check).

It was observed that cleistothecia formed on the seed (Table 2). The percentage of seeds carrying cleistothecia ranged from 3.0 (Morestan treatment) to 13.5 (Check). There was no significant difference among the treatments as to the frequency of cleistothecia occurrence on seeds.

Whether or not cleistothecia on seed could serve as a source of primary inoculum and whether the disease might spread by seed requires further investigation.

Trials with Coprantol: In this experiment 3 concentrations of Coprantol at the rate of 0.075 percent, 0.15 percent, and 0.30 percent were used (Table 3). The development of the disease followed the same pattern as described earlier. The treatments were not significantly

Table 2. Disease index, yield in kg per dunum, percent germination and infestation by cleistothecia of sugar beet seeds, as affected by Karathane, Morestan, and Melprex treatments - 1964.

Treatment	Disease index[1]	Seed kg per dunum	Germination percent	Percent seeds carrying cleistothecia
Karathane	3.7	252.0	88.7	4.6
Morestan	4.0	239.0	90.2	3.0
Melprex	4.2	209.0	91.2	6.9
Check	4.4	277.0	92.5	13.5
L.S.D. 5% level	N.S.	N.S.	-	N.S.

Table 3. Disease index, yield in kg per dunum, percent germination and infestation by cleistothecia of sugar beet seeds, as affected by treatment with different concentrations of Coprantol - 1964.

Treatment (% Coprantol)	Disease index	Seed kg per dunum	Germination percent	Percent seeds carrying cleistothecia
0.075	1.64	264.4	85.2	14.5
0.15	1.95	283.0	92.2=	16.4
0.30	1.62	283.3	88.0	15.0
Check	1.89	299.2	92.5	25.5
L.S.D. 5% level	N.S.	N.S.	-	N.S.

1. See under Materials and Methods.

different in seed yield or occurrence of cleistothecia on seeds. Coprantol at 0.3 percent concentration, despite being phytotoxic as reported by Christias (12, p. 33), did not reduce the seed yield. The results of this experiment confirm and support the conclusion reached in the previous experiments (Table 2), that the seed yield is not affected by the disease; injury is caused too late to reduce the yield.

The yield of seed obtained in these experiments (Tables 2 and 3) was low, ranging from 250.8 to 299.0 kg per dunum. Yields twice as large have been reported (12, p. 23; 51, p. 14). The low yields are apparently due to the fact that seeds were sown rather late and that germination was delayed by defective irrigation in the beginning of the experiment resulting in a poor stand and low percentage bolting.

The results of these experiments concerning the effect of disease on the yield of seed are in agreement with those of Christias (12, pp. 20-22).

Sugar Beet Root Production Experiment

Figure 1 shows the incidence of the disease throughout the growing season. The corresponding disease indices are given in Table 4. The disease spread rapidly during the month of July. The percentage of infected plants increased from 15 percent to 60 percent within 3 weeks (Figure 1 Check). The rapid spread of the disease during the month of July confirms the conclusion (Page 18) that Erysiphe betae (Van.) Welt. can flourish under the environmental conditions prevailing during this period, (Table 1, 23.1^{o}C and 53.3

percent R.H.). After the month of July the spread of the disease was at a reduced rate. Abundant cleistothecia were observed on the leaves on August 13[1].

Effect of treatments on disease incidence: The first spray was applied on July 16 when infection was approximately 50 percent. All treatments, except Melprex, reduced the disease significantly but each to a different extent. Sulfur and Morestan were effective in reducing the disease significantly by the first spray, whereas Coprantol and Karathane did so only after the second spray on July 30[2].

As shown in Figure 1, Sulfur was the best fungicide followed by Morestan, Coprantol and Karathane. The disease indices presented in Table 4 are also in the same order. Sulfur has the lowest disease index (4.6), followed by Morestan (4.8), Coprantol (19.1), and Karathane (25.2).

Sulfur (D.I. 4.6) and Morestan (D.I. 4.8) do not differ in efficacy, but sulfur is significantly superior to all the other fungicides. Morestan is not significantly different from Coprantol, but it is significantly superior to Karathane and Melprex (Figure 1). Coprantol and Karathane are not significantly different[3].

Effect of treatments on the yield of roots: As shown in Table 4 the disease significantly reduced the yield of roots. The yield of roots decreased from 9761 kg per dunum (Sulfur treatment) to 7412 kg per dunum (Check) as the disease index increased from 4.6 to 50.3. The yield of roots is therefore inversely related to the severity of the disease. This does not seem to be true for Karathane treatment which

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1. Appendix A, Plate 1.
2. Appendix B, Tables 29 and 30.
3. Appendix B, Table 18.

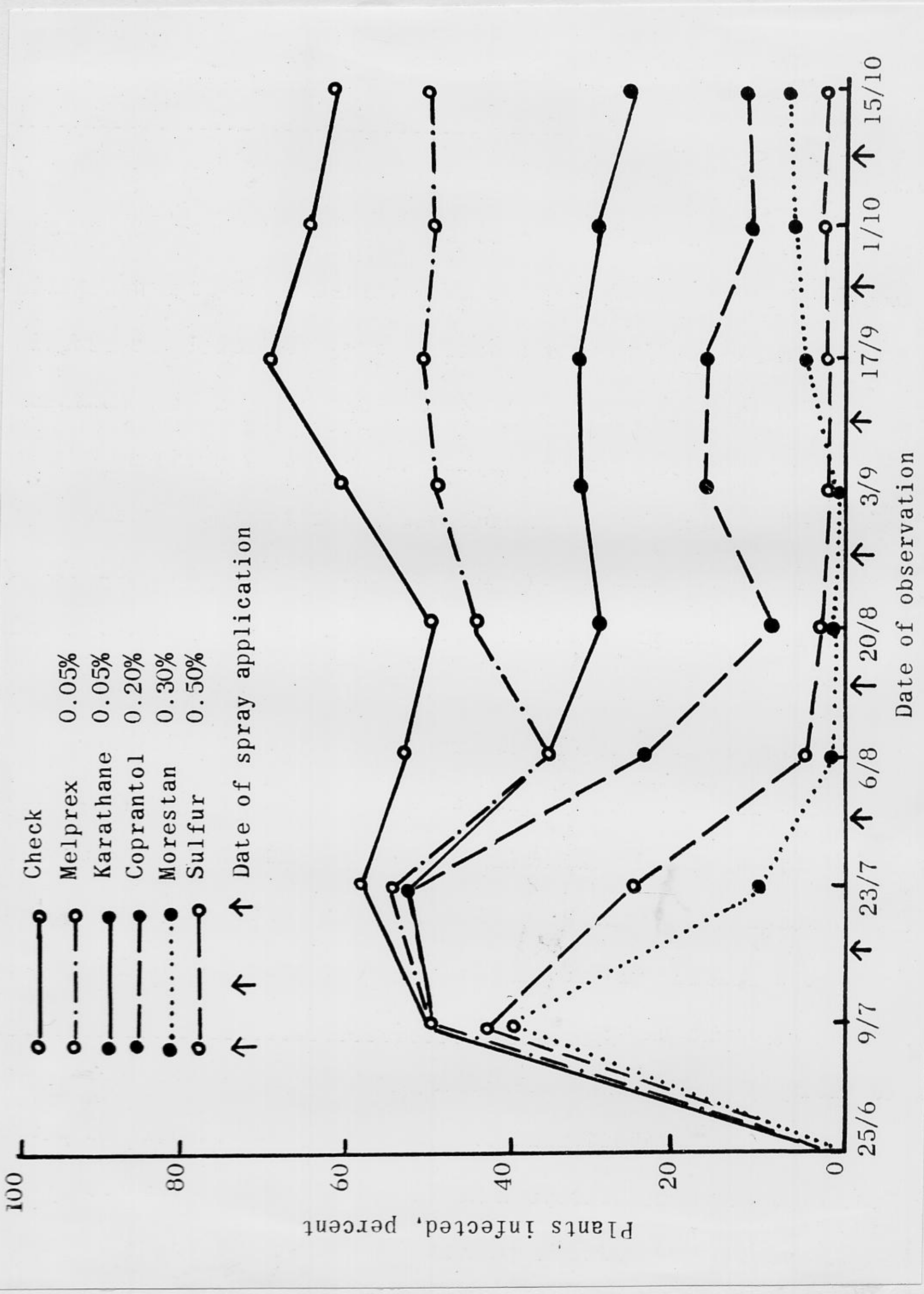

Figure 1. Effect of treatments on disease incidence on sugar beet plants at ARE in 1964 .

Table 4. Disease index, yields of roots, tops, and sugar in kg per dunum and percentages of sugar, dry matter, protein, fiber, fat, and ash as affected by different treatments - 1964.

Treatment	Disease index	Total yield kg per dunum	Roots kg per dunum	Tops kg per dunum	Sugar %	Sugar kg per dunum	Dry matter of foliage %	Dry weight basis Protein %	Fiber %	Fat %	Ash %
Sulfur	4.6	13277	9761	3516	17.4	1659	16.1	12.4	11.7	3.1	18.2
Karathane	25.2	12356	9279	3077	18.4	1578	16.3	13.1	11.2	3.0	17.8
Morestan	4.8	11839	8498	3341	17.0	1444	16.9	11.4	11.2	2.8	15.7
Coprantol	19.1	10496	8223	2273	17.4	1398	16.7	12.3	10.6	2.8	17.2
Melprex	41.8	10033	7675	2358	16.9	1314	17.2	14.7	11.4	3.3	17.8
Check	50.3	9594	7412	2141	17.0	1260	18.0	13.6	10.4	3.0	16.0
L.S.D.											
5% level	14.4	1619	1060	652	-	178	N.S.	N.S.	N.S.	N.S.	N.S.
1% level	19.9	2243	1462	902	-	246					

resulted in a highly significantly greater yield than the Check, despite a high disease index. The explanation is that the disease index is an indication of the number of diseased plants, but not a measure of intensity of infection. Another exception was the Coprantol treatment which controlled the disease effectively but did not result in significantly higher yields. Probably Coprantol used at 0.2 percent was phytotoxic.

The reduction in the yield of roots can be explained on the basis that the plants are attacked by the disease in an early stage of growth. In July, when the plants are growing actively, the disease becomes severe and damages the foliage. This hinders the synthetic activity of the leaves and causes yield reduction.

Effect of treatments on the sugar content of roots and estimated sugar yield: Data on the sugar content of roots and the yield of sugar are shown in Table 4. The estimated yield of sugar calculated on the basis of percent sucrose in root samples (see Materials and Methods , p. 12), varied from 1260 kg per dunum (Check) to 1659 kg per dunum (Sulfur treatment). The yield was increased significantly by Sulfur, Karathane, and Morestan treatments. The sugar content of the roots ranged from 16.9 percent (Melprex treatment) to 18.4 percent (Karathane treatment) with no significant difference.

Effect of treatments on the yield of tops, dry matter and forage value of foliage: In data presented in Table 4, it can be seen that the yield of foliage ranged from 2141 kg per dunum (Check) to 3516 kg per dunum (Sulfur treatment). Sulfur, Karathane and Morestan increased the

yield of tops significantly. The disease did not affect the percent dry matter, protein, fiber, fat, and ash content of the foliage.

Evaluation of treatments: The yield of roots, tops and sugar, presented in Table 5, expressed as percent increase above the control is a good index for evaluation of the extent to which each treatment improved the yield. Sulfur, Karathane and Morestan caused significant increases in the yields of roots, tops and sugar, whereas Coprantol and Melprex did not. Sulfur treatment gave the highest increase in root, top, sugar and total yield. The next highest increase in yield was obtained with Karathane and then with Morestan.

Therefore, it is apparent that Sulfur and Karathane are the most satisfactory fungicides followed by Morestan.

In general, the results presented here are in correlation with those previously reported. Graf and Wenzl (26) reported that the disease decreased the yield of sugar, foliage and roots by 21.3 percent, 18.2 percent, and 19.6 percent, respectively. In this experiment sulfur treatment increased the yields of roots and sugar by about twice as much, and that of foliage by 3 times. Bongiovanni (8) obtained a 10.5 percent increase in sugar yield with 3 Karathane applications. In the present study, Karathane was more than twice as effective in increasing the yield of sugar (25.2 percent increase), (Table 5). Christias (12) obtained a slightly lower increase in sugar by Karathane treatment (20.1 percent).

The high increases in yield obtained in this experiment are probably partly due to non-uniform spread of the disease throughout the field, and partly due to partial infection of the plants reported by

Table 5. Percent increase in total yield, the yield of roots, foliage and sugar above the Check.

Treatment	Percent increase above the control			
	Total yield	Roots (kg per dunum)	Tops (kg per dunum)	Sugar (kg per dunum)
Sulfur	38.9^{xx}	31.7^{xx}	64.2^{xx}	31.7^{xx}
Karathane	29.3^{x}	25.2^{xx}	43.7^{xx}	25.2^{xx}
Morestan	23.9^{x}	14.7^{x}	56.0^{xx}	14.6^{x}
Coprantol	9.8	10.9	6.2	10.9
Melprex	5.0	3.5	10.1	4.3

^{x} Significant at 5% level.

^{xx} Significant at 1% level.

others (67).

Spraying Schedule Experiment

Nine spraying schedules were used of which five started on July 8, two on July 22, and one on August 5, and the last one on August 19 (Tables 6 and 7). The spread of the disease followed the same pattern as described earlier (Pages 18, 21, and 22). Within 2 weeks of inoculation of the plants (mid-June) the infection became severe (Figure 2). As shown in Figure 2 the spray schedules starting on July 8 reduced the infection from 75 percent to less than 10 percent within 2.5 to 4.5 weeks (Figure 2, curves 1, 2, 3, 4, and 5). The later treatments controlled the disease within 3 weeks from application date (Figure 2, curves 7, 8, and 9). Treatment No. 6 starting on July 22 was an exception and controlled the disease within one week from application. However, as seen from Figure 3, the early treatments were more effective in controlling the disease than the later ones. The disease indices in Table 7 show the same trend.

The disease index of the last schedule starting on August 19 (D.I. 4.2 was significantly higher than that of all the other treatments, but it was significantly lower than that of the Check (D.I. 6.9). The disease indices of July 22 (D.I. 2.8) and August 5 (D.I. 3.1) schedules were not significantly different from each other. Neither were those of treatments starting on July 8[1].

The data in Table 8 show that early starting of spraying significantly improved the yield of roots, whereas starting applications later did not. The yield of roots ranged from 9188 kg per dunum (Check)

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1. Appendix B, Table 31.

Table 6. Spraying schedules used in a field experiment conducted at AREC in 1966.

Treatment No.	Date of spray application						
	July 8	July 22	August 5	August 19	September 2	September 16	September 30
1	x	x	x	x			
2	x		x		x		x
3	x	x	x	x	x	x	x
4	x		x		x		
5	x	x	x	x	x	x	
6		x		x		x	
7		x	x	x	x	x	x
8			x	x	x	x	x
9				x	x	x	x

Table 7. Disease index as affected by different spraying schedules - 1966.

Treatment No.	Application interval (weeks)	Total No. of sprays	D.I.
1	2	4	1.8
2	4	4	2.1
3	2	7	1.9
4	4	3	2.0
5	2	6	2.5
6	4	3	2.2
7	2	6	2.8
8	2	5	3.1
9	2	4	4.2
10	-	-	6.9
L.S.D. 5% level			2.1
1% level			2.8

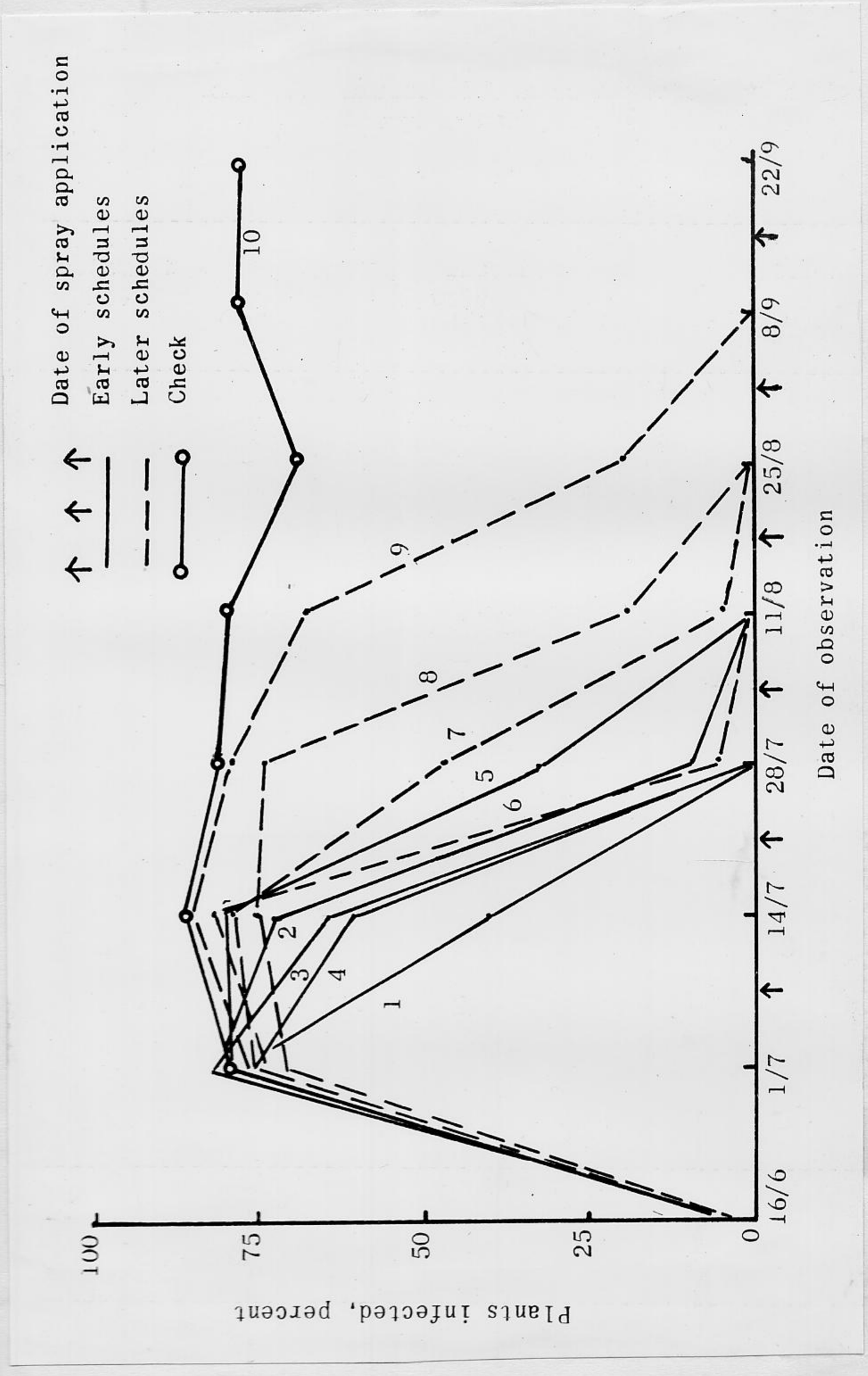

Figure 2. Effect of different spraying schedules on the control of the disease on sugar beet plants at AREC in 1966.

Spraying schedule started on:
- July 8 (Curves 1, 2, 3, 4, and 5)
- July 22 (Curves 6 and 7)
- Aug. 5 (Curve 8)
- Aug. 19 (Curve 9)

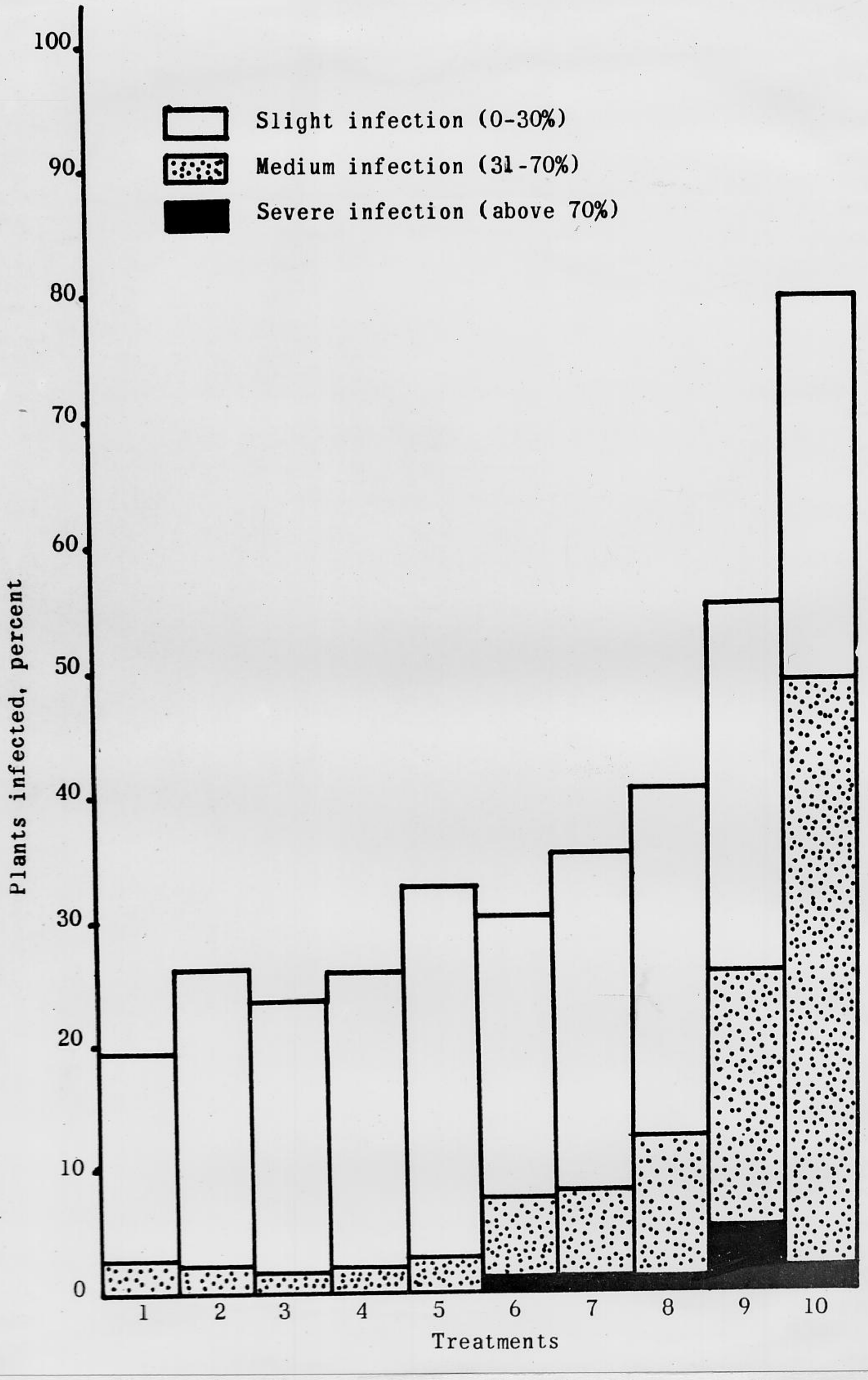

Figure 3. Diagram showing the effectiveness of different spraying schedules (Table 6) in the control of the disease .

Table 8. Disease index, yield of roots, tops and sugar in kg per dunum and percent sugar of sugar beets as affected by different spraying schedules - 1966.

Treatment No.	D.I.	Roots kg per dunum	Tops kg per dunum	Sugar	
				%	kg per dunum
1	1.8	10906	4819	15.6	1701
2	2.1	10644	4312	15.7	1671
3	1.9	10619	4337	16.2	1720
4	2.0	10494	4469	16.8	1763
5	2.5	10244	4356	15.2	1557
6	2.2	9812	4144	17.3	1698
7	2.8	9262	4181	15.0	1389
8	3.1	9950	4144	15.2	1512
9	4.2	9775	3862	15.1	1476
10	6.9	9188	3468	15.2	1397
L.S.D. 5% level	2.1	808	N.S.	N.S.	130
1% level	2.8	1093			176

to 10906 kg per dunum (Treatment No. 1). The yield of roots for the spray schedule starting on July 8 are not significantly different from each other[1], neither are their disease indices[2] (Table 7, D.I. 1.8, 1.9, 2.0, 2.1, 2.5). It is seen from Table 8 that the monthly spraying intervals gave as good yields as the biweekly ones, and that 3 to 4 spray applications controlled the disease to the same extent as did 7 to 8 applications. In future trials longer spraying intervals (40 to 45 days) and 2 to 3 application per season should be investigated for better economical returns.

The sugar content of the roots ranged from 15.1 percent to 17.3 percent. The estimated yield of sugar, calculated on the basis of percent sugar in root samples (see Materials and Methods, p. 13) ranged from 1397 kg per dunum (Check) to 1763 kg per dunum (Treatment No. 4). Early spray schedules gave significantly higher sugar yields.

The yield of tops was increased by early control of the disease, but the increase was not statistically significant. The absence of significant difference could be due to out-of-season hail storm injury which was sustained a month before harvest.

Table 9 shows the percent increase above the control of the total yield and the yield of roots, tops, and sugar. Early spraying improved the yields of roots and sugar significantly. According to these observations the highest possible yields can be obtained only if spray applications are made early enough to prevent the rapid spread and establishment of the disease at its outbreak.

The mean values of percent increase in roots foliage and sugar for the 5 treatments starting on July 8 are 15.1, 28.6, and 20.4,

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1. Appendix B, Table 32.
2. Appendix B, Table 31.

Table 9. Percent increase above the Check in the yield of roots, foliage and sugar by different spraying schedules.

Treatment No.	D.I.	Percent increase above control		
		Roots (kg per dunum)	Tops (kg per dunum)	Sugar (kg per dunum)
1	1.8	18.6^{xx}	39.0	31.8^{xx}
2	2.1	15.8^{xx}	24.3	19.6^{xx}
3	1.9	15.6^{xx}	25.0	23.1^{xx}
4	2.0	14.2^{xx}	28.9	26.2^{xx}
5	2.5	11.4^{x}	25.6	11.4^{x}
6	2.2	6.8	19.5	21.5^{xx}
7	2.8	0.8	20.6	0.0
8	3.1	8.3	19.5	8.2
9	4.2	6.4	11.4	5.6

^{x} Significant at 5% level.

^{xx} Significant at 1% level.

respectively. These results closely agree with those of Graf and Wenzl (26), Polevoi (43), Zhukova (67), and Christias (12). Graf and Wenzl (26) obtained only 18.2 percent increase in foliage. Polevoi (43) reported slightly lower percentage increase in the yield of sugar (18 percent). Lower values (12.3 percent and 16.8 percent increase in the yield of roots and sugar, respectively) were reported by Zhukova (67), probably due to partial infection of the plants (57.3 percent infection). Christias (12) obtained slightly higher root yield but lower foliage yield (18.8 percent and 21.7 percent, respectively).

Economic Analysis of the Control of the Disease

The farmers in the Beqa'a valley grow sugar beets under a contract with the sugar beet factory. The price of the beets delivered at the factory is LL. 65 per ton[1] provided it meets the minimum quality requirements.

Spraying for the control of diseases is usually handled by contractors who provide the machinery and labor needed at a cost of LL. 2 per dunum, and the growers supply the spray materials. The costs of spraying a dunum of sugar beet in the Beqa'a valley are:

1.	equipment and labor costs	LL. 2.00
2.	fungicide (Sulfur, W.P., 1.25 kg at LL. 1.25 per kg	LL. 1.56
3.	total cost per spraying	LL. 3.56
4.	total cost of four sprayings per season	LL. 14.24

In order to evaluate the economical aspects of disease control, the increase in returns above the cost of control (net returns) is

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1. Personal communication from Mr. H. Nasr, AREC Extension specialist.

used as an index. As concluded from spraying schedule experiments, on the average there is a 15 percent increase in the root yield by early sprayings (Table 9, No. 1 to 5). Increase in returns per dunum will therefore, depend on the yield per dunum. The increase in yield, the increase in returns, and the net returns per dunum for 6 and 3 tons of production per dunum are shown below.

Yield of beets per dunum (tons) (1)	Increase in yield per dunum (tons) (2)	Price per ton (L.L.) (3)	Increase in returns per dunum (L.L.) (4)	Total cost of 4 sprayings per dunum (L.L.) (5)	Net returns per dunum (L.L.) 6 = (4)-(5)
6	0.90	65.0	58.50	14.24	44.26
3	0.45	65.0	29.25	14.24	15.01

The higher-yielding fields, therefore, pay better returns by disease control. Farmers producing low yields, however, may actually improve their production by more than 15 percent by disease control. It is recommended to control the disease by 3 to 4 spray applications for higher returns.

Greenhouse Host Range Tests

Preliminary host range studies were carried out in greenhouse in 1966. In these tests 13 species of Chenopodiaceae, 13 species of Polygonaceae and 8 species and varieties of Papilionaceae (Table 10) were tested for susceptibility to Erysiphe betae (Van.) Welt. The plants were inoculated with conidia of the pathogen in September 1966 and weekly observations were made on the development of the disease.

Table 10. Plant species and varieties tested for susceptibility to the beet powdery mildew Erysiphe betae (Van.) Welt. under greenhouse conditions.

Plant No.	Kind	Source	Observations
	(a) Chenopodiaceae		
1	Atriplex hastata L.	Jardin Botanique de la Ville Dijon, France	R
2	Atriplex laciniata L.	"	R
3	Atriplex littoralis L.	"	R
4	Atriplex nitens Rebent	"	R
5	Beta cicla L.	"	S
6	Beta maritima L.	"	S
7	Beta rapa L.	"	S
8	Chenopodium capitatum	"	R
9	Chenopodium foetidum Schard	"	R
10	Chenopodium murale L.	"	R
11	Chenopodium giganteum Don.	"	R
12	Chenopodium glaucum L.	"	R
13	Chenopodium opulifolium Schard	"	R
	(b) Polygonaceae		
14	Emex spinosa Campd.	"	R
15	Polygonum aviculare L.	"	R
16	Rheum emodi Wall.	"	R
17	Rheum officinale Baillon	"	R
18	Rheum undulatum L.	"	R
19	Rumex bucephalophorous L.	"	R
20	Rumex conglomeratus Murr.	"	R
21	Rumex hydropathum Huds.	"	R
22	Rumex maritimus L.	"	R
23	Rumex obtusifolius L.	"	R
24	Rumex pulcher L.	"	R
25	Rumex anguineus L.	"	R
26	Rumex scutatus L.	"	R
	(c) Papilionaceae		
27	Astragalus cicer L.	"	R
28	Astragalus sulcutus L.	"	R
29	Colutea arborescens L.	"	R
	Pisum sativum		
30	Variety Blue Bantum	AUB, A.R.E.C.	R
31	Variety Progress No. 9	"	R
32	Variety Little Marvel	"	R
33	Variety No. 40	"	R
34	Variety Dwarf Grey Sugar	"	R

R = Plants resistant to the disease.
S = Plants susceptible to the disease.

As shown in Table 10, only the Beta species were susceptible. The other species of Chenopodiaceae and all species of Polygonaceae and Papilionaceae tested were found to be resistant. The powdery mildew of beets seems to be very host specific.

It can be concluded from these results and those reported in the literature (10, 12, 14) that, thus far, only members of the Beta genus are known to be hosts of Erysiphe betae (Van.) Welt. All cultivated and wild Beta species and varieties tested so far have been found to be susceptible. Further investigations should be made in order to determine the host range of the pathogen and to study the causes of host specificity of the fungus.

Conidia Germination Tests

The purpose of these tests was to make a preliminary study on the germination percentages of beet powdery mildew conidia on glass slides at various relative humidity levels (0 to 100 percent R.H.), in light and darkness[1].

Tests were carried out at room temperature ($27 \pm 2^{o}C$) and 5 different relative humidity levels in light and in the dark. The results are summarized in Table 11.

High percentage germination of conidia was obtained in these tests because care was taken to collect only 24-hour old conidia which are turgid and germinate well (65). The average germination of conidia for the whole range of relative humidities was above 60 percent. As shown in Table 11 the germination percentage of conidia increased as the relative humidity increased (from 41.9 percent at 0 percent R.H. to

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1. Appendix A, Plate 3.

Table 11. Percentage germination of conidia of beet powdery mildew Erysiphe betae (Van.) Welt. on dry glass slides after incubation for 24 hours at different relative humidities in light and in darkness at 27 ± 2°C.

Salt	R.H. %	Germination[1] %		Percent of germinated conidia forming appressorium[2]	
		Light	Dark	Light	Dark
P_2O_5	0.0	41.9	32.6	56.0	52.0
$MgCl_2.6H_2O$	32.5	62.8	45.7	73.0	82.0
$Mg(NO_3)_2.6H_2O$	52.5	67.0	55.3	73.5	84.0
NaCl	75.5	76.1	62.3	82.5	75.0
Distilled water	100.0	79.4	76.8	82.5	93.0
L.S.D. 5% level		8.8	12.4	N.S.	N.S.
1% level		11.9	16.8		

1. Each number represents the average of 3500 spores.

2. Each number represents the average of 1000 spores.

79.4 percent at 100 percent R.H. in light and from 32.6 at 0 percent R.H. to 76.8 at 100 percent R.H. in darkness). In these tests 52.5 percent relative humidity level was taken as the Check treatment. Although the germination percentage of conidia increases significantly by increasing relative humidities (67.0 at 52.5 percent R.H. and 79.4 at 100 percent R.H.), this increase is not so high as to warrant better infection in the field. The germination percentage of conidia at 52.5 percent R.H. is high enough for rapid infection and establishment of the disease.

In darkness the percent germination was generally lower than in light. This difference became significant at lower relative humidity levels[1] (0, 32.5, 52.5, and 75.5 percent R.H.). The effect of light disappeared completely at (100 percent R.H.) where conidia remained turgid during germination in the saturated atmosphere.

A high percentage of germinating conidia formed appressorium on dry glass slides (Table 11, 52 to 93 percent). One conspicuous appressorium was formed by the germ-tube of each conidium[2]. The appressorium formation was not affected by light or darkness and there was no significant difference in percent appressorium formation at different relative humidity levels. It appears that conidia germination and appressorium formation are stimulated by the contact of conidium with a solid surface, be it a host plant leaf or a glass-slide.

It was observed during the course of these tests that the conidia of Erysiphe betae (Van.) Welt. germinate at a fast rate. Within 4 to 6 hours of incubation 80 to 90 percent of germinable

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1. Appendix B, Table 37.
2. Appendix A, Plate 3.

conidia had already germinated. Zaracovitis (65) reported 78 and 83 percentages of conidia germination after 5 and 24 hours of incubation, respectively. The high germination percentages obtained at very low relative humidities (Table 11, 41.9 at 0 percent R.H. and 62.8 at 32.5 percent R.H.) and the rapid germination of the conidia of this fungus indicate that the sugar beet powdery mildew does not require high moisture for germination. It appears that only 50 percent relative humidity is sufficient to prevent the conidia from shrivelling in the atmosphere. Upon reaching the host leaf the microclimate probably provides a higher moisture which prevents shrivelling of conidia during germination. It is therefore clear that although the atmospheric humidity of the sugar beet growing areas in the Beqa'a is unfavorable for the spread of conventional fungi, it is suitable for the development of this pathogen on sugar beets.

Atmospheric temperature undoubtedly is an important factor in the development and intensity of the disease. A critical study of the effect of temperature on the development and spread of the disease is essential. Future work should be directed toward investigations on spore germination under wide range of temperature and humidity conditions.

Ascospore Germination and Infection Tests

Crushed cleistothecia with exposed asci and ascospores of Erysiphe betae (Van.) Welt. were mounted in water on hanging drop slides[1]. Slides were kept at room temperature. The ascospores were

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1. Appendix A, Plates 1 and 2.

observed daily. There was no germination within 4 days of preparation, by which time slides were contaminated by saprophytic fungi and were discarded.

Attempts to infect young seedlings of sugar beet with ascospores of the pathogen, using 3 methods of inoculation as described in Materials and Methods (Pages 15 and 16) were unsuccessful; inoculation by ascospores did not produce anu infection.

So far, it has not been possible to germinate and grow the spores and ascospores of this fungus in vitro, as is the case with most of the obligately parasitic fungi. This difficulty may be due to requirements for certain specific nutritional or environmental conditions. For future attempts to germinate ascospores, exposure to different temperatures or to alternating wet and dry conditions and different nutrients should be tried.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Field experiments were conducted at the Agricultural Research and Education Center (AREC) of the American University of Beirut in the Beqa'a Plain, Lebanon in 1963-64 and 1966, to determine the efficacy of different fungicides and the most economical spray schedule for the control of the powdery mildew disease on sugar beets. Greenhouse and laboratory tests were carried out to study the host range and biology of the pathogen.

The disease appeared annually in June and spread rapidly, through wind dispersal of conidia, to a serious extent (70 to 80 percent infection) by late July. Cleistothecia were abundant, especially on the lower leaves of infected plants, near the end of the season and were also present on the seed balls.

The yield of seed was not affected by the disease, whereas the yields of roots, tops and sugar were significantly reduced. The sugar percentage and the dry matter, protein, fiber, fat, and ash contents of the foliage were not affected.

Sulfur and Karathane proved to be the most effective fungicides followed by Morestan. Coprantol at concentrations of 0.2 percent and higher was phytotoxic and Melprex was not significantly different from the Check (Figure 1). The disease was best controlled by early application of fungicides.

Karathane, Morestan, Melprex and Coprantol (at 3 different concentrations: 0.30, 0.15, and 0.075 percent), all reduced the intensity of infection on seet beets to some extent.

In an experiment designed to determine the effect of the disease on sugar production and the efficacy of the different treatments Sulfur, Karathane, Morestan, Coprantol and Melprex were used. In this experiment yields as high as 9761 kg per dunum of roots, 3516 kg per dunum of tops and 1659 kg per dunum of sugar were obtained (Table 4). The Yields in untreated plots (Check) were 7412 kg per dunum, 2141 kg per dunum, and 1260 kg per dunum of roots, tops and sugar, respectively. Percent sugar in roots was 16.9 (average of all treatments).

In an effort to determine the most economical way of controlling the disease a spraying schedule experiment of 9 different schedules was carried out in 1966 using Sulfur (0.5 percent W.P.). Three to four spray applications starting early in July and at monthly intervals gave the most economical returns.

Preliminary host range studies were carried out in the greenhouse in 1966. In these tests 34 different species and varieties of Chenopodiaceae, Polygonaceae and Papilionaceae were inoculated. Only the Beta spp. were infected.

Spore germination tests indicated that, although high germination percentages were obtained at low relative humidities (62.8 percent at 32.5 percent R.H.), germination increased by increasing relative humidity.

Preliminary tests to produce infection by ascospore inoculations

of sugar beet seedlings were unsuccessful.

Conclusions

The results obtained indicate that powdery mildew is a serious disease for the sugar beet crops grown in Lebanon. Climatic and soil conditions (63) in the Beqa'a Plain are optimum for sugar beet production and experimental yields of as high as 10 tons of root per dunum have been obtained at AREC (pp. 24 and 33, 63, p. 12). The low yields, 3 to 4 tons per dunum, obtained by the farmers are therefore due to disease problems and poor cultural practices.

Weltzien (59) has reported that powdery mildew is the most common and widespread disease of sugar beets. Other diseases occur only occasionally and are unimportant under the climatic conditions of Beqa'a. Therefore special attention should be paid to the control of this disease. The significant increases in the yield of beets and sugar reported (Tables 5 and 9) justify the chemical control of the disease.

Recommendations

Based on the results obtained in the present investigations and other reports, the following recommendations can be made:

1. Spray schedules should start immediately after the first sign of disease appears in the field. If possible the growers should be informed, through Radio or TV or bulletins and or extension agents, about the time of first appearance of the disease in the area, so that sprays can be applied before the disease is established.

2. Three to four applications at monthly intervals should be done in order to get the best returns.

3. Despite the fact that the disease does not affect the seed yield, occasional spraying with fungicides is justified to prevent the rapid development and spread of the fungus. The seed plants left unsprayed will serve as a source of inoculum and infect nearby plants grown for sugar production.

4. Seed and root crops should not be grown in the same area.

5. Resistant plants if bred for high yield can be used in areas where the disease is serious. Zhukova (67) reported 4 varieties highly resistant in the South Ukraine region. Also species of Patelares group were found to be good source of resistance.

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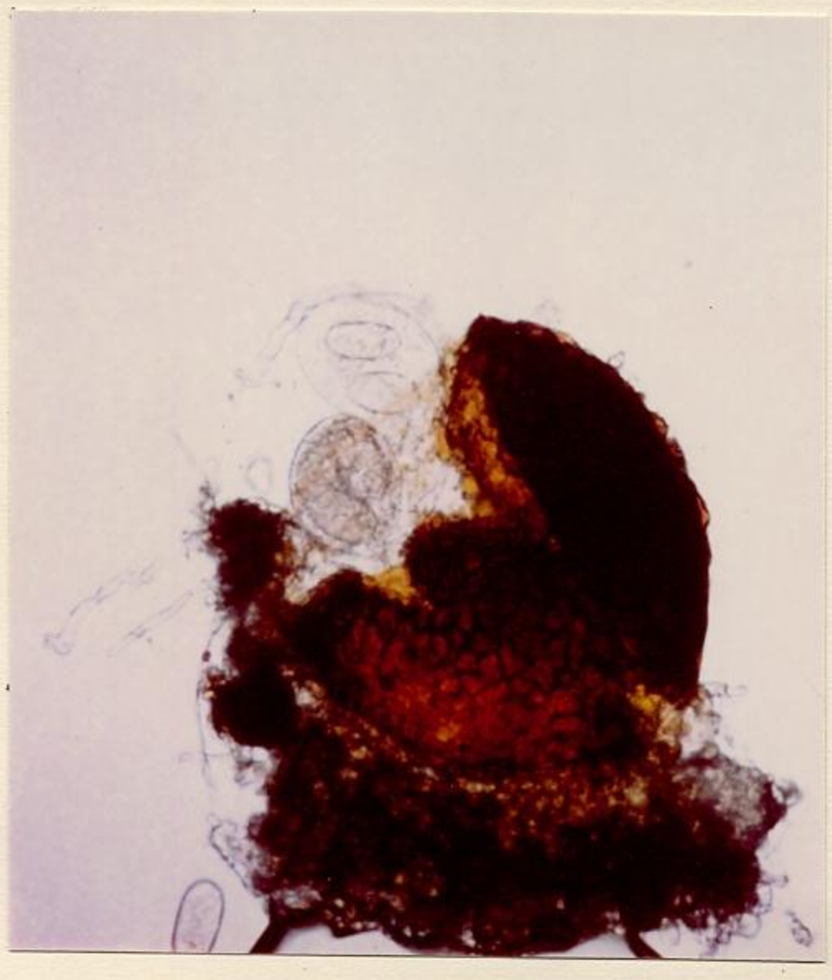
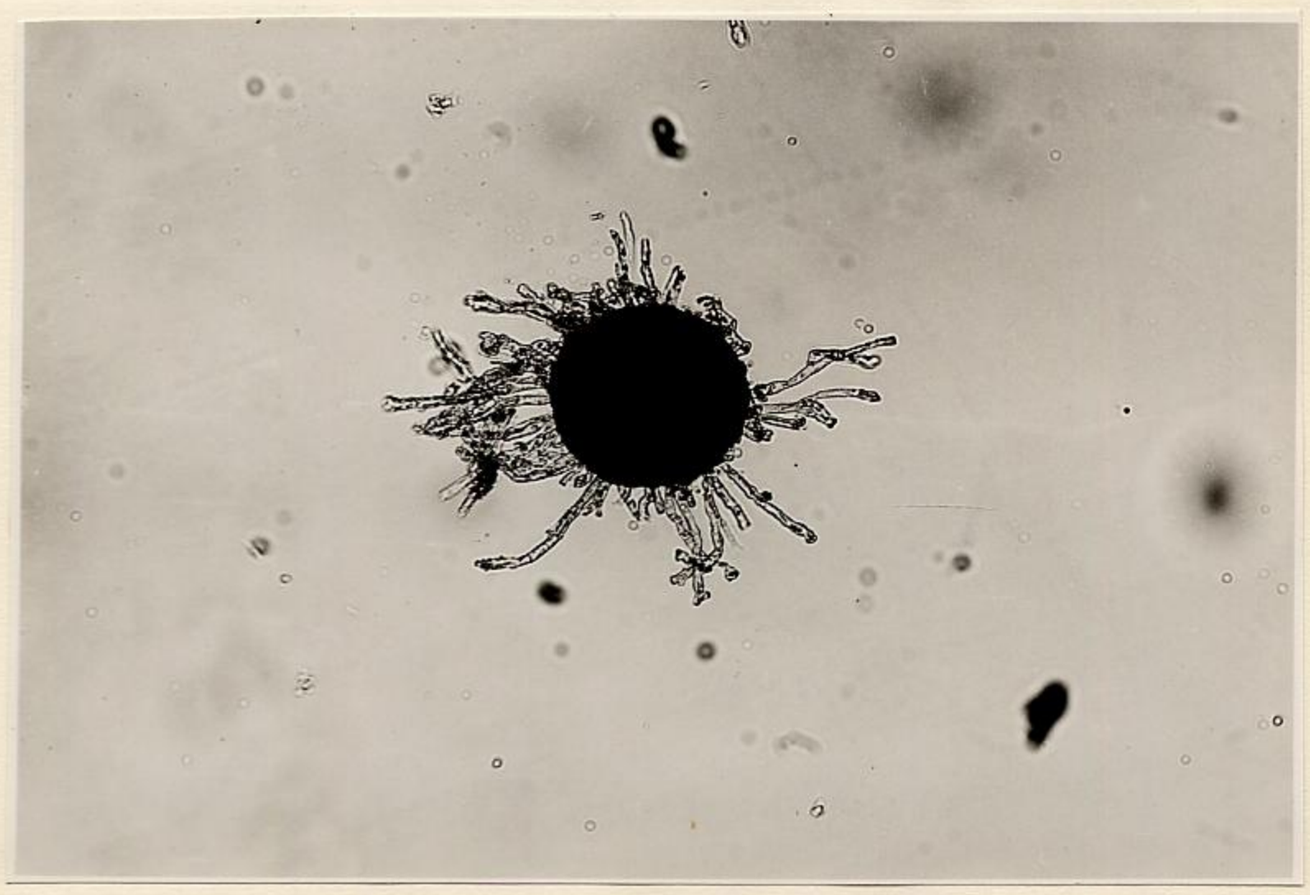
APPENDICES

APPENDIX A



a

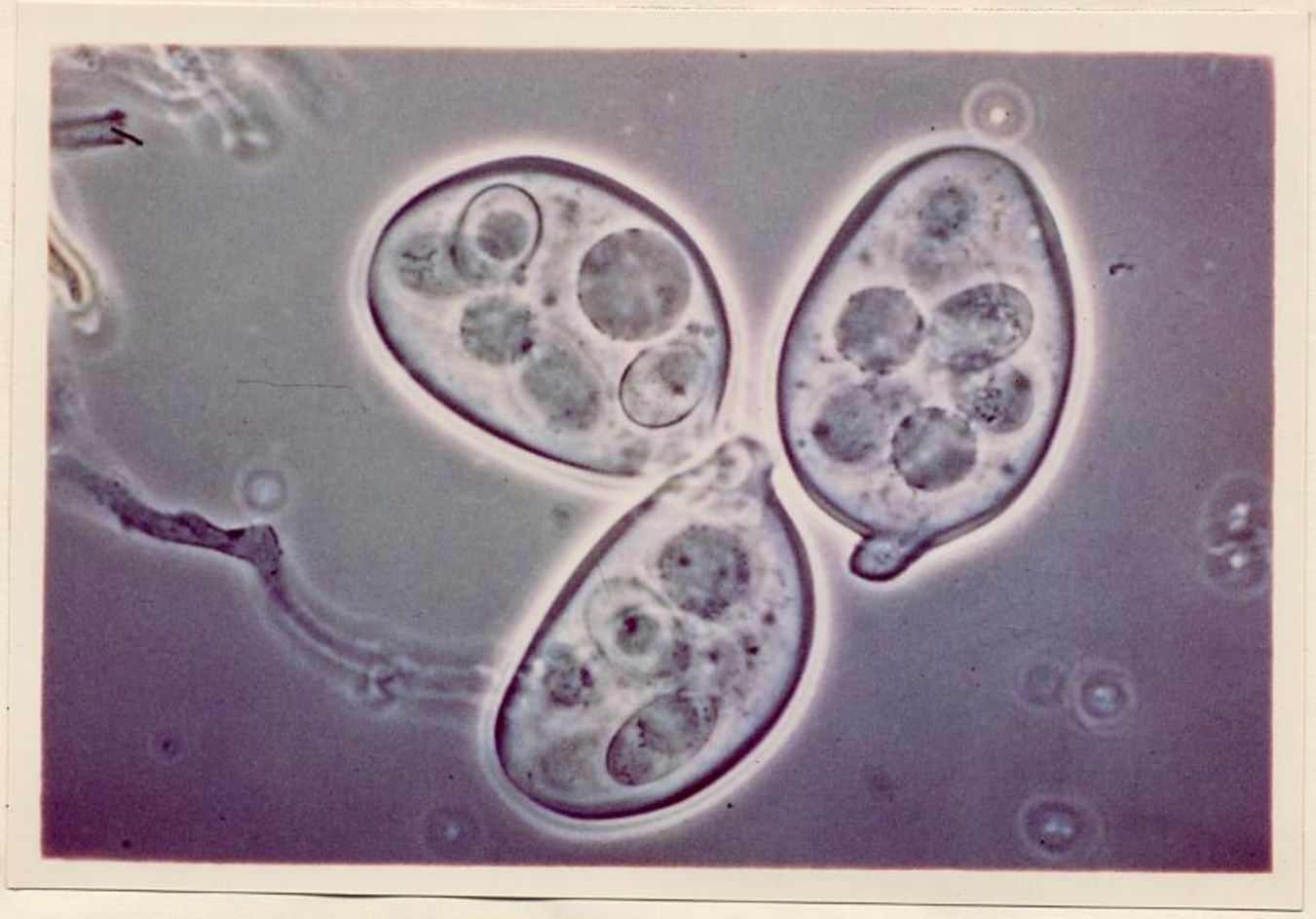


b

Plate 1. Photomicrographs showing cleistothecia of powdery mildew of sugar beets, Erysiphe betae (Van.) Welt.

a. Crushed cleistothecia with exposed asci and ascospores x 400 approximately.

b. Cleistothecium with typical appendages x 160 approximately.



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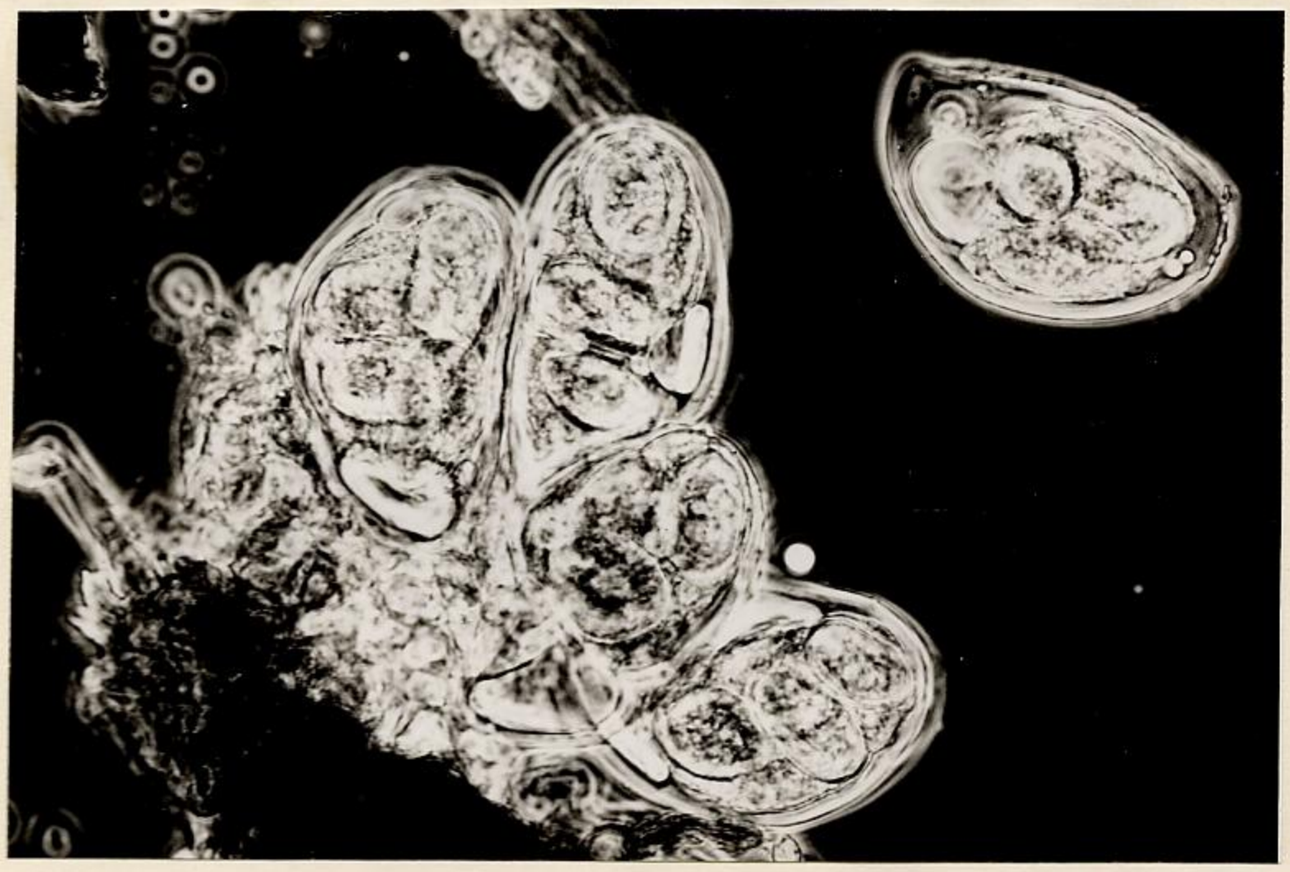

b

Plate 2. Photomicrographs showing asci and ascospores of Erysiphe betae (Van.) Welt. x 620 approximately.

a. Three asci with developing ascospores.

b. Asci and mature ascospores from cleistothecia on dry leaves after 4 years of storage at room temperature and humidity, at AUB.

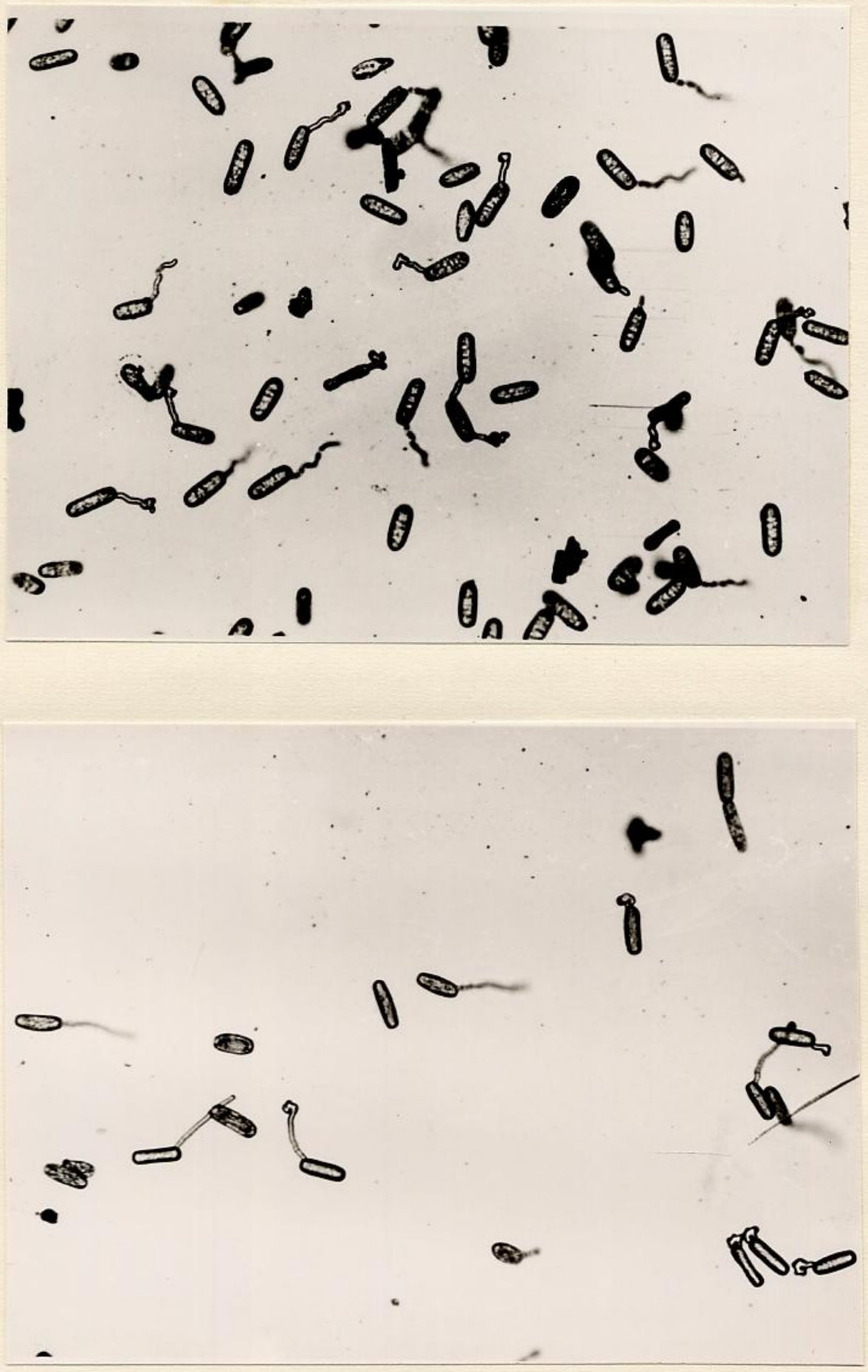

Plate 3. Photomicrographs showing germination with appressorium formation of conidia of Erysiphe betae (Van.) Welt. on dry glass slides after incubation for 8 hours in saturated atmosphere in light x 160 approximately.

APPENDIX B

I. Analyses of variance of the data of 1963-1964 "Seed Production Experiments" with Latin Square designs. Data are shown in Tables 2 and 3, p. 20.

A. Trials with Karathane, Morestan and Melprex.

Table 12. Analysis of variance of disease indices of sugar beet seed plants.

Source of variation	Degrees of freedom (D.F.)	Sums of squares (S.S.)	Mean squares (M.S.)	F	Tabulated F-value 5%	1%
Rows (R.)	3	13.55				
Columns (Col.)	3	12.63				
Treatments (Treats.)	3	0.93	0.31	0.46 N.S.	4.76	9.78
Error (E.)	6	4.03	0.67			
Total	15	31.14				

Table 13. Analysis of variance of the yield of sugar beet seeds in kg per dunum.

Source of variation	D.F.	S.S.	M.S.	F.
R.	3	31586		
Col.	3	43629		
Treats.	3	9615	3205	0.3 N.S.
E.	6	63081	10513	
Total	15	147911		

Table 14. Analysis of variance of the occurrence of cleistothecia of Erysiphe betae (Van.) Welt. on sugar beet seed balls observed in 1964.

Source of variation	D.F.	S.S.	M.S.	F.
R.	3	384		
Col.	3	1061		
Treats.	3	1600	533	4.2 N.S.
E.	6	765	127	
Total	15	3810		

B. Trials with 3 different concentrations of Coprantol (0.30, 0.15 and 0.075 percent)

Table 15. Analysis of variance of disease indices of sugar beet seed plants.

Source of variation	D.F.	S.S.	M.S.	F
R.	3	0.80	0.26	
Col.	3	0.30	0.10	
Treats.	3	0.30	0.10	0.77 N.S.
E.	6	0.77	0.13	
Total	15	2.17		

Table 16. Analysis of variance of the yield of sugar beet seeds in kg per dunum.

Source of Variation	D.F.	S.S.	M.S.	F
R.	3	31490		
Col.	3	15465		
Treats.	3	2426	809	0.57 N.S.
E.	6	8489	1415	
Total	15	57870		

Table 17. Analysis of variance of cleistothecia occurrence on seed balls.

Source of variation	D.F.	S.S.	M.S.	F
R.	3	4720		
Col.	3	1699		
Treats.	3	1699	666.6	1.30 N.S.
E.	6	2868	478.0	
Total	15	11268		

II. Analyses of variance of the data of 1964 "Root Production Experiment" with a randomized complete block design. Data are shown in Table 4, p. 24.

Table 18 Analysis of variance of disease indices of sugar beet plants.

Source of variation	D.F.	S.S.	M.S.	F	Tabulated F-value 5%	Tabulated F-value 1%
Replications (Reps.)	3	135				
Treatments (Treats.)	5	7124	1425	15.6^{xx}	2.90	4.56
Error (E.)	15	1365	91			
Total	23	8624				

^{xx} Significant at 1 percent level.

Table 18 contd.

Mean values of D.I. arranged in order of magnitude are as follows:

1	2	3	4	5	6
Check	Melprex	Karathane	Coprantol	Morestan	Sulfur
50.3	41.8	25.2	19.1	4.8	4.6

1-6 = 45.7^{xx} 2-6 = 37.2^{xx} 3-6 = 20.6^{x} 4-6 = 14.5^{x} 5-6 = 0.2

1-5 = 45.5^{xx} 2-5 = 37.0^{xx} 3-5 = 20.4^{x} 4-5 = 14.3

1-4 = 31.2^{xx} 2-4 = 22.7^{xx} 3-4 = 6.1

1-3 = 25.1^{xx} 2-3 = 16.6^{x}

1-2 = 8.5

1 2 3 4 5 6

Treatments underlined are not significantly different.

x Significant at 5 percent level.

Table 19. Analysis of variance of total yield of sugar beet plants in kg per dunum.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	7733904		
Treats.	5	42425815	8485163	7.3^{xx}
E.	15	17343610	1156241	
Total	23	67503329		

Table 20. Analysis of variance of the yield of sugar beet roots in kg per dunum.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	4833288		
Treats.	5	16537361	3307472	6.9^{xx}
E.	15	7411457	494097	
Total	23	28782105		

Table 21. Analysis of variance of the yield of sugar beet tops in kg per dunum.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	469061		
Treats.	5	7148705	1429741	7.6^{xx}
E.	15	2811845	187456	
Total	23	10429611		

Table 22. Analysis of variance of the yield of sugar in kg per dunum.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	134816		
Treats.	5	462031	92406	6.6^{xx}
E.	15	209086	13939	
Total	23	805933		

Table 23. Analysis of variance of percent sugar in the roots of sugar beet plants.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	0.42		
Treats.	5	3.71	0.74	0.49 N.S.
E.	15	22.36	1.49	
Total	23	26.49		

Table 24. Analysis of variance of percent dry matter in the foliage of sugar beet plants.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	0.60		
Treats.	5	10.00	2.00	0.64 N.S.
E.	15	46.90	3.10	
Total	23	57.5		

Table 25. Analysis of variance of percent protein in the foliage of sugar beet plants.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	12.99		
Treats.	5	26.51	5.30	2.55 N.S.
E.	15	31.18	2.08	
Total	23	70.68		

Table 26. Analysis of variance of percent fiber in the foliage of sugar beet plants.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	22.43		
Treats.	5	4.99	0.99	1.52 N.S.
E.	15	9.75	0.65	
Total	23	37.17		

Table 27. Analysis of variance of percent fat in the foliage of sugar beet plants.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	0.84		
Treats.	5	0.87	0.17	0.94 N.S.
E.	15	2.72	0.18	
Total	23	4.43		

Table 28. Analysis of variance of percent ash in the foliage of sugar beet plants.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	22.5		
Treats.	5	17.0	3.4	2.4 N.S.
E.	15	20.4	1.4	
Total	23	59.9		

Table 29. Analysis of variance of percent infected plants, for the different treatments, recorded on July 23, 1964 after the first spray application on July 16.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	330		
Treats.	5	10839	2168	17.7^{xx}
E.	15	1837	122	
Total	23	13006		

The treatment means arranged in order of magnitude from left to right are as follows:

A Check	B Melprex	C Coprantol	D Karathane	E Morestan	F Sulfur
58.1	55.6	53.8	51.8	11.2	8.8

$\bar{S}x = 5.53$ B-F = 46.8^{xx} C-F = 45.0^{xx} D-F = 43.0^{xx} E-F = 2.4

A-F = 49.3^{xx} B-E = 44.4^{xx} C-E = 42.6^{xx} D-E = 40.6^{xx}

A-E = 46.9^{xx} B-D = 3.8 C-D = 2.0

A-D = 6.3 B-C = 1.8

A-C = 4.3

A-B = 2.5

A B C D E F

Treatments underlined are not significantly different.

Table 30. Analysis of variance of the effectiveness of the different treatments in reducing the disease. Observations on percent infected plants were made, on August 8, 1964, after the second spray application on July 30, 1964.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	28		
Treats.	5	9600	1920	43.6^{xx}
E.	15	668	44	
Total	23	10296		

The treatment means arranged in order of magnitude from left to right are as follows:

A Check	B Melprex	C Karathane	D Coprantol	E Sulfur	F Morestan
52.5	47.4	35.0	25.6	3.8	0

A-F = 52.5^{xx} B-F = 47.4^{xx} C-F = 35.0^{xx} D-F = 25.6^{xx} E-F = 3.8

A-E = 48.7^{xx} B-E = 43.6^{xx} C-E = 31.2^{xx} D-E - 21.8^{xx}

A-D = 26.9^{xx} B-D = 21.8^{xx} C-D = 9.4

A-C = 17.5^{xx} B-C = 12.4^{x}

A-B = 5.1

A B C D E F

Treatments underlined are not significantly different.

x Significant at 5 percent level.

III. Analyses of variance of the data of 1966 "Spraying Schedule Experiment" with a randomized complete block design. Data are shown in Table 8, p. 33.

Table 31. Analysis of variance of the disease indices of sugar beet plants for the different spraying schedules in 1966.

Source of variation	D.F.	S.S.	M.S.	F	Tabulated F-value 5%	1%
Reps.	3	3.3				
Treats.	9	87.4	9.70	42.90^{xx}	2.25	3.14
E.	27	6.0	0.23			
Total	39	96.7				

The mean disease indices for different spraying schedules are arranged in order of magnitude from left to right as follows:

10	9	8	7	5	6	2	4	3	1
6.88	4.26	3.12	2.78	2.58	2.20	2.09	2.05	1.92	1.82

10-1 = 5.06^{xx}	9-1 = 2.44^{xx}	8-1 = 1.30^{xx}	7-1 = 0.96^{x}	5-1 = 0.76
10-3 = 4.96^{xx}	9-3 - 2.34^{xx}	8-3 = 1.20^{xx}	7-3 = 0.86^{x}	5-3 = 0.66
10-4 = 4.83^{xx}	9-4 = 2.21^{xx}	8-4 = 1.07^{xx}	7-4 = 0.73	5-4 = 0.53
10-2 = 4.79^{xx}	9-2 = 2.17^{xx}	8-2 = 1.03^{xx}	7-2 = 0.69	5-2 = 0.49
10-6 = 4.68^{xx}	9-6 = 2.06^{xx}	8-6 = 0.92^{x}	7-6 = 0.58	5-6 = 0.38
10-5 = 4.30^{xx}	9-5 = 1.68^{xx}	8-5 = 0.54	7-5 = 0.20	
10-7 = 4.10^{xx}	9-7 = 1.38^{xx}	8-7 = 0.34		
10-8 = 3.76^{xx}	9-8 = 1.14^{xx}			
10-9 = 2.62^{xx}				

6-1 = 0.38	2-1 = 0.27	4-1 = 0.23	3-1 = 0.10
6-3 = 0.28	2-3 = 0.17	4-3 = 0.13	
6-4 = 0.15	2-4 = 0.04		
6-2 = 0.11			

Spraying schedules (treatments)

1	2	3	4	6	5	7	8	9	10

Treatments underlined are not significantly different.

Table 32. Analysis of variance of the yield, in kg per dunum, of sugar beet roots for the different spraying schedules in 1966.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	7167174		
Treats.	9	12536893	1392988	4.47^{xx}
E.	27	8409545	311464	
Total	39	28113612		

The mean values of root yield in kg per dunum for the different spraying schedules are arranged in the order of magnitude as follows:

1	2	3	4	5	8	6	9	7	10
10906	10644	10619	10494	10244	9950	9812	9775	9262	9188

1-10	$= 1718^{xx}$	2-10	$= 1456^{xx}$	3-10	$= 1431^{xx}$	4-10	$= 1306^{xx}$	5-10	$= 1056^{x}$
1-7	$= 1634^{xx}$	2-7	$= 1382^{xx}$	3-7	$= 1357^{xx}$	4-7	$= 1232^{xx}$	5-7	$= 982^{x}$
1-9	$= 1131^{x}$	2-9	= 869	3-9	= 844	4-9	= 719	5-9	= 469
1-6	$= 1094^{x}$	2-6	= 832	3-6	= 807	4-6	= 682	5-6	= 432
1-8	$= 956^{x}$	2-8	= 694	3-8	= 669	4-8	= 544	5-8	= 294
1-5	= 662	2-5	= 400	3-5	= 375	4-5	= 250		
1-4	= 412	2-4	= 150	3-4	= 125				
1-3	= 287	2-3	= 25						
1-2	= 262								
		8-10	= 762	6-10	= 624	9-10	= 587	7-10	= 74
		8-7	= 688	6-7	= 550	9-7	= 513		
		8-9	= 175	6-9	= 37				
		8-6	= 138						

Spraying schedules (treatments)

1	2	3	4	5	8	6	9	7	10

Treatments underlined are not significantly different.

Table 33. Analysis of variance of the yield of foliage, in kg per dunum, for the different spraying schedules in 1966.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	743547		
Treats.	9	4661953	517995	1.5 N.S.
E.	29	9191609	340430	
Total	39	14597109		

Table 34. Analysis of variance of the estimated sugar yield in kg per dunum for the different spraying schedules in 1966.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	179299		
Treats.	9	700829	77870	9.7^{xx}
E.	27	217079	8040	
Total	39	1097207		

Table 35. Analysis of variance of the percent sugar in the roots of sugar beet plants for the different spraying schedules in 1966.

Source of variation	D.F.	S.S.	M.S.	F
Reps.	3	10.7		
Treats.	9	23.4	2.6	0.9
E.	27	75.5	2.8	
Total	39	109.6		

IV. Analyses of variance of the data on germination and appressorium formation by the conidia of Erysiphe betae (Van.) Welt., with a randomized complete block design. Data are shown in Table 11, p. 40.

Table 36. Analysis of variance for germination percentage of conidia incubated 24 hours at 5 different relative humidity levels and 27 ± 2°C.

a. Incubation in light

Source of variation	D.F.	S.S.	M.S.	F	Tabulated F-value 5%	1%
Reps.	6	725				
Treats.	4	6095	1524	24.2^{xx}	2.78	4.22
E.	24	1517	63			
Total	34	8337				

b. Incubation in darkness

Source of variation	D.F.	S.S.	M.S.	F
Reps.	6	3117	519	
Treats.	4	7798	1949	15.7^{xx}
E.	24	2979	124	
Total	34	13894		

Table 37. Paired "t" test for conidia germination at 5 different relative humidity levels in light (L) and darkness (D) after 24-hours of incubation at 27 ± 2°C.

Observations	Percent germination at									
	0% R.H.		32.5% R.H.		52.5% R.H.		75.5% R.H.		100% R.H.	
	L	D	L	D	L	D	L	D	L	D
20-10-66	30.9	18.8	70.3	34.5	65.7	56.4	72.3	51.2	75.3	82.0
28-10-66	37.5	18.0	46.2	20.1	67.5	39.0	75.2	45.9	73.5	53.1
14-11-66	65.0	63.9	82.4	50.2	74.7	59.9	70.7	51.1	83.6	81.0
16-11-66	40.3	32.8	59.5	32.4	71.8	48.7	72.4	60.2	88.7	86.5
20-11-66	36.0	29.8	58.8	66.8	63.7	63.8	91.0	82.0	82.9	81.9
21-11-66	37.8	37.8	61.9	45.6	60.6	56.7	83.2	85.6	79.1	77.7
26-11-66	46.0	27.1	60.8	70.1	64.8	62.8	68.0	59.0	72.7	75.1
t	3.1		2.4		2.8		3.5		0.8	
P[1]	0.05-0.02		0.1-0.05		0.05-0.02		0.02-0.01		0.5-0.4	

1. Percentage points of the t distribution probability.

Table 38. Analysis of variance of percentage of germinated conidia forming appressorium, at 5 different relative humidity levels, after incubation for 24 hours at 27 ± 2°C.

a. Incubation in light

Source of variation	D.F.	S.S.	M.S.	F		Tabulated F-value 5%	1%
Reps.	1	339.9					
Treats.	4	728.5	182.1	2.1	N.S.	6.39	15.98
E.	4	335.4	83.8				
Total	9	1403.8					

b. Incubation in darkness

Source of variation	D.F.	S.S.	M.S.	F
Reps.	1	7.7		
Treats.	4	2125.0	531.0	1.3 N.S.
E.	4	1565.9	391.5	
Total	9	3698.6		