STUDIES ON THE POWDERY MILDEW OF BEETS

Erysiphe betae (Van.) Welt.

by

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A Thesis Submitted to the Faculty

of Agricultural Sciences in Partial Fulfillment of

The Requirements for the Degree of

MASTER OF SCIENCE IN AGRICULTURE

Split Major: Plant Pathology-Agronomy

Minor: Soil Science

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1964

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ACKNOWLEDGEMENTS

The writer wishes to express his deep appreciation to Dr. H.C. Weltzien for his invaluable advice, efforts and constructive criticism throughout the course of this investigation. Special thanks are due to Mrs. Winnie Edgecombe for her help in identification of the weed species, to Mr. C. Kotovsky for the translation of the Russian text and to Mr. A. Alexanian for help in preparing the drawings.

The supply of the beet seed samples by the botanical gardens of Kew, England; Dijon, France; Halle, East Germany; Tabor, Zcechoslovakia; Stuttgart-Hohenheim, West Germany; and by the Kleinwanzleben Company, West Germany, is also gratefully acknowledged.

ABSTRACT

Field experiments, green house and laboratory tests were conducted in studies with the powdery mildew of beets Erysiphe betae (Van.) Welt. The disease did not affect the yield and the quality of the seed but it reduced significantly the size and yield of roots, tops and sugar. The sugar percentage of the roots and the dry matter content of the foliage were not affected.

Sulfur and Karathane were the most satisfactory fungicides, followed by Morestan. Coprantol caused phytotoxicity, while Phaltan was inferior to the first three. Highly significant increases in the yield of roots, tops and sugar (18.9%, 33.6% and 20.1% respectively) were realized following treatment with fungicides.

All the Beta species and varieties tested for resistance in this study under field and green house conditions were found to be susceptible to the disease. Some degree of resistance was observed in certain plants only under field conditions. Six Beta species were reported as new hosts of the parasite. Infection was never established on plants belonging to genera other than Beta.

Preliminary spore germination tests showed that, although germination was favored by relatively high temperature and low relative humidity, some conidia did germinate at 0% R.H. as well as in a saturated atmosphere.

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INTRODUCTION

Sugar beets were first introduced in Lebanon in the year 1947 (1, 44). The first trials were made in the Beqaa plain, located between the Lebanon and Antilebanon mountains. This plain is about 1000 m. above sea level with an average annual rainfall of 350 mm (1956-1962). (Data from AUB AREC).

In 1958 the first sugar factory was established in the S.E. Beqaa, near Anjar. With the establishment of the sugar factory the sugar beet production increased rapidly from 3000 tons grown on 1300 dunums in 1958 to 32000 tons grown on 6800 dunums in 1963. (44)

The farmers grow the sugar beets on a contract basis. The price of the beets at delivery to the factory is fixed on a weight basis and does not vary with the sugar percentage, provided the crop meets the minimum quality requirements agreed upon. The early yields were low, varying from 2.5 to 4.0 tons per dunum, probably due to lack of knowledge regarding cultural and fertilization practices and unknown disease problems. During the last 8 years however, extensive work is being done at the A.U.B. Agricultural Research and Education Center (AREC) in an attempt to adapt cultural, fertilisation and irrigation practices, followed elsewhere, to local conditions. The results of

this research work indicate that environmental as well as soil conditions in the Beqaa are particularly suitable for both, sugar and seed production. Yields as high as 600 kgs of seed per dunum and 10 tons of roots per dunum with as high a sugar content as 18.8% were obtained (44).

A preliminary study of the sugar beet diseases in Lebanon in 1962 and 1963 showed that beet rust (Uromyces betae (Pers.) Lev.), yellow virus and beet mosaic occurred only sporadically, while all the beet fields in the area were heavily attacked by the beet powdery mildew. Erysiphe betae (Van.) Welt. Leaf spot, Cercospora beticola Sacc., was found on Beta vulgaris L. var cicla only in the coast (41).

The present study was undertaken to obtain information about the powdery midlew of beets, a disease which was never recorded as serious in the traditional sugar beet growing areas of the world. The objectives of this research were as follows:

1. To observe the development of the disease throughout the growing season.

2. To evaluate its effect on the quality and yield of seed and sugar.

3. To investigate the comparative effectiveness of different chemicals as powdery mildew fungicides.

4. To develop a spraying schedule.

5. To survey its host range.

6. To test and select for varietal resistance.

7. To make a preliminary study of the physiology of spore germination.

It was believed that information obtained along the above lines of investigation would be helpful in combating the disease in an effective and economical way.

REVIEW OF LITERATURE

1. Geographic Distribution of the Pathogen

Powdery mildew of sugar beets has been reported so far only from Europe, North America and Asia. It was observed for the first time by Vahna (Weltzien, 40) in Czechoslovakia. It was then again reported only once from this country by Neuwirth (30). Later the pathogen was observed and reported from many other European countries. Its presence in France was first demonstrated by Ducomet (16). Later records of the pathogen in France are those of Crepin (13), Haudiquet (21) and Payen (31). In all cases however, the disease in France was insignificant and no serious damage was observed.

In Spain it was observed for the first time in 1927 (2). Dominguez (15) included it among the minor sugar beet pathogens, occurring in Spain. The first observation of the pathogen in England was made in 1935 (3). Later, it was found by Stirrup (32). It was then again reported from England by Hull (23). In England the disease is not serious (25).

In Belgium it was observed and reported by Decoux et al. (14); in Germany it was reported in 1928 by Neuwirth (39); in Austria by Wenzl (43) and by Graf and Wenzl (20); in Switzerland by Blumer (6); in Denmark in 1959 (4) (anonymous), and in Italy by Canova (9) and Bongionvanni (7).

In general, it appears that the disease is only occasionally important in Europe, especially in the southern and south eastern parts of this continent.

From Russia it was first reported by Nevodovsky (29). It was then found in different regions of the country by Mouravieff (27), Mourashkinsky (26), Golovin (19), Polevoi (34), Pozhar (36), Sherchenko (38), Polevoi and Chebolda (35) and Zhukova (47). In Russia the disease is widespread and as Mouravieff emphasized, it has very dangerous potentialities, particularly for the major sugar beet growing areas of the Ukraine.

In the United States it was only recorded by Yarwood (45) in California and Carsner (10) in Washington and Oregon. In North America however, the disease has never caused serious damage.

Recently the pathogen was found also in countries of the Middle East. So, Goffart (18) and Bachthaler (5) reported it from Turkey. Viennot and Bourgin (39) found it in Iran. Nevo (28) observed it in Israel in 1960-61, and Weltzien (40) described it in Lebanon. Although in Europe and America the disease appears to be insignificant (with the exception of Russia), it is by far the most important disease of sugar beets in Lebanon and the other Middle Eastern countries.

2. Taxonomy

Most of the workers mentioned above observed only

the Oidium form of the fungus. Some used simply the name Oidium and others made use of already published nomenclature to refer to the fungus. The taxonomy of the organism presented many difficulties mainly due to lack of information regarding its perfect stage. The first description was given by Vahna (Weltzien, 40). Recently the fungus was renamed by Weltzien (4) as Erysiphe betae (Van.) Welt. For a critical discussion of its taxonomy the reader is referred to the work of Weltzien (40).

3. Physiology

No information about the physiology of the fungus and its spores (asexual and sexual) is available in the literature. Its host range has not been determined. Its main host appears to be the cultivated beet, Beta vulgaris L., although few varieties have been reported to exhibit various degrees of resistance (8, 11, 47). Crepin (13) and Canova (9) found the fungus also on Beta maritima L. plants, in France and Italy respectively.

4. Effect on yield

No reports are available about the effect of the disease on the seed yield, while various authors have recently reported losses in root yield. The first report was given by Graf and Wenzl (20) who found by sulfur treatment that the disease decreased the yield of sugar, foliage and roots by 21.3%, 18.2% and 19.6% respectively. Polevoi (34) obtained a 15% increase in root yield, 0.44% increase

in sugar percentage and 18% increase in sugar yield, and Bongiovanni (7) a 10.5% increase in sugar yield by Karathane treatment. Zhukova (47) reported that 57.3% infection decreased the yield of roots and sugar by 12.3% and 16.8% respectively. In Russia it was found that sulfur spray increased the yield of sugar by 20% (37).

5. Control

(a) Chemical. Neuwirth (30) used 3% bordeaux mixture and Salikol. Klika (24) controlled the disease successfully by sulfur vaporization. Graf and Wenzl (20) obtained very good results by three applications of copper oxychloride as spray at a rate of 1.7 kg. of copper in 400 liters of spray per hectare. Haudiquet (21) suggested Zineb and copper products or oxiquinoline. In Russia the disease was successfully controlled by sulfur, both, as spray and dust. Polevoi (34) obtained good results using milled and colloidal sulfur. Bongionvanni (7) finally found that three bi-weekly Karathane applications at a rate of 0.15 kg. per hectare were superior to an equal number of Sn-triphenylacetate applications at a rate of 0.3 kg. per hectare.

(b) Resistant varieties. Sherchenko (38) described methods of selection for resistance and listed the most resistant strains. Polevoi and Chebolda (35) made selections of resistant varieties in the irrigated areas of

Central Asia and Kazakhstan. Zhukova (47) reported that the varieties Kirgizskaya 018, Frunzenskaya 986, Kirgizskaya 055, Yaltushkovskaya odnosemyannaya and Belotserkovskaya odnosemyannaya exhibited the highest degree of resistance.

MATERIALS AND METHODS

I. Field experiments

Field experiments were conducted at the A.U.B. Agricultural Research and Education Center, located in the North Central Beqaa Plain. The weather in this location is usually dry and hot in summers, without any precipitation. Winters are cold, with ununiformly distributed rainfall. The amount and distribution of rainfall and temperature for the years 1962 and 1963 are shown in Table 1, p. 18.

A. September 1962-July 1963 Experiments: Sugar Beet Seed Production

Two experiments were conducted simultaneously during the period from September 1962 to July 1963 to determine the effect of the disease on seed production. Experiment 1 included trials with Karathane, Sulfur and Poly-kil. Experiment 2 was designed to evaluate three spraying schedules.

1. Seedbed preparation and experimental design

The land was disk plowed, harrowed and smoothened. Before planting, nitrogen was applied at a rate of 12 kgs N per dunum as ammonium sulfo-nitrate, and phosphorus at a rate of 20 kgs P_2O_5 per dunum as simple superphosphate, (18.5% P_2O_5). Later, in spring, nitrogen was applied twice

at a rate of 4 kgs N per dunum as a side dressing.

The experimental design was a 4 x 4 Latin Square. Each experimental area was a rectangle of 15 x 23.5 m. Plots consisted of 4 rows, 5 m long. The distance between rows was 75 cms.

2. Planting and early cultural practices

Seeds of the variety Pedigree E were planted on November 14, 1962. 3 weeks later the plants were thinned to a distance of 20-25 cms. Weeding was done when necessary.

In the fall the fields were irrigated by sprinklers, once per week. In early April, irrigation furrows were opened between the rows and water was applied in the furrows, once per week.

3. Treatments:

In Experiment 1, treatments were as follows:

Treatment No.	Chemical	Spray Started on	Total No. applications
1	Karathane[1]	May 10	5
2	Sulfur[2]	"	5
3	Poly-kil[3]	"	5
4	Control		-

[1]Dinitrocaprilphenyl crotonate

[2]Colloidal Sulfur (Wettable powder)

[3]Butylene polymer.

In Experiment 2, treatments were dates at which spraying schedule with 0.05% Karathane started. The following 4 treatments were included.

Treatment No.	Sprays started on	Total No. of applications
1	December 4, 1962	9
2	April 5, 1963	8
3	June 7, 1963	3
4	Control; No spray	0

Treatments were distributed at random.

4. Mode of Application:

All preparations were applied as sprays by means of Knapsack sprayers, in the following concentrations:

Chemical	Concentration
Karathane	0.05%
Sulfur (wettable S powder)	0.5%
Poly-kil	2 kgs in 50 gallons of water.

The first 3 sprays were applied at a rate of 600 lit/ha. Thereafter, the plants were sprayed to run-off. For this purpose, 24 liters from each preparation were required (= 4000 l/ha). The sprays were applied once in 2 weeks. Observations and data were taken at bi-weekly intervals, alternating with the sprays. All spraying operations were carried out in the morning, between 9.00

and 11.00 a.m. in order to avoid wind effects. When necessary, plastic boards were placed between rows, next to the delivering nozzles, to intercept weak wind currents and prevent adjacent rows from receiving wind-carried spray.

5. Method of recording data

Data on the extent of infection were collected as follows: The lower leaves of all plants within each row were examined individually and the number of infected plants per row was recorded separately. During the first three observations, magnifying lenses were used to detect early mycelial growth, invisible to the naked eye. Afterwards, infected plants were recorded by mere visual observation. In order to obtain an abstract, over-all evaluation of the treatments a disease index was calculated for each plot when all data had been recorded, one week before harvest, (17). The sum of counts from the two mid-rows per plot was divided by the plot whose sum of counts from the two mid-rows was the smallest: i.e.;

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

where:

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

ΣT_x = Sum of counts of plot x (2 mid-rows)

Σt_{min} = Smallest sum of counts among all plots (healthiest plot) (2 mid-rows).

By applying the above formula, one disease index was calculated for every plot. It is obvious that the smallest possible disease index is 1, and it is that of the healthiest plot.

6. Harvesting and threshing:

The seeds were harvested in mid-July. The stalks were cut with a sharp pruning shear to minimize shaking and shattering. Data were taken on 4 m. from the 2 mid-rows per plot. The stalks were placed in sacs and hung to dry. The seeds dropped during the harvesting operation were picked from the ground by hand within each row to determine the amount of shattering.

Threshing was done three weeks after harvesting by means of an adjusted small grain threshing machine. The seeds were next separated from the chaff, by sieving. Purity analysis and germination tests were run in the laboratory. Also the weight of 1000 seeds was recorded (in quadriplicates).

7. Methods of statistical analysis

The data were statistically analysed using the Analysis of Variance Method. The "t-test" was also used when significant differences between treatments were obtained.

B. April-November 1963 Experiment; Sugar Beet Root Production

Land preparation, fertilization, planting, thinning, irrigation, method of collecting infection data, mode of application and method of statistical analysis of data were the same as these described for the previous experiments. Seeds of the Pedigree-E variety were planted in early April.

1. Experimental design

A randomised block design was used. The plots consisted of 4 rows, 5 m. long and spaced 50 cms apart. The plants within rows were spaced at a distance of 20-25 cms.

2. Treatment

Seven treatments, each replicated 4 times, were distributed at random in equal numbers of plots within one replication. The different treatments are shown in the following table.

3. Harvesting and data recorded:

In early November the beets were dug out by means of shovels and spades. 4 m. from the 2 mid-rows per plot were used for data taking. The cleaned roots were separated from the tops and the weight of both was recorded separately. One kg. of fresh foliage was secured from every plot for moisture and dry matter determinations. These samples

Treatment	Conc.%	Spray Started	Spray Ended	Total No. Applications
Karathane	0.05%	July 19	Sept. 27	6
Sulfur	0.5	"	"	6
Coprantol[4]	0.3	"	"	6
Morestan[5]	0.2	"	"	6
Phaltan[6]	0.1	"	"	6
Control A	-			
Control B	-			

were dried in the oven for 48 hours at 75° C. and after cooling their dry weight was determined.

After recording the weight of roots, 4 beets, representative of the entire size range of the lot, were picked, tagged in sacs and taken to the laboratory for determination of sugar content. Percentage sucrose in the roots was then determined by the method described in the "Official Methods of Analysis" of the A.O.A.C. (Association of Official Agricultural Chemists, 7th edition, Washington D.C.). Measurements on the length and maximum thickness of the beets were taken from 10 beets

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[4]Copper oxychloride

[5]6-Methyl-2, 3-quinoxalinedithiol cyclic carbonate.

[6]N-trichloromethyl thio-phthalimide.

per plot. A disease index was calculated for every plot as in the previous experiments.

C. Variety Field Trials

The species and varieties listed in Table 7 were planted in the field in 5 m rows in early April 1963. The plants were exposed to natural infection. The disease development and the reaction of the different species and varieties were recorded at biweekly intervals.

II. Green House Variety Tests (September 1962-June 1963)

Seed samples of Beta species and varieties obtained from European Botanical Gardens (see Table No. 7) were planted in flats and placed in the greenhouse. The young seedlings were then infected artifically at the 2-leaf stage. Artificial infection was accomplished by transfering conidia from infected leaves to the healthy seedling leaves by means of a small, camel's hair brush. Observations on disease development were made daily.

III. Spore Germination Tests

Conidia from young infections were dusted on thoroughly cleaned and flamed glass slides. Single slides were placed in Zwolfer chambers set at six different relative humidity levels and placed in thermostat-incubators (48).

Each R.H. level was run at 2 germination temperatures, namely 25°C and 30°C for 24 hours. The following salt solutions were used to provide the various R.H. levels, covering the range from 0 to 100%.

Salt		Conc. (gr./100 cc water)	R.H. %
Phosphorus pentoxide	P_2O_5 (Pure)	dry	0
Magnesium chloride	$MgCl_2 \cdot 6H_2O$	52.8	33.0
Magnesium nitrate	$Mg(NO_3)_2 \cdot 6H_2O$	223.0	52.9
Sodium chloride	Na Cl	35.7	75.3
Barium chloride	$Ba Cl_2$	39.3	90.2
Distilled Water		-	100.0

Each test was replicated 5 times. 400 measurements (100 x 4) were taken from each replication.

Table 1: Amount and distribution of rainfall and temperature for the years 1962 and 1963 in the Beqaa, Lebanon

	Rainfall mm		Mean air Temperature		Relative Humidity	
Months	1962	1963	1962	1963	1962	1963
January	93:1	124:1	6:3	7:1	78:63	77:8
February	130:6	70:0	5:1	7:4	68:23	68:0
March	10:5	82:4	10:8	6:9	63:40	70:4
April	43:3	53:3	11:3	12:0	68:0	70:4
May	3:7	11:7	17:0	14:0	60:1	70:0
June	0	0	21:4	20:5	53:0	62:2
July	0	0	27:8	22:0	51:5	59:0
August	0	0	24:5	23:5	48:0	53:1
September	0	0	21:6	21:0	53:0	58:4
October	19:3	49:6	17:1	16:5	62:1	61:5
November	0	16:4	14:1	11:2	50:0	68:9
December	164:1	70:6	7:8	5:4	-	69:3

EXPERIMENTAL RESULTS AND DISCUSSION

I. Sugar Beet Seed Production

A. Trials with Karathane, Sulfur and Poly-kil. Experiment 1.

1. Disease Development

The first mycelial growth became detectable on April 5, on 8% of the plants. (Fig. 1, curve C). The number of infected plants then increased as the season progressed. By the end of May, over 50% of the plants were already infected. By the end of June, infection was about 70% and by July 12 it was 99%. The curve acquires a steep slope in July when per cent infection increased from 70% to 99% within two weeks. This indicates that conditions favorable for rapid spread of the disease commence in late June. The relatively high temperature and low relative humidity prevailed during the end of the experiment (as shown in Table 1, the average for July 1963 was 22.0°C and 51.5% R.H.) show that Erysiphe betae is one of the powdery mildews highly adapted to these conditions. However, there is also the possibility of an increased host susceptibility in older plants.

Cleistothecia were first detected on the lower leaves of three plants on April 19. As the season progressed, cleistothecia formation increased and by July the lower

dead leaves of all untreated plants were completely covered with cleistothecia.

2. Effect of treatments on disease development

The first two sprays, applied on May 10 and May 24 respectively, were very effective. Karathane decreased the disease from 34% on April 19 to 0% on May 31; Sulfur from 34% to 2%, and Poly-kil from 35.5% to 5% during the same period. (Fig. 1, curves K, S and P). This decrease was due to complete coverage of the foliage with the spray material and the fact that the vegetative growth was completed when the first spray was applied, on May 10, so that no new leaf area was formed. By this time all plants had bolted and attained full development. After May 31 the disease in the treated plants was insignificant.

The three treatments differ significantly from the control at the 1% level. The disease indices are presented in Table 2. Karathane has a disease index of 1.85; Sulfur 1.82; Poly-Kil 1.85 and control 7.80. By extrapolation, (Fig. 1, curves K, S, P and C), we can conclude that the difference became significant about May 3, and it remained so thereafter, until the end of the season.

3. Effect of treatments on seed yield and quality

The yield data presented in Table 2 show that the disease does not affect seed production. The seed yield

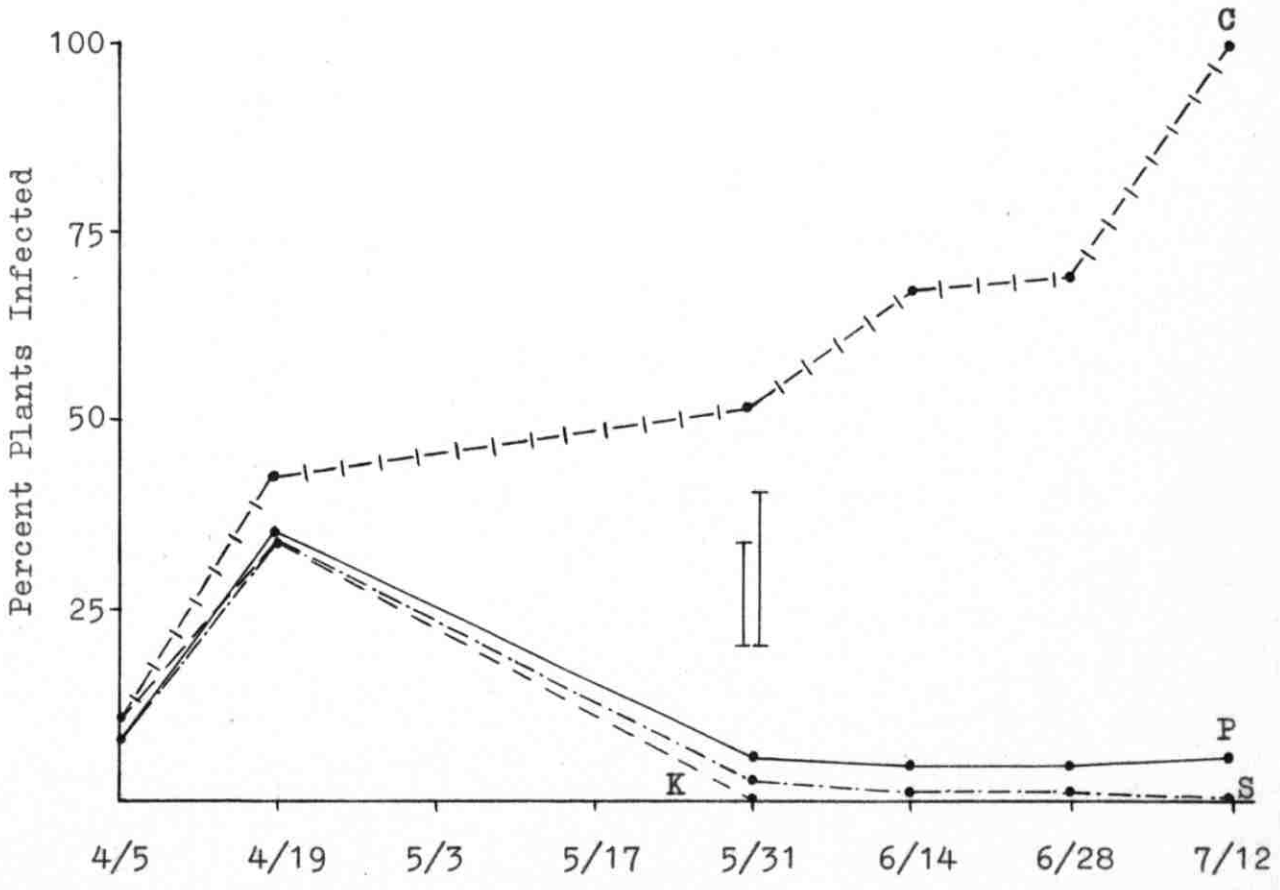

Fig. 1: Effect of treatments on disease development:
P=Poly-kil; K=Karathane; S=Sulfur; C=Control
⊢——⊣ L.S.D. at 5% and 1% level.

varied from 391.1 kgs/dunum (Poly-kil treatment) to 426.8 kgs/dunum (control), but this difference is not statistically significant.

One explanation of this effect is that the crop escapes the disease. In the Beqaa plain, sugar beets grown for seed production are planted in mid-September and harvested in mid-July of the following year. The disease, although it appears in the field as early as April, becomes serious only in June. By this time the plants are fully grown and the roots have attained full development. Any damage to the foliage is not serious because the plants have already adequate root reserves and stored energy to produce seed.

Another explanation is that, in spite of damage to vegetative plant organs, the plants may be actually stimulated to produce seed as a result of response to injury. When optimum conditions for plant growth prevail, the plants will produce abundant vegetative growth. Adverse growth conditions on the other hand cause a shift from vegetative growth to seed production. This shift appears to be a normal physiological reaction in plants and it has survival value. Among the adverse factors that cause this shift, injury is undoubtedly an important one, whether mechanical, insect injury or others. Disease is certainly a form of injury and as such it may have a share in this effect.

Table 2 Disease development, yield in kg. per dunum and quality characteristics of sugar beet seed, as affected by Karathane, Sulfur and Poly-kil treatments

Treatment	Disease Index	Seed kg./ dunum	Germination %	Weight of 1000 seeds grs	Seedlings/ 200 seed balls
Karathane	1.85	410.0	83.4	16.0	281
Sulfur	1.82	406.4	83.0	16.2	280
Poly-kil	1.85	391.1	81.0	14.6	294
Control	7.80	426.8	82.5	14.9	285
L.S.D. 5% level	1.85	-	-	-	-
1% level	2.85	-	-	-	-

Table 3: Disease development, yield in kg per dunum and quality characteristics of sugar beet seed as affected by different spraying schedules

Spraying Schedule started on	Disease Index	Seed kg/ dunum	Germination %	Weight of 1000 seeds grs	Seedlings/ 200 seed balls
December 4	1.90	536.8	85.6	15.6	306
April 5	1.85	612.1	83.6	15.9	294
June 7	6.50	527.6	84.1	14.8	280
No spray (control)	10.95	451.4	85.5	15.4	310
L.S.D. 5%	3.60	-	-	-	-
1%	5.45	-	-	-	-

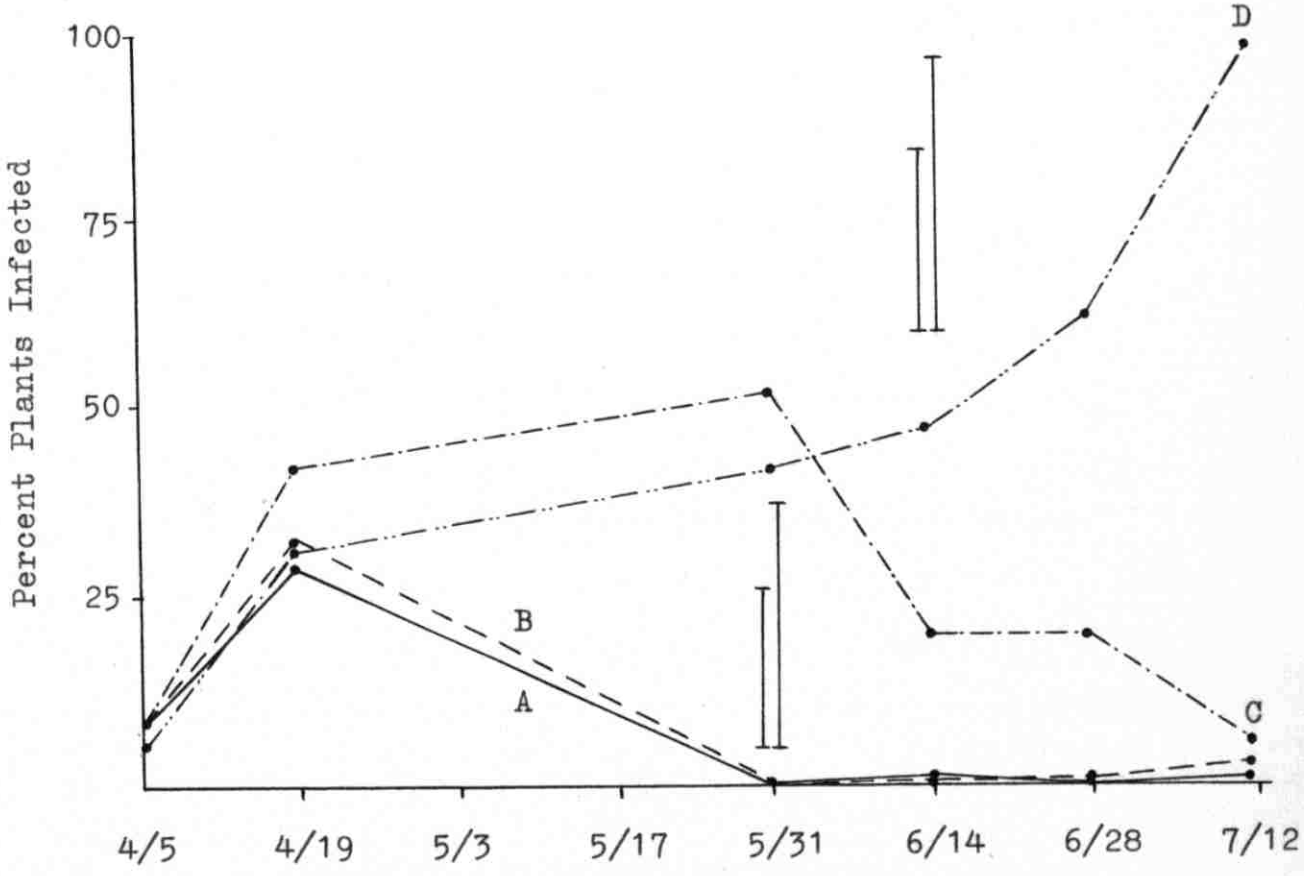

Fig. 2: Effect of spraying schedules on disease development. Schedules started on:
A=Dec. 4, 1962; B=April 5, 1963;
C=June 7, 1963; D=Control
⊢——⊣ L.S.D. at 5% and 1% level.

The quality of the seed from all plots appears to be satisfactory. It is shown in Table 2 that the germination percentage ranges from 81.0 (Poly-kil treatment) to 83.4 (Karathane treatment). The germination percentages do not differ significantly among the treatments. The disease thus does not affect the germinability of the seed.

The weight of 1000 seeds at 10.8% moisture content and the number of seedlings per 200 seed balls were studied as these two seed characteristics affect quality. As it is shown in Table 2 the weight of 1000 seeds varied from 14.6 grs (Poly-kil treatment) to 16.2 grs (Sulfur treatment) and the number of seedlings per 200 seed balls from 280 (Sulfur treatment) to 294 (Poly-kil treatment). These differences are not statistically significant. Both, were not affected by the disease.

B. Effect of Different Spraying Schedules.

Experiment 2.

In this experiment the development of the disease followed the same pattern as already described earlier. (cf. Fig. 1 and 2). The results are summarized in Table 3 and Fig. 2.

The first spraying schedule, started on Dec. 4 (Fig. 2, curve A) was not superior to the second, started on April 5, (Fig. 2, curve B). The disease indices of the first two schedules (Table 3) are 1.90 and 1.85. Fig. 2

shows that the curves of these schedules (A and B) almost coincide. However, the third schedule, started on June 7 (D.I. 6.50, Table 3), differs significantly from the first two (D.I. 1.90 and 1.85) and the control (D.I. 10.95).

The difference between the third schedule and the first two ones was highly significant on May 31. After June 14 and until the end of the season the schedules did not differ significantly. The difference between the third spraying schedule and the control became significant on about June 14 and it remained so until harvest.

The spray applied on April 5 appears to be ineffective. The disease increased from 7% on April 5 to 32% on April 19 (averages of curves A and B, Fig. 2) when the second spray was applied. Thereafter it decreased linearly and by May 31, infection dropped to zero. After May 31, plants carrying infection in the treated plots were very rare.

The continued spread of the disease after the spray of April 5 is explained on the basis that the quantity of spray applied (600 lit/ha) was probably not enough to ensure complete coverage of the foliage. Moreover, vegetative growth at that time was active and the new leaf area remained unprotected and subject to attack by the fungus. After April 19 the plants were sprayed to run-off, the coverage was complete and the disease declined sharply. This also explains the fact that, unlike the spray on

April 5, one spray on June 7 (Fig. 2, curve C) was effective in reducing the disease from 52% (May 31) to 20% (June 14).

In this experiment the yield of seed varied from 451.4 kgs/dunum (control) to 612.1 kgs/dunum (2nd schedule); the germination percentage from 83.6 (2nd schedule) to 85.6 (1st schedule); the weight of 1000 seed at 10.8% moisture from 14.8 grs (3rd schedule) to 15.9 grs (2nd schedule) and the number of seedlings per 200 seed balls from 280 (3rd schedule) to 310 (control). None of these differences is statistically significant. As in the previous experiment, the disease did not affect the yield and quality of seed for the same reasons explained on p. 22.

II. Sugar Beet Root Production

1. Disease Development

Fig. 3 shows the development of the disease throughout the growing season. The corresponding disease indices are given in Table 4.

The spread was very rapid during the month of July. Percent infection increased from 0.6% on June 26 to 83% on July 26 (Fig. 3, curves A and B). It was mentioned earlier (page 19) that the disease showed a similar rapid spread during the month of July (Fig. 1 and 2). The results of this experiment confirm the conclusion that

Erysiphe betae is favored by high temperature and low relative humidity (Table 1). The disease continued to spread after July 26 but at a reduced rate. At the end of the growing season infection was 97.5%.

Cleistothecia were first observed on July 12. Later the number of plants carrying cleistothecia increased and by mid-November cleistothecia were extremely abundant, especially on the lower dead leaves of untreated plants.

2. Effect of treatments on disease development

The spraying schedule started on July 19. At this date the infection had already reached approximately 65%. All treatments were effective in reducing the disease significantly but each to a different extent. The fungicidal action of the different compounds differs significantly. As shown in Fig. 3, Coprantol was the most effective fungicide, followed by Sulfur, Karathane, Morestan and Phaltan. Coprantol and Sulfur cured all infected plants within 5 to 7 weeks. The other three fungicides never gave complete control until the end of the experiment. The disease indices presented in Table 4 are also in the same order. Coprantol has the lowest disease index (3.1), followed by Sulfur (5.0), Karathane (10.4), Morestan (15.4) and Phaltan (23.7).

Coprantol (D.I. 3.1) and Sulfur (D.I. 5.0) do not

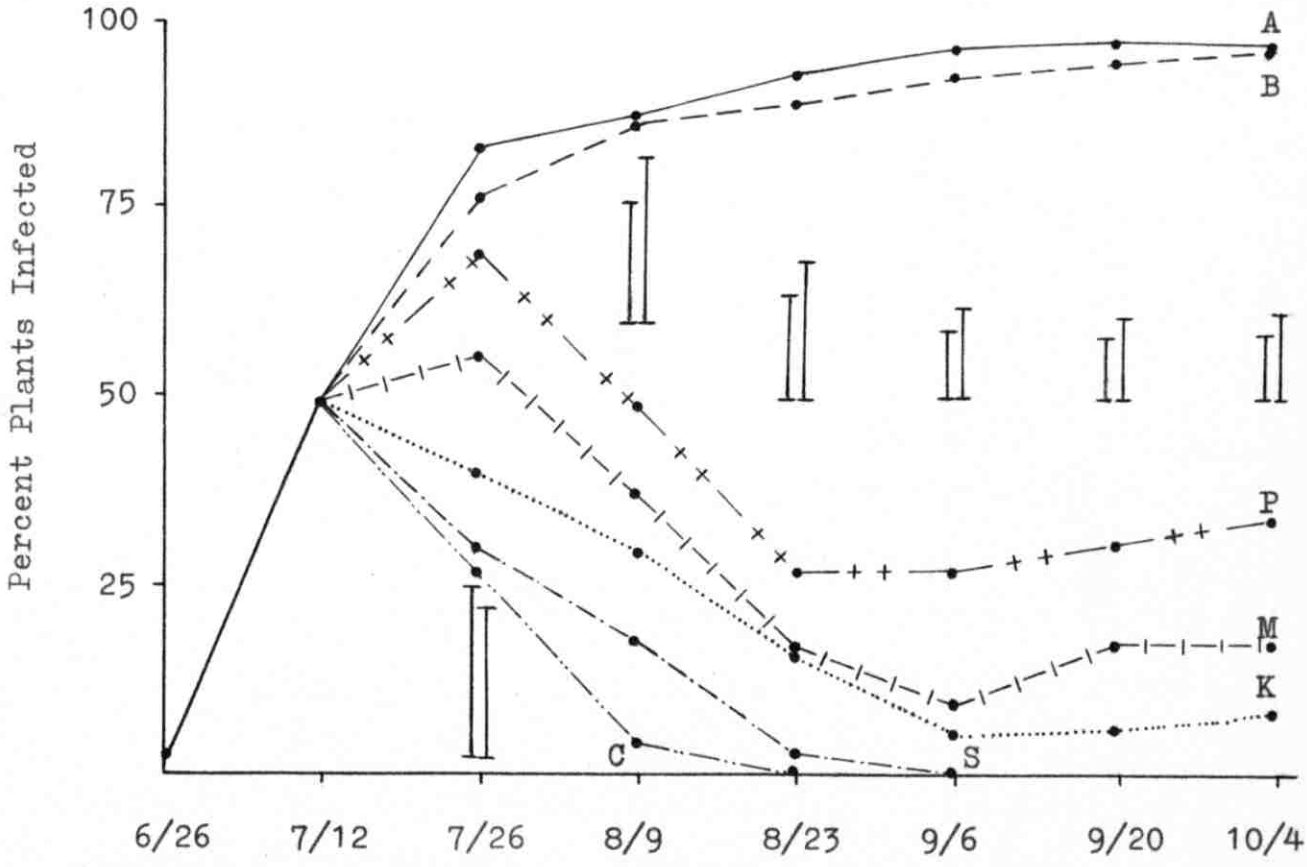

Fig. 3: Effect of treatments on disease development:
C=Coprantol; S=Sulfur; K=Karathane;
M=Morestan; P=Phaltan; A and B controls.
⊢——⊣ L.S.D. at 5% and 1% level.

differ significantly. (Fig. 3, curves C and S), but Coprantol is significantly superior to all the other fungicides (curves K, M and P). Sulfur does not differ significantly from Karathane (D.I. 10.4) but it is significantly superior to Morestan (D.I. 15.4) and Phaltan (D.I. 23.7) (Fig. 3, curves K, M and P). Karathane and Morestan do not differ significantly. Phaltan is significantly inferior to Morestan after August 23 (curves P and M). Phaltan is also significantly inferior to Karathane, Sulfur and Coprantol.

3. Effect of treatments on the yield and size of roots

The data in Table 4 show that the disease reduces significantly the yield of roots. The yield varied from 9769 kgs/dunum (sulfur treatment) to 7786 kgs/dunum (control B). All the treatments, except Coprantol, differ significantly from the controls. Fig. 4 shows that as the disease index increases from 5.0 (sulfur treatment) to 53.7 (control B) the yield of roots decreases from 9769 kgs/dunum to 7786 kgs. dunum. It follows therefore that the yield of roots is inversely related to the severity of the disease. This is not true for Coprantol which, although it has the lowest disease index (3.1), also gave the lowest yield (8819 kgs/dunum) as compared to the other treatments. This is because Coprantol, at the concentration used in this experiment (0.3%, as recommended by the

Table 4: Disease development, yield of roots, tops and sugar, sucrose content and other characteristics of sugar beets as affected by Karathane, Sulfur, Morestan, Coprantol and Phaltan treatments

Treatment	Disease Index	Total Yield	Roots Kgs/ Dunum	Tops Kgs/ Dunum	Max. Root Diam. Cms.	Root Length Cms.	Sugar Percentage	Sugar Kgs. /Dun.	Dry Matter of foliage percent
Karathane	10.4	13374	9762	3612	13.0	30.9	16.50	1608	15.0
Sulfur	5.0	14025	9769	4256	12.8	29.6	16.32	1588	14.6
Morestan	15.4	13156	9381	3775	11.4	29.0	16.80	1576	14.1
Coprantol	3.1	11894	8819	3075	10.6	28.4	15.74	1392	15.3
Phaltan	23.7	12375	9150	3225	11.4	28.3	16.14	1476	14.9
Check A	55.6	10843	8062	2781	10.0	28.1	16.36	1316	16.2
Check B	53.7	10661	7786	2875	9.6	26.3	16.12	1253	17.2
L.S.D.									
5% level	5.7	1158	1050	611	0.9	2.3	-	239	-
1% level	7.8	1589	1440	837	1.2	-	-	-	-

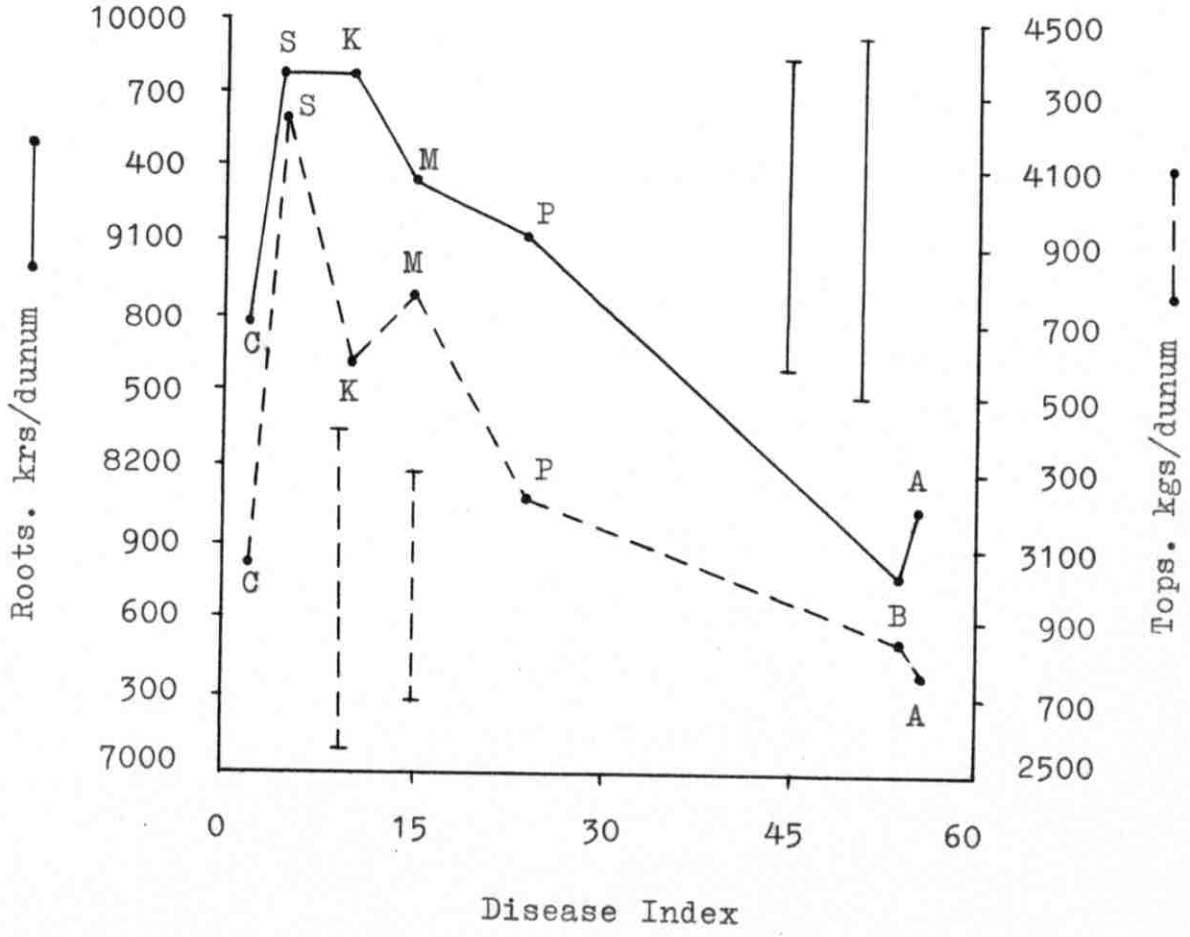

Fig. 4: Effect of treatments on the yield of roots and foliage: C=Coprantol; S=Sulfur; K=Karathane; M=Morestan; P=Phaltan; A and B controls. ⊢—⊣ L.S.D. at 5% and 1% level.

manufacturer for other fungus diseases), showed phytotoxicity. Although it proved to be an excellent eradicant (46), it damaged the foliage and gave low yield. The reduction of the root yield can be explained on the basis that the plants are attacked by the disease when they are still at an early stage of growth. The plants grown for their roots are planted in early April and harvested in mid-November. As early as July, the disease has already become severe, while the plants are growing actively. Their foliage and roots are still undeveloped. Any damage to the foliage at this stage of growth hinders the synthetic activity of the leaf tissue and may cause yield reduction.

Table 4 shows that the size of the roots was reduced significantly. Both the length and the diameter were affected. The root length varied from 26.3 cms (control B) to 30.9 cms (Karathane treatment). Karathane and Sulfur gave a significant increase in root length over the average of the two controls, while Coprantol, Morestan and Phaltan did not (Fig. 4).

The maximum diameter of the roots varied from 9.6 cms (control B) to 13.0 cms (Karathane treatment)(Table 4). Fig. 5 shows an inverse relationship between root diameter and the severity of the disease. As the disease index increases from 5.0 (sulfur treatment) to 53.7 (control B) the root diameter decreases from 12.8 cms to 9.6 cms.

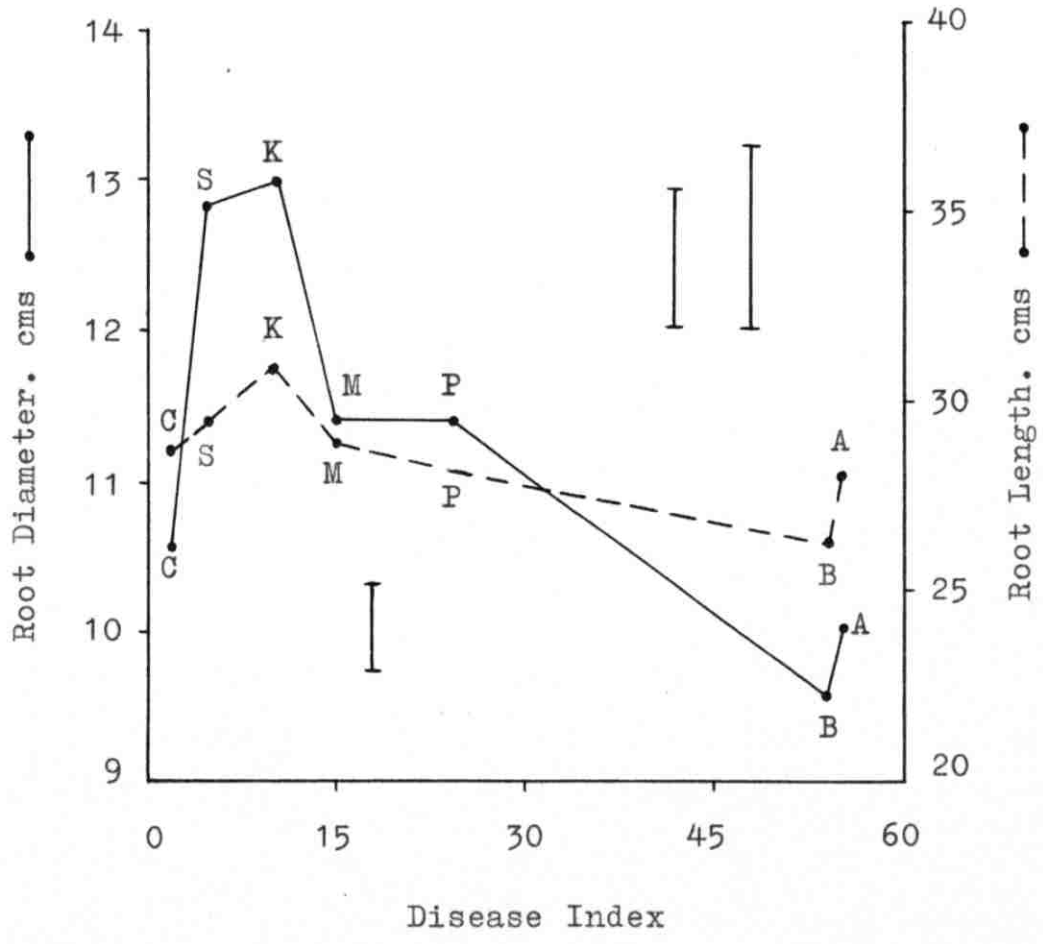

Fig. 5: Effect of treatments on the size of beet roots: C=Coprantol; S=Sulfur; K=Karathane; M=Morestan; P=Phaltan; A and B controls.
⊢——⊣ L.S.D. at 5% and 1% level.

An exception is again Coprantol which, because of its phytotoxic effect, did not increase the root diameter. All other treatments increased the root diameter significantly. Sulfur and Karathane do not differ significantly. Also Morestan and Phalton do not differ significantly. Sulfur and Karathane however gave significantly bigger root diameter than Morestan and Phaltan, and these significantly bigger than the controls (Fig. 5).

4. Effect of treatments on the sugar content of roots and sugar yield.

Data on the sugar content of the roots and the yield of sugar are presented in Table 4. The yield of sugar varied from 1253 kgs/dunum (control B) to 1608 kgs/dunum (Karathane treatment). Sulfur, Karathane and Morestan increased the yield of sugar significantly, whereas Coprantol and Phaltan did not. Fig. 6 shows that there is an inverse relationship between the yield of sugar and the severity of the disease. As the disease index increases from 5.0 (sulfur treatment) to 53.7 (control B) the yield of sugar decreases from 1588 kgs/dunum to 1253 kgs/dunum.

The sugar content of the roots ranged from 15.74% (Coprantol treatment) to 16.80% (Morestan treatment). This difference is not statistically significant. Fig. 6 shows that the sugar percentage in roots does not vary as the severity of the disease increases. In this experiment, the sugar content of the roots was not affected by the disease.

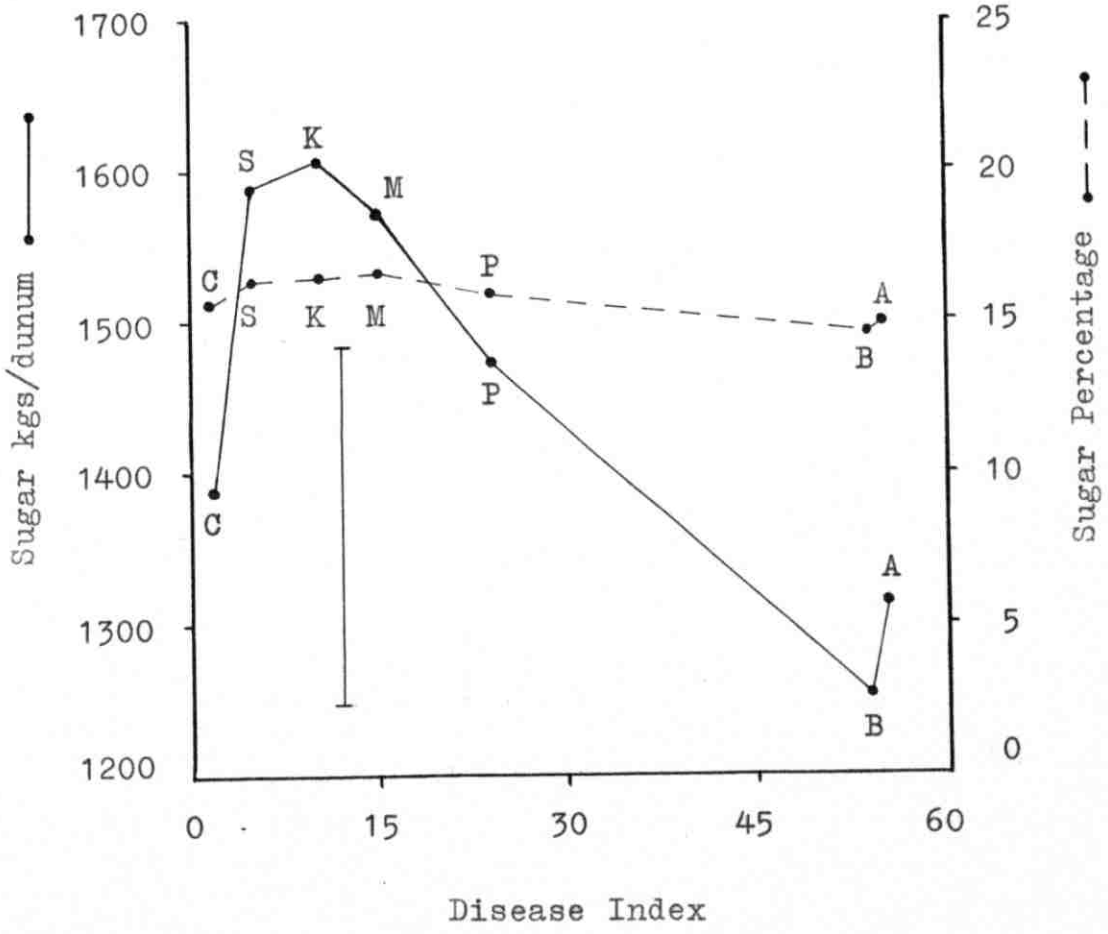

Fig. 6: Effect of treatments on the percentage concentration and yield of sugar:
C=Coprantol; S=Sulfur; M=Morestan;
K=Karathane; P=Phaltan; A and B controls.
⊢——⊣ L.S.D. at 5% and 1% level

5. Effect of treatments on the yield of tops and dry matter of the foliage.

Data on the yield of tops and dry matter are presented in Table 4. The yield of green foliage ranged from 2781 kgs/dunum (control A) to 4256 kgs/dunum (Sulfur treatment). Sulfur gave significantly higher yield of green foliage than all the other treatments, except Morestan. Sulfur, Karathane and Morestan increased the yield of tops significantly but Coprantol and Phaltan did not. (4256 kgs/dunum, 3612 kgs/dunum and 3775 kgs/dunum as compared with 3075 kgs/dunum and 3225 kgs/dunum respectively).

Fig. 4 shows again an inverse relationship between the yield of green foliage and the severity of the disease. As the disease index increases from 5.0 (sulfur treatment) to 55.6 (control A) the yield decreases from 4256 kgs/dunum to 2781 kgs/dunum. This represents a reduction of 34.7% in yield.

6. Evaluation of treatments

An evaluation of the treatments may be based upon the extent to which each one improved the yield or other characteristics of the roots as compared with the controls which were taken as reference.

Table 5 shows the percent increase above the controls of the total yield and the yield of roots, foliage

Table 5: Percent increase above the control of the total yield and the yield of roots, foliage and sugar and other characteristics of sugar beets

Treatment	Disease Index	Percent increase above the control						
		Total Yield	Roots Kgs/D	Tops Kgs/D	Max. Root Diam. Cms.	Root Length	Sugar Percentage	Sugar Kgs/D.
Karathane	10.4	19.6**	18.8**	21.7*	24.6**	12.0*	0.16	20.1*
Sulfur	5.0	23.3**	18.9**	33.6**	23.4**	8.1*	0.05	19.1*
Morestan	15.4	18.3**	15.5**	25.1**	14.0**	6.2	0.33	18.5*
Coprantol	3.1	9.6	10.1	8.0	7.5	4.2	-0.31	7.8
Phaltan	23.7	13.1**	13.4*	12.3	14.0**	3.9	-0.06	13.0

* Significant at 5% level.

**Significant at 1% level.

Table 5: Percent increase above the control of the total yield and the yield of roots, foliage and sugar and other characteristics of sugar beets

Treatment	Disease Index	Percent increase above the control						
		Total Yield	Roots Kgs/D	Tops Kgs/D	Max. Root Diam. Cms.	Root Length	Sugar Percentage	Sugar Kgs/D.
Karathane	10.4	19.6**	18.8**	21.7*	24.6**	12.0*	0.16	20.1*
Sulfur	5.0	23.3**	18.9**	33.6**	23.4**	8.1*	0.05	19.1*
Morestan	15.4	18.3**	15.5**	25.1**	14.0**	6.2	0.33	18.5*
Coprantol	3.1	9.6	10.1	8.0	7.5	4.2	-0.31	7.8
Phaltan	23.7	13.1**	13.4*	12.3	14.0**	3.9	-0.06	13.0

* Significant at 5% level.

**Significant at 1% level.

and sugar as well as the length and diameter of the roots. Karathane and sulfur improved all significantly, whereas Morestan, Coprantol and Phalton did not. The highest increase of the total yield and the yield of roots and tops was obtained with Sulfur treatment (23.3%, 18.9% and 33.6% respectively). Karathane gave the highest increase in sugar yield (20.1%) and root diameter (24.6%). Morestan and Phaltan increased the diameter (14%) but not the length of the roots, but Phaltan also failed to increase the yield of sugar. In no case Coprantol gave a significant increase above the controls.

It follows from the above and from the discussion on page 30 that Sulfur and Karathane are the most satisfactory fungicides. Their effect is almost equal. Morestan ranks third, while Phaltan, used at a concentration of 0.1%, proved unsatisfactory. Perhaps a higher concentration might have given better results. Coprantol cannot be evaluated since it caused toxicity. At a lower concentration however, this fungicide may be very satisfactory.

7. Comparison with earlier findings

The results presented here agree with those of Graf and Wenzl (20) except for the yield of foliage. They reported only an 18.2% decrease in foliage yield, whereas in this study it was found that Sulfur treatment increased the yield of tops by 33.6% (Table 5). Polevoi (34) reported slightly lower percentage increases of the

yield of roots and sugar (15% and 18% respectively) but he also observed a 0.44% increase in sugar percentage. It was not indicated however, whether this increase was statistically significant. Bongiovanni (7) obtained a 10.5% increase in sugar yield with three Karathane applications. In the present study, Karathane was twice as effective in increasing the yield of sugar (20.1% increase), (Table 5). The relatively low values reported by Zhukova (47) were due to partial infection, a fact that may be true also in some of the other reports.

III. Tests for Varietal Resistance under Field Conditions

In these tests 8 Beta species, 21 sugar beet varieties, 5 garden beet varieties and 4 swisschards were exposed to spontaneous infection. Included were also 3 species of other Chenopodiaceae, among which 3 spinach varieties and 2 weeds, one Amaranthus and one Polygonum species.

All Beta species and sugar beet varieties tested are listed in Table 7. They were all found to be susceptible to the disease.

Table 6 summarizes observations on the extent of infection made throughout the growing season. The infection followed the same pattern as demonstrated in the yield trials (Fig. 3). It started in June, then it increased steadily through July and August and by September 6, infection was complete. Cleistothecia formation was abundant on all plants late in the season.

There was however some degree of resistance visible, especially in the garden beets and some of the Beta maritima L. collections. The garden beet variety Seneca Detroit remained almost disease-free until August and only 6 out of 22 plants (27%) showed slight infection (spots only) in September. The growth of mycelium and sporulation in all other garden beets was also limited. Many plants developed spots only. As a reaction to the disease, all the garden beet varieties showed a characteristic reddish discoloration at the infection loci. The mycelial growth was limited to the reddish areas only. Within these areas cleistothecia were formed late in the season.

Beta maritima L. plants from Dijon, France, exhibited a similar type of resistance. Infection was low in July and August but in September, 21 out of 22 plants were infected (Table 6). But the infection was mild, the mycelium was not well developed and sporulation was not abundant. The infected areas of the leaves showed the characteristic reddish discoloration. Embedded in the mycelial mat, cleistothecia were detected on the lower leaves of infected plants late in the season.

Other Beta species and varieties which exhibited the same type of relative resistance, even if all plants carried infection, were the following:

Beta vulgaris L. from Kew, England; Beta vulgaris L. from Halle, East Germany; Beta rapa L. and Beta vulgaris L. var. cicla, both from Dijon, France. No infection was

observed on any of the other Chenopodiaceae tested, neither on the three spinach varieties nor on the Chenopodium species. The other two weeds were not infected also.

It can be concluded from these results and also from a study of the literature that, until now, only members of the Beta genus are known as hosts of Erysiphe betae (Van.) Welt. These include all cultivated and wild Beta species and varieties so far tested. While Crepin (13) and Canova (9) have already found the parasite on Beta maritima L., the fungus is now for the first time reported on Beta diffusa Coss, Beta patula Ail, Beta trigyna Walds et Kit, Beta rapa L., Beta patellaris Mog. and Beta sentelaris Mog.

Whether the relative resistance observed in some cases could be used for a breeding program has to be further investigated before definite conclusions can be drawn. This is also true in regard to the type and extent of resistance exhibited. In addition, the host range within and outside the Beta genus should be further investigated.

IV. Green House Variety Tests

All the species and varieties listed in Table 7 were also tested in the green house and their reaction to the disease was observed. Tables 8, 9 and 10 summarize results obtained on November 19, 26 and December 3 from the first group of 15 sugar beet varieties after artificial inoculation on November 6, 1962. Severe, medium and

Table 6: Susceptibility of test plants (Table 7) to the beet powdery mildew Erysiphe betae (Van.) Welt under field conditions

Plant[7]	Number of plants infected (out of 22) June 28	July 12	August 9	Sept. 6	Observations[8]
1	0	10	19	all	SS
2	2	13	21	all	SS
3	0	3	16	all	SS
4	0	16	18	all	SS
5	0	14	15	all	SS
6	0	12	20	all	SS
7	0	8	15	all	SS
8	0	16	20	all	SS
9	0	7	20	all	SS
10	0	12	17	all	SS
11	0	9	all	all	SS
12	0	8	9	all	SS
13	0	10	18	all	SS
14	0	12	18	all	SS
15	0	18	21	all	SS
16	0	7	18	all	SS
17	0	16	16	all	SS
18	0	20	20	all	SS
19	1	13	16	all	SS
20	0	13	17	all	SS
21	0	16	17	all	SS

[7]For actual names and source of plants see Table 7

8 = Mycelium not well developed. Mostly spots

S = Incomplete susceptibility. (Some degree of resistance

SS= High susceptibility

R = Plants showed reaction to the disease

RR= Complete resistance.

Table 6 (cont.)

Plant	Number of plants infected (out of 22) June 28	July 12	August 9	Sept. 6	Observations
22	0	7	all	all	SS
23	0	2	14	all	*, S, R.
24	0	15	all	all	SS
25	0	2	10	all	SS
26	0	6	7	all	*, S, R
27	0	8	13	all	*, S, R
28	0	0	5	all	*, S, R
29	0	0	2	6	*, S, R
30	-	-	-	-	
31	0	4	11	all	*, S, R
32	0	8	15	all	SS
33	0	8	14	all	*, S, R
34	0	5	10	all	SS
35	2	9	all	all	SS
36	0	4	7	21	*, S, R
37	-	-	-	-	Not germinated
38	-	-	-	-	"
39	-	-	-	-	"
40	-	-	-	-	"
41	0	6	all	all	SS
42	0	3	9	all	*, S, R
43	0	16	all	all	SS
44	0	5	all	all	SS
45	0	8	all	all	SS
46	0	8	all	all	SS

Table 6 (cont.)

Plant	Number of plants infected (out of 22)				Observations
	June 28	July 12	August 9	Sept. 6	
47	0	0	0	died out	RR
48	0	0	0	died out	RR
49	0	0	0	died out	RR
50	0	0	0	0	RR
51	0	0	0	died out	RR
52	0	0	0	0	RR
53	0	0	0	died out	RR

Table 7: Plant species and varieties tested for resistance to the beet powdery mildew Erysiphe betae (Van.) Welt. under field and green house conditions

Plant No.	Kind	Source
	(a) Sugar beet varieties	
1	Debrovica-A	AUB Agric. Res. & Ed. Center
2	Debrovica-V	"
3	Pedigree-E	"
4	Pedigree-SSA	"
5	Polypane	"
6	Polypane-N	"
7	G.W.-619	"
8	G.W.-674	"
9	G.E.-777	"
10	Kuhn-R	"
11	Nationa-Burakow A.J.-3	"
12	Holleshog-P	"
13	Trirave	"
14	Klein-Standard	"
15	Buszczynski CLR	"
16	K.W.-E 3191	"
17	K.W.-N 3192	"
18	K.W.-Z 3193	"
19	K.W.-CR 3194	"
20	K.W.-Polybeta 3195	"
21	3196	"

Table 7 (cont.)

Plant No.	Kind	Source
	(b) Swisschards	
22	B. vulgaris L. var. cicla	Zagreb-Yugoslavia
23	B. vulgaris L. var. cicla	Dijon-France
24	B. vulgaris L. var. cicla	Tabor-Zcechoslovakia
25	B. vulgaris L. var. cicla	Beirut (local swiss-chard)
	(c) Garden beet varieties	
26	Detroit Dark Red	AUB res. & Ed. Center
27	Boston Crosby or Early Wonder	"
28	Local	"
29	Seneca Detroit	"
30	Detroit Perfected Strain	"
	(d) Beta species	
31	Beta vulgaris L.	Kew-England
32	Beta vulgaris L.	Zagreb-Yugoslavia
33	Beta vulgaris L.	Halle-E. Germany
34	Beta maritima L.	Kew-England
35	Beta maritima L.	Tabor-Zcechoslovakia
36	Beta maritima L.	Dijon-France
37	Beta trigyna Waldst et Kit	Kew-England
38	Beta trigyna Waldst et Kit	Stuttgart-Germany
39	Beta trigyna Waldst et Kit	Dijon-France
40	Beta trigyna Waldst et Kit	Halle-E. Germany
41	Beta trigyna Waldst et Kit	Tabor-Zcechoslovakia
42	Beta rapa L.	Dijon-France
43	Beta diffusa Coss	Halle-E. Germany
44	Beta patula Ail	Tabor-Zcechoslovakia

Table 7 (cont.)

Plant No.	Kind	Source
45	Beta patellaris Mog.	Tabor-Zcechoslovakia
46	Beta sentelaris Mog	"
	(e) Other Chenopodiaceae	
	(i) Spinach varieties	
47	Giant Nobel	AUB Res. & Ed. Center
48	Bloomsdale-Long Standing	"
49	Viking	"
	(ii) Weed species	
50	Chenopodium ambrosioides L	Dog River-Beirut
51	Chenopodium botrys L.	"
52	Amaranthus retroflexus L	"
53	Polygonum lapathifolinum L	"

slight infection were counted separately. The disease development is shown in Fig. 7 (drawn from the average values of all 15 varieties).

The infection developed rather fast and reached 100% by December 10, 34 days after artificial inoculation. Plants with slight and medium infection decreased steadily after November 19, whereas heavily infected plants increased. Thirteen days after artificial inoculation (Nov. 19), 59.9% of all the plants were infected (Table 8). Of these, 24.5% carried severe infection, 12.8% medium and 22.6% slight infection. On November 26 (20 days after inoculation), 95.7% of the plants were infected (Table 9). Of these, 71.6% carried severe infection, 12.2% medium and 11.9% slight infection. On December 3 (27 days after inoculation) the infection reached 96.7% (Table 10). 93.9% of the plants showed severe infection and only 3% medium infection.

Plants with slight infection decreased from 22.6% on Nov. 19, (Table 8), to 11.9% on November 26, (Table 9), to 0% on December 3, (Table 10). Plants with medium infection also decreased from 17.8% on November 19, (Table 8), to 12.2% on November 26 (Table 9) to 3.0% on December 3 (Table 10). Plants with severe infection increased from 24.5% on November 19 (Table 8), to 71.6% on November 26, (Table 9) to 93.9% on December 3, (Table 10). On December 10, infection reached 100%. All the plants carried

severe infection. After December 10, and until April 27, 1963, when they were discarded, the plants stayed severely infected. The plant growth had practically ceased, probably also due to lack of nutrients in the green house flats. The leaves were small, rather narrow, folded or twisted, and the lower ones covered with cleistothecia, frequently died. Cleistothecia on leaves were first observed on December 12, 1962, 36 days after artificial inoculation. On January 6, 1963 cleistothecia were abundant on all varieties, especially on the older, lower leaves.

All the other Beta species and varieties tested in the green house also showed a similar disease development. Infection always reached 100% between the 4th and the 5th week after inoculation and for this reason no grading of the severity of the disease was made.

Under green house conditions, none of the Beta species and varieties (Table 7) were found to be resistant. On the leaves, mycelium and cleistothecia developed profusely in all tests.

Unlike the field trials, all the garden beet varieties tested showed no particular resistance under green house conditions. The disease developed as fast on these varieties as on the other sugar beet varieties and no particular reaction was observed. Mycelium development, sporulation and cleistothecia formation were profuse. This is also

Table 8: Disease development on 15 sugar beet varieties under green house conditions. Counts were made on November 19, 1962, following artificial inoculations with Erysiphe betae (Van.) Welt. conidia on November 6.

Variety	Plants per flat	Plants infected	Degree of infection* Severe	Medium	Slight	% infection
Pedigree-E, flat 1	39	22	5	3	14	56.4
" " 2	39	32	14	6	12	82.0
" " 3	46	39	24	9	6	84.8
Kuhn-R	27	3	0	1	2	11.1
Nationa-Burakow	14	1	0	0	1	7.1
Debrovica-A	40	15	3	3	9	37.5
" -V	41	33	20	8	5	80.5
G.W.-619	46	39	17	10	12	84.8
G.W.-676	35	19	5	6	8	54.3
G.E.-777	25	18	6	6	6	72.0
Pedigree-SSA	18	4	2	0	2	22.2
Holleshog-P	30	21	4	6	11	70.0
Trirave	26	18	7	4	7	69.2
Buszczynski	35	27	17	2	8	77.1
Klein-Standard	35	14	3	3	8	40.0
Polypane	29	10	3	1	6	34.5
Polypane-N	31	19	6	4	9	61.3
Av. plants	32.7	19.6 =	8.0	4.2	7.4	
Av. % infection			24.5	12.8	22.6	59.9

*Extent of infection is expressed as per cent of infected leaves of individual plants. 0-30% infection was designated arbitrarily as slight, 30-70% as medium and above 70% as severe.

Table 9: Disease development of 15 sugar beet varieties under green house conditions. Counts were made on November 26, 1962, following artificial inoculation with Erysiphe betae (Van.) Welt. conidia on November 6

Variety	Plants per flat	Plants infected	Degree of infection* Severe	Medium	Slight	% infection
Pedigree-E, flat 1	39	39	33	3	3	100.0
" " 2	39	39	36	3	0	100.0
" " 3	46	46	46	0	0	100.0
Kuhn-R	27	22	13	2	7	81.5
Nationa-Burakow	14	9	4	3	2	64.3
Debrovica-A	40	38	23	4	11	95.0
Debrovica-V	41	41	41	0	0	100.0
G.W.-619	46	46	41	2	3	100.0
G.W.-676	35	35	30	3	2	100.0
G.E.-777	25	25	22	2	1	100.0
Pedigree-SSA	18	16	13	1	2	88.9
Holleshog-P	30	28	15	7	6	93.3
Trirave	26	26	17	6	3	100.0
Buszczynski	35	32	22	3	7	91.4
Klein-Standard	35	34	17	7	1	97.1
Polypane	29	27	13	12	2	93.1
Polypane-N	31	29	11	10	8	93.5
Av. plants	32.7	31.3	23.4	4.0	3.9	
Av. % infection			71.6	12.2	11.9	95.7

*See footnote in Table 8.

Table 10: Disease development on 15 sugar beet varieties under green house conditions. Counts were made on December 3, 1962, following artificial inoculation with Erysiphe betae (Van.) Welt. conidia on November 6.

Variety	Plants per flat	Plants infected	Degree of infection*			% infection
			Severe	Medium	Slight	
Pedigree-E, flat 1	39	39	37	2	0	100.0
" " 2	39	39	38	1	0	100.0
" " 3	46	46	46	0	0	100.0
Kuhn-R	27	23	22	1	0	85.2
Nationa-Burakow	14	10	9	1	0	71.4
Debrovica-A	40	39	37	2	0	97.5
Debrovica-V	41	41	41	0	0	100.0
G.W.-619	46	46	44	2	0	100.0
G.W.-676	35	35	34	1	0	100.0
G.E.-777	25	25	24	1	0	100.0
Pedigree-SSA	18	17	17	0	0	94.4
Holleshog-P	30	28	26	2	0	93.3
Trirave	26	26	25	1	0	100.0
Buszczynski	35	33	32	1	0	94.3
Klein-Standard	35	35	34	1	0	100.0
Polypane	29	28	27	1	0	96.5
Polypane-N	31	30	29	1	0	96.8
Av. plants	37.7	31.7	30.7	1.0	0.0	
Av. % infection			93.9	3.0	0.0	96.9

*See footnote in Table 8.

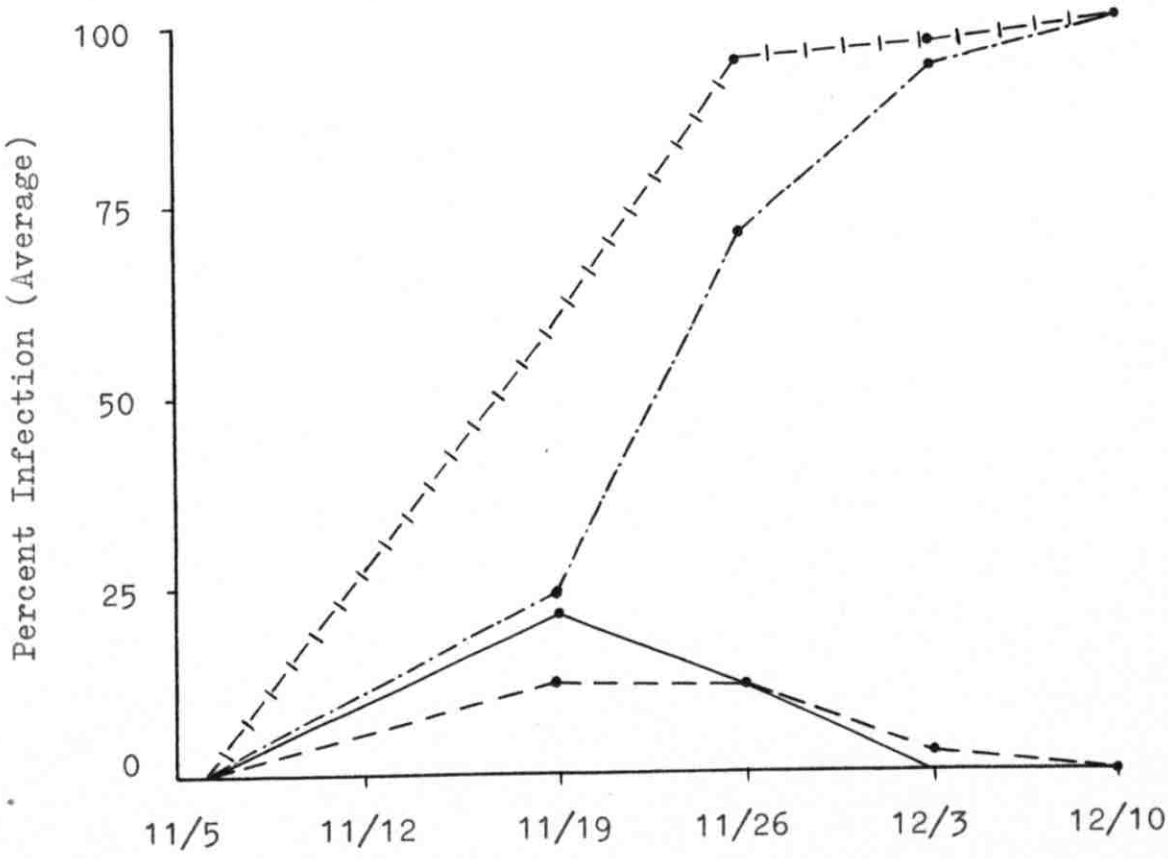

Fig. 7: Disease development on 15 sugar beet varieties under green house conditions.

——— Slight

– – – Medium

—·—·— Heavy

—|—|— Total

true for all the other plants which exhibited some resistance under field conditions.

The other Chenopodiaceae--three spinach varieties and the weed species--were found to be completely resistant. In no case any infection developed on these plants.

Under the green house environment the disease developed twice as fast than it did under field conditions. Only 36 days were required for complete infection (100%) following artificial inoculation under green house conditions (Fig. 7). Under field conditions more than two months were required for complete infection (Table 6). Even if the results obtained under green house conditions do not compare exactly with those obtained under field conditions most of the Beta species and varieties tested showed 100% infection, both under field and green house conditions.

V. Spore Germination Tests

It must be emphasised that the present study is only a preliminary one. The purpose of these tests was to find out whether beet powdery midlew conidia were able to germinate on a dead substrate and observe a range of temperature and relative humidity over which the asexual spores of the fungus would germinate, as no such information was available earlier.

Two temperatures, 25°C and 30°C, and six relative humidities were maintained. The results are summarised in Table 11.

The germination percentages obtained under the conditions of these tests were relatively low. This is frequently true in powdery mildew germination tests (42).

With one exception, the average germination of 2,000 conidia was always below 30%. The highest germination percentage was 57.6% at 33% R.H. and 30°C. and the lowest 0.9% at 0% R.H. and 30°C. It is obvious that germination is significantly depressed at high and low values of relative humidity. Nevertheless, some conidia undoubtedly do germinate at 0% R.H. as well as in a saturated atmosphere.

Germination at 25°C was more uniform over a wider range of relative humidity. Differences between germination percentages obtained at 33.0%, 52.9%, 75.3%, 90.2% and 100.0% relative humidity and 25°C were not statistically significant. On the contrary, germination at 30°C gave a peak at 33.0% relative humidity. This value (57.6% germination) differs significantly at 1% level from all the other values obtained at this temperature.

High temperature and low relative humidity therefore seem to favor germination. It was mentioned earlier (p. 19) that the fast spread of the disease in the field during late June, July and August was due to favorable conditions of temperature and humidity. The results presented here substantiate this view. The outdoor temperature and relative humidity values for July and August 1963

(see Table 1) are best, within the range found favorable for the germination of conidia. August had the highest mean air temperature (23.5°C) and lowest relative humidity (53.1% R.H.) of the year, followed very closely by July (22.0°C and 59.0% R.H. respectively). However, the subject deserves a more critical approach and future work should be directed toward investigations on spore germination under a wider range of temperature and humidity conditions.

Table 11: Effect of temperature and relative humidity on the germination of beet powdery mildew conidia Erysiphe betae (Van.) Welt.

Salt	gr/1000 gr of water	% R.H.	Germination % at 25°C	Germination % at 30°C
P_2O_5	pure	0.0	3.7*	0.9
$MgCl_2 6H_2O$	52.8	33.0	17.8	57.6
$Mg(NO_3)_2 6H_2O$	223.0	52.9	20.3	28.0
NaCl	35.7	75.3	25.9	23.6
$BaCl_2$	39.3	90.2	26.1	15.6
Dist. water	-	100.0	13.7	17.4
L.S.D. at	5% level		15.0	17.6
at	1% level		-	24.0

* Each number represents the average of 2,000 measurements

CONCLUSIONS

The results obtained so far indicate beyond doubt that powdery mildew is a serious disease for the sugar beet crops grown in Lebanon. Climatic and soil conditions, as specified by Hughes et.al. (23), are optimum for sugar beet production in the Beqaa plain. The low yields, 3-4 tons/dunum, obtained by sugar beet growers in the area then have to be attributed to disease problems and poor cultural practices.

As far as diseases are concerned, it has been reported by Weltzien (41) that powdery mildew is the most common and widespread disease of sugar beets, while other diseases occur only sporadically and are unimportant under the Beqaa conditions. Therefore, attention has to be focused on this particular disease. The significant increases in yield of sugar reported here (Table 5) indicate that chemical control is necessary for high yields. Spraying schedules should start immediately after the disease appears in the field.

It has been pointed out that the disease does not affect the seed yield. In spite of this fact, occasional spraying with fungicides should be justified to check the unlimited development and sporulation of the fungus. If the plants to be grown for seed are left

entirely unsprayed, they will become a source of infection for nearby plants grown for sugar production. For this reason, growing plants for seed and sugar production in the same area should be limited.

The considerable attention that the disease has received during the last few years is an indication that it is becoming increasingly important. The fact that it has been reported from many areas as a new disease on sugar beets only recently suggests that it is spreading steadily. It seems that semi-arid and arid areas, where sugar beet production has been attempted recently, are the most favorable environment for the pathogen. This is also supported by the preliminary spore germination tests.

The role of the wild Beta species in the manifestation and spread of the disease must also be emphasised. The results presented here showed that the pathogen is able to attack at least six other Beta species, besides the cultivated beet, Beta vulgaris L., and it is very likely that it attacks many others as well. So, the host range is considerably wide, among the wild species which undoubtedly play an important role in the survival and spread of the pathogen.

Though in the present study no resistant plants were found, it is very probable that resistant plants do occur. Zhukova (47) reported 4 varieties highly resistant

in the South Ukraine region. Also species of the Patellares group (Section IV) were found to be good sources of resistance (12).

The subject of resistance has to receive serious attention. Work needs to be done in selection among both cultivated varieties and wild species since the availability of a source of resistance is a prerequisite for a successful breeding program (33). As long as no resistant varieties are available, suitable spraying programs can be designed to control the disease and secure high sugar yields.

SUMMARY

Two experiments were conducted simultaneously at the A.U.B. Agricultural Research and Education Center in the Beqaa, Lebanon, in 1962-1963 to determine the effect of the powdery mildew disease on the sugar beet seed production. The first experiment included trials with Karathane, Sulfur and Poly-kil. The second was designed to test 3 different spraying schedules. In both experiments the development of the disease on both, treated and untreated plots, was followed by bi-weekly observations.

The disease was first observed in the field as early as April 5 on 8% of the plants. Then it increased steadily and reached 99% on July 12. Cleistothecia were abundant on the lower leaves of infected plants, especially in the later part of the season.

The 3 fungicides tested were equally effective. After May 31 the disease on all treated plots was insignificant (Fig. 1). The disease did not affect the yield of sugar beet seed. The germination percentage, the weight of 1000 seed balls and the number of seedlings per 200 seed balls were also unaffected.

The first two spraying schedules, started on

December 4, 1962 and April 5, 1963 respectively, equally controlled the disease (Fig. 2). The third, started on June 7, was significantly inferior.

A third experiment included trials with Karathane, Sulfur, Coprantol, Morestan and Phaltan and it was designed to determine the effect of the disease on sugar production. The disease spread rapidly in July and August and infection was 97.5% in early October. Cleistothecia were abundant on all infected plants.

The size and yield of roots, tops and sugar were significantly reduced, but the sugar percentage and the dry matter content of the foliage were not affected. In this experiment, yields as high as 9769 kgs/dunum of roots (Sulfur treatment), 4256 kgs/dunum of tops (Sulfur treatment) and 1608 kgs/dunum of sugar (Karathane treatment) were obtained (Table 4). The lowest yields in untreated plots (controls) were 7786 kgs/dunum of roots, 2781 kgs/dunum of tops and 1253 kgs/dunum of sugar. Percent sugar in roots was 16.28 (average of all treatments).

Sulfur and Karathane were the most satisfactory fungicides followed by Morestan. Coprantol caused phytotoxicity while Phaltan was significantly inferior to the first three.

Tests for varietal resistance under field conditions were conducted in 1963. 8 Beta species, 21 sugar

beet varieties, 5 garden beet varieties, 4 swisschards, 3 Chenopodiaceae (3 spinach varieties and 2 weeds) one Amaranthus and one Polygonum species were exposed to spontaneous infection and their reaction to the disease was observed (Tables 6 and 7).

All the Beta species and varieties tested were found to be susceptible. Some degree of resistance was observed however on all garden beet varieties tested and also on Beta maritima L. plants from Dizon, France, Beta vulgaris L. from Kew, England, Beta vulgaris L. from Halle, E. Germany, Beta rapa L. and Beta vulgaris L. var. cicla, both from Dijon, France. No infection was observed on any of the other Chenopodiaceae, Amaranthus and Polygonum species.

The same plants were also grown in the green house and infected artifically. 4 to 5 weeks were required for complete infection (100%), following artificial inoculation. Unlike in field trials, all the Beta species and varieties tested in the green house were found to be completely susceptible. Infection reached always 100% and no particular reaction was visible. Mycelium and cleistothecia grew profusely.

Preliminary spore germination tests indicated that conidia germination was favored by relatively high tempera-

ture and low relative humidity. In general, germination was low but always possible within the entire relative humidity range from 0% to 100%.

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