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Title: USE OF PETROLEUM OILS TO PREVENT SPREAD OF STYLET-BORNE VIRUSES BY APHIDS

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The use of petroleum oil prevented, to varying degrees, the transmission of three stylet-borne viruses in three different crops. The use of oils resulted in a marked improvement in the number of lily bulbs harvested from treated plots as compared to the number of lily bulbs harvested from untreated plots. A random sample of the harvested bulbs forced in the greenhouse showed that substantially more bulbs germinated from treated plots than from untreated plots. Lily virus symptoms were prevented in 13% of the plants in treated plots. All untreated plants were infected. However, this relatively small difference was probably due to the use of too many infector plants. Treated lilies showed more stunting and mottling than did the untreated lilies.

The influences of oil sprays on the transmission of bean yellow mosaic virus in beans were studied in 1967 and 1968. Virus

symptoms in 1967 were shown to vary significantly with planting dates. The early planting had a greater incidence of plants showing virus symptoms than did the later planting. Oil sprays reduced virus symptoms by 20.9% in the early planting and by 40.7% in the later planting. Oil sprays reduced BYMV symptoms from 10-30% in 1968, depending on the treatment. However, the statistical significance of these treatment effects was questionable.

The spread of BYMV in 1968 was strongly correlated with the daily number of aphids trapped at two widely separated trap locations. These correlations were improved when the number of aphids trapped were adjusted for the possible effects of the oil sprays. The implications of the correlations were threefold. First, the direct relationship between virus symptoms and aphid numbers suggested that the timing of sprays to periods of high aphid migrations could improve virus prevention. Second, the prevention of virus spread could be improved by the application of oil during periods when one or more aphid species particularly efficient in virus transmission are migrating. Third, the value of oil could be improved by the maintenance of a highly efficient oil residue for longer periods of time.

Oil sprays reduced white-break virus (cucumber mosaic virus) symptoms in gladiolus from 9.5% to 3.1% in the field. However, similar results were not obtained when sample corms from the field plots were forced in the greenhouse.

Use of Petroleum Oils to Prevent Spread of Stylet-Borne Viruses by Aphids

by

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USE OF PETROLEUM OILS TO PREVENT SPREAD OF STYLET-BORNE VIRUSES BY APHIDS

INTRODUCTION

Petroleum oils have been used to control insects and mites since 1880 (Chapman, 1967). In addition, various types of oils have been utilized for the control of some plant diseases (Calpouzos, 1967) and weeds (Crafts and Reiber, 1952).

The discovery about seven years ago that oils could interfere with aphid transmission of virus prompted research into the specific viruses and transmission mechanisms subject to this phenomenon, types of oils effective in virus prevention, the mechanisms involved in the inhibitory effects of oils on virus transfer, and the overall effects of oils on the yields of specific crops. However, very little attention has been given to factors that may have influenced variations in the extent of the protection afforded by oil. In view of this deficiency, it is the purpose of this paper to describe the effects of oil sprays on the transmission of stylet-borne viruses by aphids in the field and to suggest means by which prevention of stylet-borne virus transmission by oils could be improved.

REVIEW OF LITERATURE

The use of oil for the prevention of stylet-borne virus transmission was suggested when Bradley (1956) discovered that transmission of potato virus Y (PVY) was greatly reduced if aphids probed through a low-melting paraffin wax. Additional research (Bradley, Wade and Wood, 1962) showed that virus inhibition was a product of the oil in the wax and not of the wax itself. Furthermore, it was found that other oils produced similar results. The following year Bradley (1963), working with a light white paraffin oil, found that PVY transmission by Myzus persicae (Sulzer) could be reduced in any one of several ways: (1) by coating with oil the leaf on which an aphid feeds; (2) by manually touching the aphid labium to an oil coated leaf; or (3) by placing the exposed stylets directly into oil. Bradley found also that oils impeded either the uptake or the inoculation of the virus or both, although not to the same degree. Oil did not interfere with the probing and feeding behavior of the aphids, a fact later substantiated by Vanderveken and Vilain (1967).

Hein (1964) demonstrated that dried whole milk protected against the transmission of lettuce mosaic virus (LMV) by M. persicae. Milk reduced infection equally well if either the test plant, the source plant, or both the test and source plants were sprayed. The following year Hein (1965) showed that skim milk did not protect against LMV

as did whole milk. She concluded that milk fat was the effective ingredient. Furthermore, both corn and mineral oil emulsions reduced transmission of celery mosaic virus, in addition to LMV. Jaeger (1966) found that 1-3% emulsions of milk or peanut oil effectively inhibited LMV transmission by M. persicae in the greenhouse and reduced LMV incidence in the field.

Loebenstein, Alper and Deutsch (1964) discovered that a 1% oil emulsion was capable of reducing cucumber mosaic virus (CMV) transmission by Aphis gossypii Glov. However, unlike Hein (1964), these workers found that while spraying the source plant was more effective than spraying the test plant, spraying both source and test plants produced the best results. They found that the number of local lesions produced by mechanical transmission of tobacco mosaic virus (TMV) and CMV was greatly reduced when combined with oil. However, they found that TMV could be separated from an oil-TMV emulsion by ultracentrifugation. This led them to conclude that the oil did not inactivate the virus directly. Hein (1966), while supporting this conclusion, found that oils did not affect mechanical transmission.

Allen (1965) was the first worker to test the effect of oils in the field. He found that paraffin oil applied to potatoes reduced the spread of potato virus A by 50% the first year and 30% the second year. Bradley, Moore and Pond (1966), also working in the field, found that three sprays of oil applied at weekly intervals gave

approximately the same control of PVY as six weekly oil sprays. In addition, Bradley and his co-workers found that the potato yields were reduced with the six applications but not with the three applications of oil. Nitzany (1966) found that oils applied every six days significantly reduced incidence of PVY in pepper without reducing yields. Loebenstein, Deutsch, Frankel and Sabar (1966), working with CMV in cucumber in the field, showed that spraying with oil always reduced virus infection, but yield was only increased in two of six experiments. The effect of oil lasted from five to seven days and low-volume spraying gave better control of virus than conventional high-volume spraying. Pond (1966) found that the effects of oil sprays on potato yield varied considerably among the varieties tested. However, if the four-gallon per acre application rate was doubled, drastic reductions in yields were noted. The use of emulsified oil produced higher yields than did the use of non-emulsified oils. However, these results were reversed when the number of applications was reduced from six to three. Deutsch and Loebenstein (1967) found that 20 weekly sprays of 5-10% oil emulsions greatly reduced the spread of iris yellow mosaic virus in iris. However, yield was also drastically reduced.

Vanderveken, Bourge and Semal (1966) were the first to show that oil could also inhibit the transmission of a semi-persistent virus, beet yellows virus (BYV), by M. persicae. In addition, they found

that bean common mosaic virus was not affected by oil sprays, a fact not supported by Vanderveken and Vilain (1967). In a follow-up paper Vanderveken and Semal (1966) showed that a 2% paraffin oil gave better inhibition of BYV with four to five aphids (M. persicae) than with 10-12 aphids per plant.

Vanderveken and Vilain (1967) reviewed several hypotheses proposed to explain the mechanism by which oil inhibits virus transmission.

Crane and Calpouzos (1967) found that oil delayed symptom expression of virus yellows of sugar beets from 30 to 60 days after symptoms developed in the controls. This led them to conclude that virus transmission was not prevented by an oil coat on the probed leaf surface.

Vanderveken (1968) compared the effects of mineral oils, lipids, silicone oils (synthetic oils) and terpineol (an essential oil) on aphid transmission of beet mosaic virus (BMV), a non-persistent virus, and BYV, a semi-persistent virus. He found that BMV transmission was strongly inhibited by mineral oil, corn oil and whole milk and that BYV transmission was only inhibited by mineral oil. Terpineol, silicone oils and skim milk had little effect on the transmission of either BMV or BYV.

Vanderveken, Semal and Vanderwalle (1968) reviewed the general state of knowledge concerning the application of oils to control plant viruses.

OIL SPRAYS FOR THE PREVENTION OF VIRUS SPREAD IN LILIES

Materials and Methods

The 1967 lily experiment was conducted on field 1378 at the Grant Farm of the Oregon Bulb Farms, Gresham, Oregon. The test lilies were planted on October 25, 1966, in soil previously fumigated with Telone (Dow Chemical Company) at 35 gallons per acre.

Each of four north-south rows were divided into four 25-foot subdivisions. Each east-west group of four subdivisions comprised a plot. The first and third plots from the south end were sprayed with oil while the second and fourth plots were left as unsprayed controls. The subdivisions were each planted with 20 four to five inch infected bulbs of the hybrid Enchantment and 80 Lilium formosanum bulbs, a species quite susceptible to a virus which is apparently universally present in Enchantment. Every fifth bulb in each subdivision was Enchantment, to act as a source of virus.

All treated plots were sprayed with VOLCK Supreme Oil (see Appendix) using a three-gallon compressed-air hand sprayer. The oil was applied as an emulsion in water. The first spray, a 1/2% emulsion, was applied on April 28. Nine subsequent oil sprays were applied at approximately weekly intervals and consisted of 1, 2, 3, 4, 4, 2, 2, 2 and 2% concentrations. The last spray was applied on June 30.

The consecutive increases in oil concentrations for the first six sprays were undertaken to determine the relationship of concentration to phytotoxicity. The reversion to 2% concentrations for the last four sprays was due to the poor adherence of Bordeaux mixture to plants that had already been sprayed with a 4% oil emulsion.

The Formosanum lily bulbs were harvested and a random sample of 25 bulbs per subdivision were sent to Oregon State University in November, 1967 for vernalization and subsequent forcing. Some subdivisions did not yield the necessary 25 bulbs so the sample size of these subdivisions consisted of all the bulbs harvested. All bulbs were placed in a cold room at 40° F on November 20. The bulbs were packed in aerated cellophane bags containing moist wood shavings.

The bulbs were removed from cold storage and planted in six-inch clay pots containing a mixture of sphagnum moss, soil and perlite in a 1:1:1 ratio. The bulbs were planted at intervals from December 27 to February 18. I followed the suggestions of Kiplinger and Langhans (1967) for general bulb care.

The incidence of virus was recorded after several leaves had expanded.[1] Plants were classified as being either symptomless, mottled, or both mottled and distorted. The latter condition was

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[1]The results of the virus evaluation for this experiment and all other virus experiments in this paper were based on visual observations of virus symptoms. Hence, they were only indicative of the actual virus incidence.

labeled as distorted. Results were evaluated as percentages of the number of bulbs forced. An analysis of the number of bulbs harvested from check and treated subdivisions was also undertaken.

Results

The average number of bulbs harvested for the oil treatment (40 bulbs per subdivision) was much greater than the average number of bulbs collected from the untreated control (27. 5 bulbs per subdivision). This difference proved to be highly significant ($P < 0.01$).

Forcing trials in the greenhouse were hindered by the early planting of bulbs from one untreated plot. A large percentage of these bulbs failed to germinate as a result of inadequate vernalization. It was, therefore, decided not to include this plot in symptom evaluation. In order to improve comparison between the remaining untreated plot and the two treated plots, the treated plots were maintained as two groups and compared with the untreated plot. This comparison is summarized in Table 1.

It should be noted that no symptomless plants were found in the controls while the treated subdivisions yielded between 12 and 14% symptomless plants. It is also interesting to note that a greater percentage of stunted and mottled plants were found in the oil treated lilies. However, the percentage of dead plants was considerably larger in the control than in the treated groups.

Table 1. Comparison of the numbers of greenhouse-forced plants showing virus symptoms from two treated and one untreated lily plots.

		Symptomless	Stunted	Mottled	Failed to germinate
Oil	Number of lilies	12	24	33	17
	Percent	14.0%	27.9%	38.4%	19.8%
Control	Number of lilies	0	12	12	62
	Percent	0.0%	14.0%	14.0%	72.1%
Oil	Number of lilies	11	18	32	31
	Percent	12.0%	19.6%	34.8%	33.7%

Discussion and Conclusions

The effectiveness of oil sprays in the prevention of virus infection is indicated by the marked improvement in the number of bulbs harvested, by the better germination of the harvested bulbs, and by the percent of healthy plants found in the treated plots as compared to the untreated plots. However, the treated lilies had a greater incidence of stunting and mottling than did the control lilies (Table 1). This apparent inconsistency can be explained if one notes that, of the bulbs harvested, more bulbs from the oil-treated plots germinated than did the bulbs from the untreated plots (Table 1). The increased severity may well have been due to the earlier infections of unprotected plants. The earlier the infection, the greater the damage to the plant, damage which may result in death. Lilies infected later in

the season are not subjected to this long pathogenic period. Therefore the symptoms manifested during forcing trials in the greenhouse were in proportion to the virus severity. This suggests that early protection is of the utmost importance but that later protection cannot be overlooked if one wishes to gain maximum protection.

It is probable that oil afforded the lily plants better protection from virus than is indicated by the data. The exposure of the lily plants to a high virus level, due to the planting of too many Enchantment virus source-plants, produced a high virus incidence in all plots. Since oil is not 100% effective in virus control, one must expect the numbers of infections in treated plots to approach the numbers infected in untreated plots with time. That is, a randomly feeding aphid would have a greater chance of alighting on a healthy plant in a lightly infected plot than in a heavily infected plot.

Visual observations suggested that both Enchantment and Formosanum are quite tolerant of weekly oil sprays of 1/2 to 4% concentrations. However, the higher concentrations did inhibit adherence of Bordeaux mixture to the foliage. This was somewhat alleviated by the use of a 2% concentration.

In conclusion, it seems certain that oils do protect lily plants from virus infection. It, likewise, is evident that in order to receive maximum protection sprays must be continued into the summer. If this oil material were mixed with Bordeaux mixture in compatible

concentrations and applied according to the normal Bordeaux spray schedule, the use of oil could become economically practical. The improved bulb harvest and germination may well be worth the additional cost.

OIL SPRAYS FOR THE PREVENTION OF WHITE-BREAK (CMV)[2] IN GLADIOLUS

Materials and Methods

Three east-west rows of gladioli were planted on April 28, 1967 at the Oregon State University Vegetable Crops Farm. The outer two rows were planted with 1 1/4-1 1/2 inch diameter corms of mixed varieties obtained through Week's Gladiolus Farm, Salem, Oregon. The corms were raised at Grants Pass, Oregon where CMV is not a problem. It is, therefore, assumed that these bulbs had a low CMV incidence. The corms were planted six inches apart. The center row consisted of CMV-infected gladioli corms which were to act as a source of virus. The individual virus-free rows were divided into eight 30-foot subdivisions, each separated by three feet. Each north-south group of two subdivisions comprised a plot. The first, third, fifth and seventh plots from the east end were left as unsprayed controls while the second, fourth, sixth and eighth plots were sprayed with oil. The infectious center row was not sprayed.

All treated plots were sprayed with VOLCK Supreme Oil using a three-gallon compressed-air hand sprayer. The oil was applied as an emulsion in water. The first spray, a 1/2% oil concentration, was applied on May 18 when the gladioli were approximately four inches

[2]Cucumber mosaic virus.

high. Seven additional sprays were applied at weekly intervals with the last spray occurring on June 7. The spray concentrations were 1, 2, 2, 2, 2, 1 and 2%, respectively.

Virus evaluation in the field began on July 21 when all opened flowers were cut and examined for typical white-break symptoms (Figure 1). The numbers infected were recorded and calculated as a percent of the total number of flowers in a plot. Similar counts were made on July 21 and 27; August 3, 10, 16, 24, and 30; and September 6, 13, 20 and 28. These percentages then were transformed into degrees using the angular transformation (Fisher and Yates, 1963) for further analysis.

On October 28 the gladiolus were dug. The leafy portions were cut and the corms were set out in a warm greenhouse (80° F) to dry. After two weeks they were transferred to a cool, relatively dry room where they were kept until they were forced.

Fifty medium sized bulbs were selected from each plot and planted in a 1:1 soil to sand mixture. Planting began on March 27 and continued at intervals to April 9, 1968. The number of flowers showing white-break symptoms for each plot were recorded. Percentages were calculated on the basis of the total number of plants that flowered. In addition, data was taken on the number of plants showing mild mottle, severe mottle, mild speckle and severe speckle symptoms. Those not showing the above symptoms and having

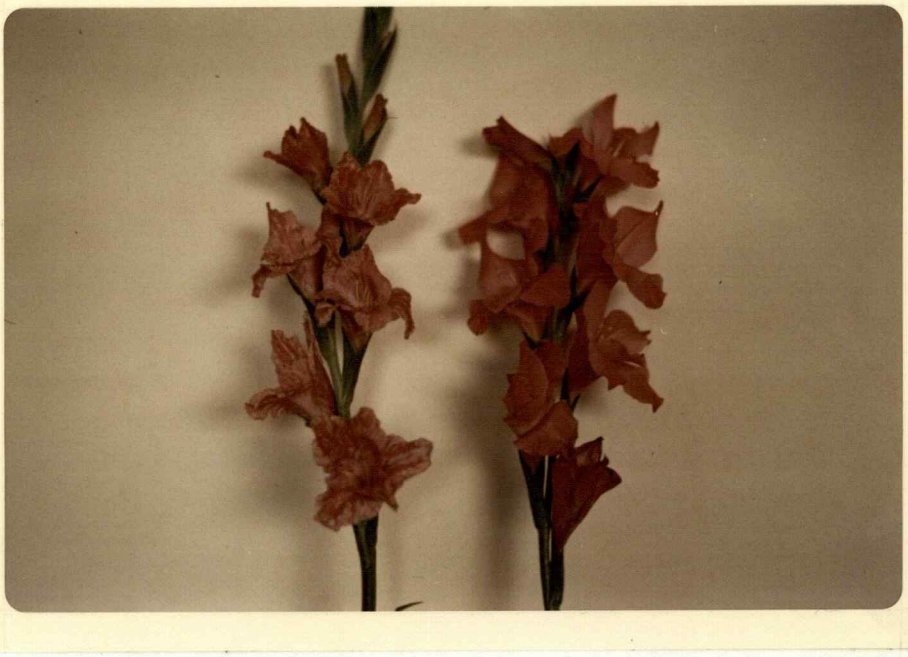

Figure 1. Gladiolus infected with white-break virus (CMV).

Left: white-break symptoms
Right: normal flower

flowers without white-break were listed as symptomless. Mottle, speckle, and white-break all could occur in the same plant.

In order to prevent the recording of data twice from any plant, each plant was discarded after the evaluation was made. The percentages were transformed to degrees using the angular transformation for further analysis.

Results

An analysis of variance of the field results showed that the control plants had significantly more white-break than did the oil-treated plants ($P < 0.05$). The oil-treated plants had 3.1% incidence of white-break while the control plants had an incidence of 9.5% (Table 2a). However, similar results were not obtained when the gladioli were greenhouse-forced (Table 2b). The control groups had a white-break incidence of 9.4% while the oil groups had an 11.3% incidence. Analysis of variance showed that this difference was not significant.

Analysis of variance for the additional data indicated that significantly ($P < 0.05$) more symptomless plants were found in the treated plots while significantly ($P < 0.05$) more plants showing severe speckle symptoms were found in the untreated plots. The differences between control and oil treatment were not significant for mild mottle, severe mottle and mild speckle symptoms (Table 3). Significant correlations between any of the above symptoms and the

Table 2. Effects of oil sprays on white-break in gladiolus.

Tmt. #1 (Oil)			Tmt. #2 (Control)		
Plots	Number of flowers with white-break/total	Percent	Plots	Number of flowers with white-break/total	Percent
		a. Field trial			
2	5/119	4.2	1	10/98	10.2
4	4/111	3.6	3	17/118	14.4
6	0/109	0.0	5	10/111	9.0
8	5/114	4.4	7	5/117	4.3
Total	14/453	3.1		42/444	9.5
		b. Field trial corms after greenhouse forcing			
2	2/39	5.1	1	2/37	5.4
4	4/34	11.8	3	5/45	11.1
6	7/36	19.4	5	4/33	12.1
8	3/33	9.1	7	3/34	8.8
Total	16/142	11.3		14/149	9.4

Table 3. Virus symptom expression in field trial corms after greenhouse forcing.

Symptom	Tmt. #1 (Oil) Percent of total	Tmt. #2 (Control) Percent of total	Significance
Symptomless	50.7	33.6	*
Mild mottle	60.6	71.1	N. S.
Severe mottle	3.5	6.7	N. S.
Mild speckle	2.1	5.4	N. S.
Severe speckle	1.4	6.7	*

* = Significant at 95% level.

N. S. = Not significant at 95% level.

incidence of white-break were not found.

Discussion and Conclusions

Assuming that the virus evaluation technique was consistent in both the field and greenhouse, an explanation for the discrepancy in white-break incidence cannot be given with certainty. Therefore, the following explanations are speculative in nature.

If one assumes that the field evaluations were accurate than it must be concluded that an increase occurred in recorded virus incidence between the field and greenhouse evaluations. The possibility exists that flower cutting and corm harvesting may have mechanically transmitted the CMV (Brierley, 1962). However, if this were true, why was there not an equivalent increase in the untreated plots, especially if virus incidence was indeed greater at the time of the field count? In fact, this very question continually arises. For example, if one supposes that the increase was due to an influx of aphids after the oil sprays were discontinued, it must again be asked why there was not a corresponding increase in the control. It also is possible that the virus was present but symptoms were not visible until the corms were forced in the greenhouse. Again the same question arises. It should be noted that unlike the first two explanations, this last explanation necessitates a failure of oils to control CMV spread.

Since significant differences were found for the field evaluation, I feel that one of two possible sets of circumstances could account for the results. The first case is based on the premise that the oils did not have any effect on virus infection, but delayed symptom expression. Although Crane and Calpouzos (1967) showed that oil delayed the development of virus yellows (a semi-persistent virus) symptoms on sugar beets in the greenhouse from 30-60 days, other work has not indicated the presence of this phenomenon for non-persistent viruses (Bradley, 1963; Vanderveken, Bourge and Semal, 1966; Vanderveken and Vilain, 1967).

The second possibility is based on the premise that there was an equivalent virus increase in the two treatments after spraying was discontinued. This would have been caused by an aphid influx after spraying was discontinued or by mechanical transmission of the virus in flower cutting and corm harvesting, or both. However, there would have had to have been a disproportionate virus increase in the treated plots. A likely explanation is that severely infected plants were overlooked and left in the field because of stunting (Brierley and Smith, 1962). The treated plots were not as severely infected as the untreated plots, thus permitting the harvest of the majority of corms planted. In this way the harvested corms from oil sprayed plots would have contained more virus-infected corms than the untreated plots.

The fact that the oil treatment had a greater percentage of symptomless plants and a smaller percentage of plants displaying severe speckle symptoms (Table 3) suggests to me that the oil was indeed protecting the plants against virus infection. In addition, other cases in which oil protected against CMV infection (Loebenstein, Alper and Deutsch, 1964; Loebenstein, Deutsch, Frankel and Sabar, 1966) lead me to conclude that the last explanation is most plausible.

APHID TRAPPING - 1968

Materials and Methods

A Johnson-Taylor Insect Suction Trap (Burkard Manufacturing Company Limited, Rickmansworth, Hertfordshire, England) was set up at the Oregon State University Entomology Farm, Corvallis, Oregon. The trap was situated in an open-grass area having rectangular dimensions of approximately 100 feet in width by 200 feet in length. The 200-foot sides were adjacent to cultivated parcels while the 100-foot sides were adjacent to a sheep grazing field on the east and a group of wooden garages on the west. The trap was 20 feet from the garages in relation to the length but centrally located in relation to the width. The grass was cut twice during the summer between which it grew freely to a height of four feet.

The trap was in operation 24 hours a day from June 8 through October 28 regardless of weather conditions. Collections were made daily between the hours of 7:00 a. m. and 9:00 a. m. The usual collection time was 8:00 a. m.

The number of aphids collected per day was recorded and the specimens were stored in 70% ethanol for future reference. Only winged aphids were counted and stored. No attempt was made to identify the aphids. These records were used in conjunction with the results of the 1968 Bean Experiment for a correlation analysis.

An identical trap was located at the Knieling Farm, Salem, Oregon. Collections were handled in the same manner as those from the Corvallis trap. Trapping began on May 1 and continued through September 10, 1968. A correlation analysis involving these records and the 1968 Bean Experiment was also undertaken.

Results

A graphic representation of the aphid collection data for the Corvallis and Salem trap locations can be found in Figures 2 and 3, respectively. The specific daily figures have been used in conjunction with the 1968 bean virus incidence as part of a correlation analysis.

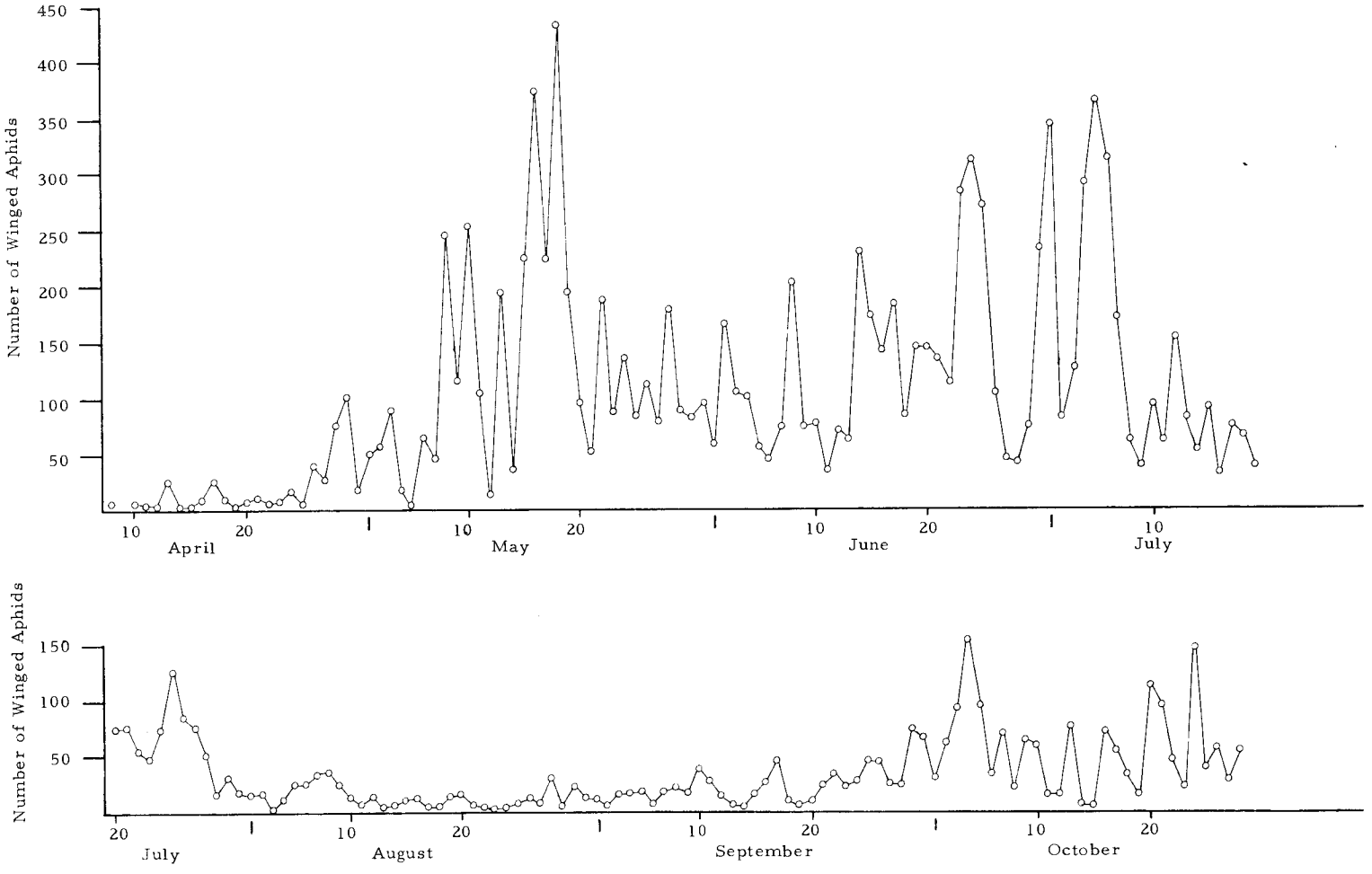

Figure 2. Numbers of winged aphids collected in a Johnson-Taylor Suction Trap at Corvallis, Oregon.

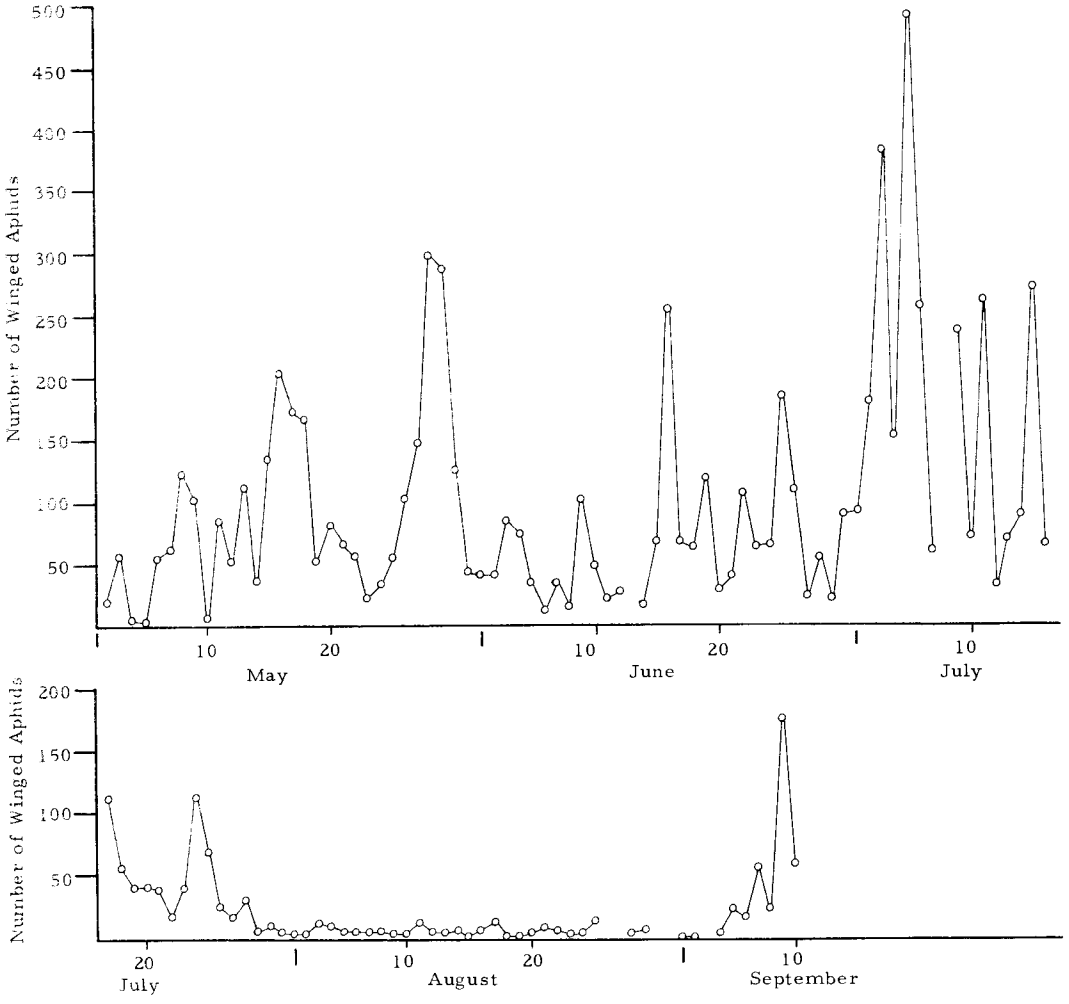

Figure 3. Numbers of winged aphids collected in a Johnson-Taylor Suction Trap at Salem, Oregon. Unconnected points reflect the absence of one or more counts between the unconnected points.

INFLUENCE OF OIL APPLICATIONS ON APHID TRANSMISSION OF BEAN YELLOW MOSAIC VIRUS (BYMV)

Materials and Methods

An attempt was made to develop correlations between the number of alate aphids trapped at Salem and Corvallis (see Aphid Trapping section, p. 20) with the spread of bean yellow mosaic virus in the 1968 Bean Experiment (p. 38).

Virus values were figured from the five treatments for each of five count dates.[3] The net virus increase was determined by subtracting the virus incidence for one count date from the virus incidence for the previous count date. For example, if a count yielded 64 plants with BYMV symptoms and the previous count had a virus incidence of 40, then the net increase would be 64 minus 40 = 24.

Hampton (1967) found that BYMV symptoms were delayed an average of three weeks from the time of inoculation. Therefore, it was necessary to figure back three weeks from the count date to determine the last day that aphid flights theoretically could have influenced this virus incidence. Since each count represents the cumulative increase of virus between counts, one, in determining the period of influence, would have to allow for the three week symptom delay

[3]The count dates were June 25, July 2, 9, and 16 and August 15. The August 8 count was excluded for the reasons described in the results of the 1968 Bean Experiment.

plus the number of days between the counts. In other words, if a specific count (i. e., Count II) occurs seven days after the previous count (i. e., Count I), then the period of greatest influence should fall between three and four weeks prior to that count (Count II).

Based on the above considerations a correlation analysis was performed involving the net virus increases for the untreated controls and the number of aphids trapped during the proper influencing periods. This was done for both the Salem and Corvallis trap collections. Strong correlations between the number of aphids caught and the net virus increases for the controls suggested that the aphids trapped during the influencing periods were representative of the actual viruliferous aphid population. Hence, the oil sprays could be considered as rendering a portion of this viruliferous aphid population ineffective. It was necessary to give the oil sprays daily efficiency ratings due to a reduction of the oil film with time (Riehl, Wedding and Rodriguez, 1958; Rohrbaugh, 1934; Riehl, 1967). The ratings were developed for a seven day period based on the evidence of Loebenstein, Deutsch, Frankel and Sabar (1966) that the effects of oils could last seven days and on the oil coverage studies found in the Appendix. Oil coverage studies (see Appendix) suggested that the sprays might be 95% effective on day I of spraying. Based generally on the figures of Riehl, Wedding and Rodriguez (1958) for loss of oil residues and on personal experimentation, the daily efficiency figures

for the remaining days were evolved: day II, 57%; day III, 21%; day IV, 15%; day V, 5%; day VI, 3%; and day VII, 1%. In short then, 95% of those aphids trapped on day I for a particular spray, 57% on day II, 21% on day III, etc. were eliminated from the correlation analyses for the oil treatments two through five. The resulting correlations were satisfactory except for the period from June 12 through June 18 when relatively low aphid numbers corresponded to a relatively high virus incidence for the July 2 count. It is possible that this represents a period of high bean susceptibility or a period during which a highly infectious aphid population was dispersing, or both.

Results

The results of the correlation analyses from both the Salem and Corvallis traps are summarized in Table 4a and b. The two tables show excellent agreement in most aspects.

Discussion and Conclusions

It should be noted that the entire correlation model was developed using only the Corvallis trap figures. Once developed, the model was used to analyze correlations between the Salem trap collection figures and the virus incidence in the 1968 Bean Experiment. General agreement was found at all levels for the correlations developed from the two trap locations. However, any differences

Table 4. Correlations of aphid numbers to virus incidence.

Date	Treatments[2] (time of initial application--interval between sprays)									
	1 (control)		2 (emergence--7 days)		3 (emergence--10 days)		4 (delay--7 days)		5 (delay + 1 week--10 days)	
	Aphid totals[3]	Net virus increase[4]	Aphid totals	Net virus increase	Aphid totals	Net virus increase	Aphid totals	Net virus increase	Aphid totals	Net virus increase
					a. Corvallis trap[1]					
May 31 - June 11	1096	20	1096	22	1096	20	1096	20	1096	34
June 12 - June 18	951	20	870	30	951	19	870	26	951	27
June 19 - June 25	1414	24	998	7	961	7	998	24	1156	25
June 26 - July 2	930	17	761	15	894	18	761	15	761	19
July 3 - August 1	2902	81	2452	40	2765	55	2690	38	2555	37
r[5]	.9879***		.7280		.9599***		.8882**		.7616	
					b. Salem trap[1]					
May 31 - June 11	576	20	576	22	576	20	576	20	576	34
June 12 - June 18	597	20	535	30	597	19	535	26	597	27
June 19 - June 25	624	24	356	7	452	7	356	24	445	25
June 26 - July 2	588	17	331	15	556	18	331	15	331	37
July 3 - August 1	3203	81	2369	40	2866	55	2859	38	2519	37
r	.9967***		.8090*		.9713***		.8873**		.7376	

1 = see Aphid Trapping, p. 20.

2 = as described in 1968 Bean Experiment, p. 38.

3 = number of aphids remaining after adjustment using daily efficiency figures (since oil sprays were not applied to the controls, control values are equivalent to total number of aphids trapped.

4 = difference in the virus incidence for one count date (occurring 2 weeks after last day of date period) and previous count date.

5 = correlation coefficient based on correlation between aphid totals and net virus increase.

* = significant at 90% level.

** = significant at 95% level.

*** = significant at 99% level.

evident are of little consequence when the distance separating the traps is considered (approximately 45 miles). In addition, the inclusion of the "daily oil efficiencies" improved all the correlation coefficients for the Salem trap and all but the Treatment 4 correlation coefficient for the Corvallis trap. The reason Treatment 4 did not conform is unknown. The amazing similarities in the correlations for these two widely-separated traps are evidence that the model is indeed valid.

The implications of the results are threefold. First, the work implies that the timing of sprays to periods of high aphid migrations would be more efficient in virus control than the applications of oils without regard to aphid dispersals since the oil sprays prevent virus spread through their effects on the virus transmission of aphid populations. The correlations I have developed and the work of Zettler (1967), which showed "that the proportional airborne winged aphid populations are relatively uniform over large areas," indicate that forecast systems could be developed with relative ease. The system could involve either weekly forecasts on a seasonal basis or the preparation of a fairly accurate dispersal schedule based on several years of trapping. In either case only a minimum number of traps would be needed to type an area of substantial size.

Second, the fact that the relatively high virus incidences for the July 2 count date consistently corresponded to low aphid numbers

during the June 12 through June 18 influencing period suggests that more is involved in virus transmission during this period than is implied by a direct relationship between aphid numbers and virus incidence. It is known that the relative abundance of different aphid species in an area varies with time (Zettler, 1967). Therefore, it is possible that a large proportion of the aphid population migrating during June 12 through June 18 was comprised of one or more aphid species that were particularly efficient as vectors of BYMV. Thus, virus inoculations for a given period may not be directly related to aphid numbers alone but may rather be a product of both the size and the transmission efficiency level of an aphid population. It then becomes obvious that the prevention of virus spread by oils could also be improved through the application of oil during periods when an aphid population is at a high transmission efficiency level.

Third, the rapid deterioration of spray efficiencies from 95 to 1% over a seven day period implies that the value of oil could be increased by the retention of a high efficiency rate for a longer period. The improved correlation coefficients obtained from the incorporation of daily spray efficiencies into the correlation analyses implies that more than 77% of the virus protection afforded by a single oil spray is due to the effects of day I and day II of spraying. The remaining five days represent less than 23% of the total virus protection afforded by this spray. The results of the 1967 Bean Experiment show

this very well. In the experiment the protection afforded the early planting was due to the effects of the first two days of a single spray and this protection was approximately half that obtained for the late planting from the seven-day influence of one spray and the one-day influence of a second spray. Hence, it is clear that an oil spray that could maintain a 95% efficiency for several days would be far superior in virus control to an oil spray which showed a rapid loss of spray efficiency.

The correlations, as based on symptom delay, net virus increase and aphid numbers and as effected by oil applications, explain to a considerable degree the influences of various factors involved in the prevention of stylet-borne virus spread. Furthermore, correlations such as this could be used in conjunction with other experimental techniques to understand, develop and apply these factors in an attempt to improve the use and economic feasibility of oil sprays in the prevention of stylet-borne virus spread by aphids.

OIL SPRAYS FOR PREVENTION OF BEAN YELLOW MOSAIC VIRUS (BYMV) SPREAD IN BEANS - 1967

Materials and Methods

Two 261-foot east-west rows of the bean Phaseolus vulgaris L., variety Blue Lake (Oregon State University seed lot 949) were planted on either side of three gladiolus rows at the Oregon State University Vegetable Crops Farm. The gladioli were a source of bean yellow mosaic virus (BYMV). The two outer rows were planted on May 27 while the two inner rows were planted on June 10. Each bean row was divided into eight 30-foot subdivisions each separated by three feet. Each north-south group of four subdivisions comprised a plot. The first, third, fifth and seventh plots from the east end were left as unsprayed controls while the second, fourth, sixth and eighth plots were sprayed with oil.

All the treated plots were sprayed with VOLCK Supreme Oil using a three-gallon compressed-air hand sprayer. The oil was applied as an emulsion in water. The May 27 planting received a total of five sprays beginning on June 9 and continuing at approximately weekly intervals through July 7. The initial spray was applied at a 1/2% concentration with the four subsequent sprays being applied at 1, 2, 2 and 4% concentrations, respectively. The June 10 planting, on the other hand, received three sprays commencing on June 23 with

a 2% spray concentration, a 1% spray on June 30 and finishing with a 2% spray on July 7.

Virus counts were taken on July 1 for the May 27 planting and on July 20 for the June 10 planting. Counts were completed by physically pulling up each plant and recording the presence or absence of typical BYMV symptoms (Zaumeyer and Thomas, 1957). The percentage of infection for each subdivision was calculated on the basis of the total number of plants for that subdivision. These percentages then were transformed to degrees using the angular transformation (Fisher and Yates, 1963). Analysis of variance and paired difference tests were used in evaluation of the data.

Results

Table 5 summarizes the results of the 1967 bean experiment. The effects of oil on both the early (May 27) and the late (June 10) plantings were highly significant ($P < 0.001$). Untreated subdivisions in the same plot that were planted on different dates were paired in order to test for significant differences in virus incidence for the different planting dates. This paired-observation analysis was repeated for the treated subdivisions. Highly significant differences ($P < 0.001$) were found between both untreated and treated pairs. However, the average difference in the virus incidence between treated and untreated plots for the May 27 planting (40.7%) was

significantly different ($P < 0.01$) than the average differences between treated and untreated plots for the June 10 planting (20.9%).

Visual observations indicated that there was virtually no phytotoxicity from any of the oil sprays.

Table 5. Summary of the effects of oil sprays for prevention of virus spread in beans - 1967.

Date	Treatments		Sign.	Percent of virus control	Sign.
	Control	Oil			
May 27	67.6_1%	53.4_1%	**	20.9%	*
June 10	51.2_1%	29.7_1%	**	40.7%	
Paired observations	24.3_2%**	44.4_2%**			

1 = percent of bean plants showing virus symptoms.
2 = difference in virus incidence for comparable plots planted on different dates.
* = significant at 99% level.
** = significant at 99.9% level.

Discussion and Conclusions

Results of this experiment clearly showed that oil sprays have indeed protected beans from BYMV infection. The results further indicated that virus infection varied significantly with planting dates. The early planting (May 27) had a greater virus incidence than did the later (June 10) planting. However, the effects of the oil were not proportionate for these two dates.

The virus counts for the early planting date indicated that the oil sprayed plots had an average of 20.9% fewer virus infected plants

than the untreated plots. On the other hand, the counts for the late planting date indicated that the oil sprayed plots had an average of 40. 7% fewer virus infected plants than the untreated plots. The statistically significant variation of these data suggested that the oil sprays were less effective in the early planting than in the late planting; if they had not been, the amount of virus control in the treated plots would have been similar for both plantings.

If one considers that symptom manifestation generally takes three weeks (Hampton, 1967), it becomes apparent that the July 1 virus count for the early planting was a measure of virus inoculation occurring prior to June 10. Since the June 9 1/2% spray was the only spray applied prior to June 10, it seems probable that this was the only spray responsible for producing the results attributed to oil in the July 1 virus count. Theoretically, the influence exerted by this spray on the virus incidence recorded for the July 1 count would have lasted only two days, June 9 and 10. Any protection afforded by the spray after these two days would not have become evident until after July 1 due to the three week symptom delay. However, the results of the correlations developed in the "Influence of Oil Applications on Aphid Transmission of BYMV" (page 24) suggest that 77% of the virus protection afforded by a single oil spray is due to the effects of day I and day II of spraying. It would, therefore, seem that the two day influence of the June 9 spray could have produced substantial

protection against virus inoculation. Likewise, the results of the July 20 virus count (late planting) would have been influenced by the June 23 and June 30 sprayings. In this case the results of correlations developed in the "Influence of Oil Applications on Aphid Transmission of BYMV" suggest that the June 23 spray would have exerted its maximum seven-day influence while the June 30 spray would have exerted only a one-day influence (when the effect of the spray would have been at a maximum).[4]

The difference in the amount of control produced by the oil sprays for the two dates could be attributed to four factors: (1) variation in spray concentration; (2) variation in the number of aphids flying during the protected periods; (3) variation in the transmitting efficiency of the aphids flying during the protected periods; and (4) variation in the length of time oils influenced virus incidence and in oil efficiency levels. It is possible that any one of these factors may have been the prime cause of the different influences of the sprays. However, it appears likely that this difference was due to a combination of these variants. The fact that the untreated plots in the later planting contained less virus than did untreated plots in the earlier planting suggests that more aphids were flying or the flying aphid population contained a greater percentage of individuals that

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[4]For further information on daily spray efficiencies see "Influence of Oil Applications on Aphid Transmission of BYMV, " page 24.

transmitted the virus (Swenson, 1968b) for the period during which virus was spread in the early planting (May 27-June 10), or both. Regardless of whether factor (2) or (3) or both were involved, it follows that an equivalent increase in protection would be necessary to counteract this potential increase in virus incidence. However, if anything, there was a decrease in protection due to the low oil concentration (1/2%). It is, therefore, likely that the sprays of higher concentrations (2% and 1%) applied to the late planting were more effective in controlling virus than those applied to the early planting. One might also consider that the difference in protection for the two planting dates may be due to a strong two-day influence in the early planting as opposed to a not so strong eight-day influence (the combination of a three-day strong influence plus a five-day weak influence).[5] It would seem that this factor and factors (1), (2) and (3) combined to produce the differential effects of the oil sprays. It is possible that plant susceptibility may have been a factor but this is unlikely since both of the initial sprays were applied 13 days after planting and the mean temperature of 75° F for the earlier planting was lower than the 85° F mean of the later planting. This indicates that, if anything, these early plants should have been less susceptible (Webb, 1956; Stimman and Swenson, 1967; Swenson, 1968a).

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[5] Ibid.

In conclusion, this experiment presented evidence that oils can protect beans from BYMV infection. Interpretation of the results suggest that a few sprays or even a few days of a single spray can give substantial protection against BYMV spread. That a 20-40% virus reduction can be realized from the limited effects of one to two sprays of relatively low concentrations suggests that oils hold tremendous potential for control of stylet-borne viruses. The differential effects of the individual sprays further suggest that virus protection might be enhanced by developing a spray program based on periods of peak aphid flights and by maintaining a high oil efficiency for longer periods.

OIL SPRAYS FOR PREVENTION OF BEAN YELLOW MOSAIC VIRUS (BYMV) SPREAD IN BEANS - 1968

Materials and Methods

The 1968 experiment, planted at the Oregon State University Vegetable Crops Farm, consisted of 11 east-west rows with a distance of 36 inches between each. Every third row was comprised of gladioli which were to act as a source of bean yellow mosaic virus (BYMV). A wooded area running parallel to the plot was located 100 feet to the south. The remaining three sides of the plot were adjacent to cultivated farm land.

Gladiolus corms of various varieties, all exceeding one inch in diameter, were planted in the three gladiolus rows. The remaining eight rows were planted with Blue Lake variety beans (Phaseolus vulgaris L.) from Oregon State University seed stock 949. The gladioli were all planted by hand on May 3, 1968. The eight rows of beans were planted on May 10.

Each bean row was a replicate. These replicates were numbered from one to eight in a south (closest to the woods) to north (adjacent to cultivated land) direction. Each replicate was divided into five 48 foot plots with two feet between each plot. Five treatments were randomly assigned to each of the first three replicates (1-3). The remaining five replicates (4-8) were assigned treatments

according to a 5 x 5 latin square design. (To prevent confusion, the "line" designation of the latin square refers to a line of plots running in a north-south direction. The five such "lines" were numbered from one to five in an east-west direction.)

The following is a list of the five treatments employed in this experiment:

Treatment	First spray	Interval between sprays	Total number of sprays
1	Untreated control		
2	at emergence	7 days	7
3	at emergence	10 days	5
4	14 days after emergence	7 days	3
5	21 days after emergence	7 days	3

The initial spray of Treatment 2 was applied on June 4 when the beans were still in the primary leaf stage. The initial spray of Treatment 3 also occurred on June 4. The first spray of Treatment 4 was applied on June 18 when the average height of the beans was between two and four inches. Treatment 5 was applied for the first time on June 25 when the beans were between 10 and 12 inches tall. All sprays consisted of a 3 1/2% oil in water emulsion.

The June 4 spray (initial spray of Treatments 2 and 3) was applied with a three-gallon compressed-air hand sprayer. All other sprays were applied with a specially built constant pressure sprayer (Figure 4). A 3 1/2 gallon galvanized tank (Pak-Tank) incorporated

Figure 4. Constant pressure sprayer.

in the sprayer was pressure regulated at 45 psi via a compressed air cylinder. The air pressure inlet was at the bottom of the spray tank allowing agitation by the bubbling of forced air through the oil emulsion. The spray outlet supplied three nozzles (#45 Spraying System Company): a center fixed nozzle pointing straight down and two adjustable lateral nozzles that sprayed the plants from opposite sides. This arrangement permitted maximum coverage with minimum effort. A pressure gauge was mounted on the spray boom and read 35 psi when the spray tank was maintained at 45 psi. This entire rig was supported by a tubular frame mounted on two bicycle wheels. An odometer-speedometer unit (calibrated in 1/100 miles) was included.

The sprayer was calibrated to apply approximately 163 gallons per acre. Since the spray was a 3 1/2% oil in water emulsion the actual amount of oil applied per acre was 5.7 gallons. Shell 61S Oil[6] was used in the first three sprays (June 4, first spray for Treatments 2 and 3; June 12, second spray for Treatment 2; June 14, second spray for Treatment 3) and in the eighth spray (July 4, fourth spray for Treatment 3). The remaining sprays were of VOLCK Supreme Oil.

Virus incidence was evaluated weekly commencing on June 25 and continuing through August 15 with the exception of a two week lapse between July 16 and August 8. The number of plants showing

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[6]See Appendix.

BYMV symptoms, as described by Zaumeyer and Thomas (1957), were recorded for each treatment. These figures were analyzed statistically and were utilized in a correlation analysis with aphid trapping data.

Results

Table 6, in addition to summarizing the weekly virus counts, gives the levels of significance of an analysis of variance based on the entire experiment, analyzed as a randomized block. Tables 7 and 8 give the significance levels for the 3 x 5 randomized block and the 5 x 5 latin square portions, respectively, of the experiment.

The final virus count (August 15), calculated as a percent, indicates that 31.6% of the controls were infected. Treatment 2 (emergence, applied every seven days) had a 22.8% virus incidence, a value quite similar to the 22.1% incidence of Treatment 3 (emergence, applied every ten days). Treatment 4 (delayed, every seven days) yielded a 23% infection, while Treatment 5 (delayed plus one week, applied every ten days) produced a 28.2% virus incidence. Replicate differences were highly significant for most of the count dates for the experiment as a whole and for the 3 x 5 randomized block portion of the experiment.

Two factors should be noted. First, the overall decrease in the number of infected plants for August 8 was probably due to a

Table 6. Weekly counts of bean plants displaying BYMV symptoms in the 1968 bean experiment.

Date	Treatments 1	2	3	4	5	Total	Significance level	Replicates 1	2	3	4	5	6	7	8	Significance level
June 25	20[1]	22	20	20	34	116	90.0%	14[1]	52	11	10	9	9	6	5	99.9%
July 2	40	52	39	56	61	238	<80.0%	30	69	45	23	23	15	22	11	99.9%
July 9	64	59	46	70	86	325	95.0%	32	86	65	31	32	27	36	16	99.9%
July 16	81	74	64	85	105	409	90.0%	47	103	76	43	39	39	40	22	99.9%
August 8	60	44	48	47	66	265	<80.0%	42	56	45	29	23	28	22	20	99.0%
August 15	162	114	119	123	142	660	80.0%	144	88	110	66	74	60	56	52	99.9%
Total	427	365	336	391	494			309	454	352	202	200	188	182	126	

1 = total number of plants showing BYMV symptoms.

Table 7. Weekly counts of bean plants displaying BYMV symptoms based on the 3 x 5 randomized block portion of the 1968 bean experiment.

Date	Treatments 1	2	3	4	5	Total	Significance level	Replicates 1	2	3	Significance level
June 25	12[1]	15	15	15	20	77	90.0%	14[1]	52	11	99.9%
July 2	21	34	24	30	35	144	< 80.0%	30	69	45	95.0%
July 9	36	35	28	39	45	183	< 80.0%	32	86	65	99.0%
July 16	44	41	38	49	54	226	< 80.0%	47	103	76	99.0%
August 8	27	27	25	31	33	143	< 80.0%	42	56	45	80.0%
August 15	82	67	61	62	70	342	< 80.0%	144	88	110	< 80.0%
Total	222	219	191	226	257			309	454	352	

1 = total number of plants showing BYMV symptoms.

Table 8. Weekly counts of bean plants displaying BYMV symptoms based on the 5 x 5 latin square portion of the 1968 bean experiment.

	Treatments						Significance	Replicates					Significance	Lines					Significance
Date	1	2	3	4	5	Total	level	4	5	6	7	8	level	1	2	3	4	5	level
June 25	8[1]	7	5	5	14	39	< 80.0%	10[1]	9	9	6	5	< 80.0%	12[1]	10	11	3	3	80.0%
July 2	19	18	15	16	26	94	< 80.0%	23	23	15	22	11	< 80.0%	19	23	26	10	16	< 80.0%
July 9	28	24	18	31	41	142	80.0%	31	32	27	36	16	< 80.0%	29	32	38	20	23	< 80.0%
July 16	37	33	26	36	51	183	< 80.0%	43	39	39	40	22	< 80.0%	40	41	47	24	31	< 80.0%
August 8	33	17	23	16	33	122	90.0%	29	23	28	22	20	< 80.0%	26	32	29	16	19	< 80.0%
August 15	80	47	58	61	72	318	99.0%	66	74	70	56	52	90.0%	57	68	74	62	57	80.0%
Total	205	146	145	165	237			202	200	188	182	126		183	206	225	135	149	

1 = total number of plants showing BYMV symptoms.

human counting error and does not represent a real decrease. It does, however, seem that the figures represent a true proportion of the actual virus incidence since the error probably involved the oversight of mild symptoms masked by natural bean maturation and, as such, would have been unbiased. In view of this fact, these figures have been utilized in the evaluation of this experiment. However, because the exact proportion was unknown, these figures have been ignored in the correlation analysis. Second, the four Shell 61S Oil sprays alluded to in Materials and Methods seem to have had virtually no effect on virus prevention. The lack of emulsifier caused an unequal oil distribution both in the water carrier and on the leaf surfaces. A distribution study revealed that less than 1% of the oil actually was reaching the leaves. In addition, the distribution on a particular leaf was disproportionately poor.

Discussion and Conclusions

The treatment effects appear questionable when examining the experiment (Table 6). However, the general lack of statistical significance can be attributed to two factors. The first involves the failure of the Shell oil to maintain a stable emulsion. This is especially important when it is realized that the use of the Shell oil virtually provided no protection early in the season when bean susceptibility was probably the greatest (Swenson, 1968b). This lack of protection

permitted the introduction of a high level of virus incidence providing little or no initial differences between treatments. This high, non-differential virus incidence would have required an increasingly stronger oil spray influence as the season progressed in order to produce significant treatment differences. However, this was impossible since the period of greatest virus spread already had passed. Consequently, the relatively small difference in the treatment effects may be indicative of a potentially larger difference (had the spray timing been better).

The existence of the wooded area immediately to the south of the plot also may have affected the results. The presence of a high virus incidence in replicates one, two and three and the decrease in virus incidence with increasing distance from the woods suggests that the trees may have acted as a windbreak (Swenson, 1968b). The somewhat lower virus incidence in the first replicate cannot be explained readily on the basis of a direct windbreak effect.

If one keeps the above factors in mind, the data from the 3 x 5 randomized block design (Table 7) are not wholly unexpected. The initial virus incidence due to the possible windbreak effect was sufficiently high so that one would expect a slowly diverging virus incidence between treated and untreated plots with time, resulting in a small final difference. This would be due to the failure of the oil to exert an increasingly stronger influence as the season progressed and

to the high, non-differential initial virus incidence.

On the other hand, the 5 x 5 latin square (Table 8) had a small early virus incidence. Hence, one would expect a wider divergence in virus incidence between treated and untreated plots with time, resulting in a larger final difference. The highly significant final count supports this line of reasoning.

In my opinion, this experiment demonstrates the need for better spray timing if we are to obtain satisfactory virus control.

SUMMARY

The use of petroleum oil prevented, to varying degrees, the transmission of three stylet-borne viruses in three different crops. The use of oils resulted in a marked improvement in the number of lily bulbs harvested from treated plots as compared to the number of lily bulbs harvested from untreated plots. A random sample of the harvested bulbs forced in the greenhouse showed that substantially more bulbs germinated from treated plots than from untreated plots. Lily virus symptoms were prevented in 13% of the plants in treated plots. All untreated plants were infected. However, this relatively small difference was probably due to the use of too many infector plants. Treated lilies showed more stunting and mottling than did the untreated lilies.

The influences of oil sprays on the transmission of bean yellow mosaic virus in beans were studied in 1967 and 1968. Virus symptoms in 1967 were shown to vary significantly with planting dates. The early planting had a greater incidence of plants showing virus symptoms than did the later planting. Oil sprays reduced virus symptoms by 20. 9% in the early planting and by 40. 7% in the later planting. Oil sprays reduced BYMV symptoms from 10-30% in 1968, depending on the treatment. However, the statistical significance of these treatment effects was questionable.

The spread of BYMV in 1968 was strongly correlated with the daily number of aphids trapped at two widely separated trap locations. These correlations were improved when the number of aphids trapped were adjusted for the possible effects of the oil sprays. The implications of the correlations were threefold. First, the direct relationship between virus symptoms and aphid numbers suggested that the timing of sprays to periods of high aphid migrations could improve virus prevention. Second, the prevention of virus spread could be improved by the application of oil during periods when one or more aphid species particularly efficient in virus transmission are migrating. Third, the value of oil could be improved by the maintenance of a highly efficient oil residue for longer periods of time.

Oil sprays reduced white-break virus (cucumber mosaic virus) symptoms in gladiolus from 9.5% to 3.1% in the field. However, similar results were not obtained when sample corms from the field plots were forced in the greenhouse.

Future research should concentrate on increasing the duration of a highly efficient oil residue. This will simplify spray timing by permitting a wider effective range with which to work. Also, the development of a forecast system for aphid migration and subsequent spray timing can be accomplished easily because of aphid population uniformity over wide areas and should, therefore, be of next importance. The determination of the second implication (above) would be

difficult at best.

In conclusion, the additional research required to develop long duration oil sprays and to improve timing of applications to aphid peaks would vastly improve the value of petroleum oils in the prevention of stylet-borne virus spread.

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APPENDIX

OILS AND OIL COVERAGE

The following is a comparative list of the two petroleum oils utilized in all of the preceding experiments:

	VOLCK Supreme Oil (Chevron Chemical Company, Ortho Division, Richmond, California)	Shell 61S Oil (Shell Chemical Company, Division of Shell Oil Company, Portland, Oregon)
Gravity, °API	31.3	30.4
Specific Gravity @ 60°F	0.8692	0.8740
Pounds per gallon @ 60°F	7.24	7.278
Color, ASTM	1.0	20.5
Flash point, COC, °F	400	300
Pour Point, °F	+20	-70
Viscosity		
SUS at 100°F	145	63.5
SUS at 210°F	43	34.8
Unsulfonated Residue, Vol. %	98	92.5
Distillation, °F @ 10 mm Hg		
IBP	384	296
10% Recovered	444	333
20% "	463	350
30% "	472	362
40% "	482	373
50% "	490	385
60% "	501	398
70% "	513	411
80% "	524	430
90% "	540	448
95%	560	462
Emulsifier	1.5-1.7% nonionic ester	none
Dye	0.007% blue-green	none

Figures 5 and 6 show the distribution of VOLCK Supreme Oil on a bean leaf on Day I and Day III of spraying. In the case of Shell oil,

a figure comparable to Figure 5 would contain at the most one oil blotch. By the seventh day oil blotches were occasionally visible in random selections of leaf sections for the VOLCK Supreme Oil.

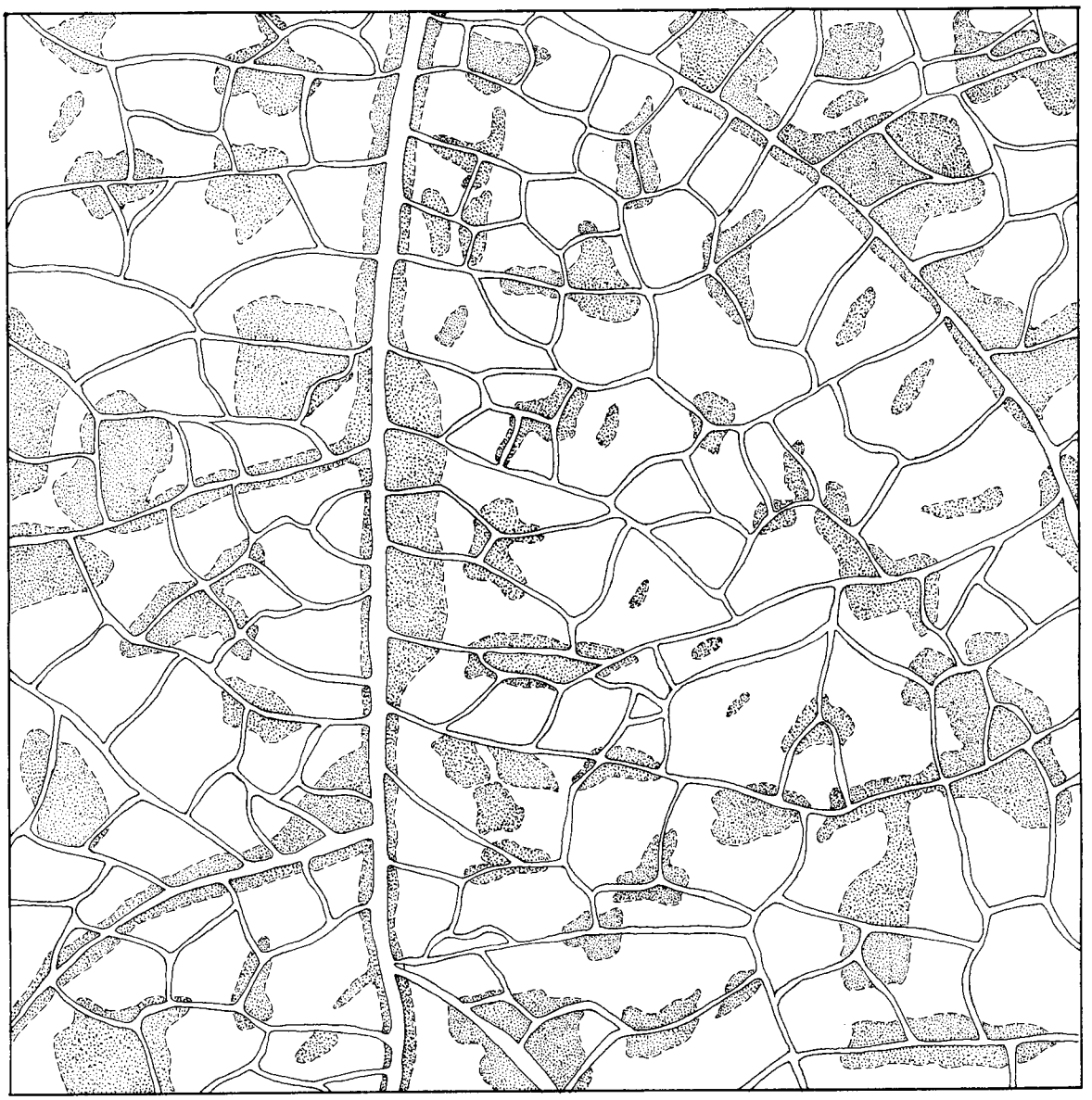

Figure 5. Diagrammatic representation of distribution of VOLCK Supreme Oil on a 9/16 x 9/16 inch section of a bean leaf on the day of spraying. (Shaded sections represent oil deposits.)

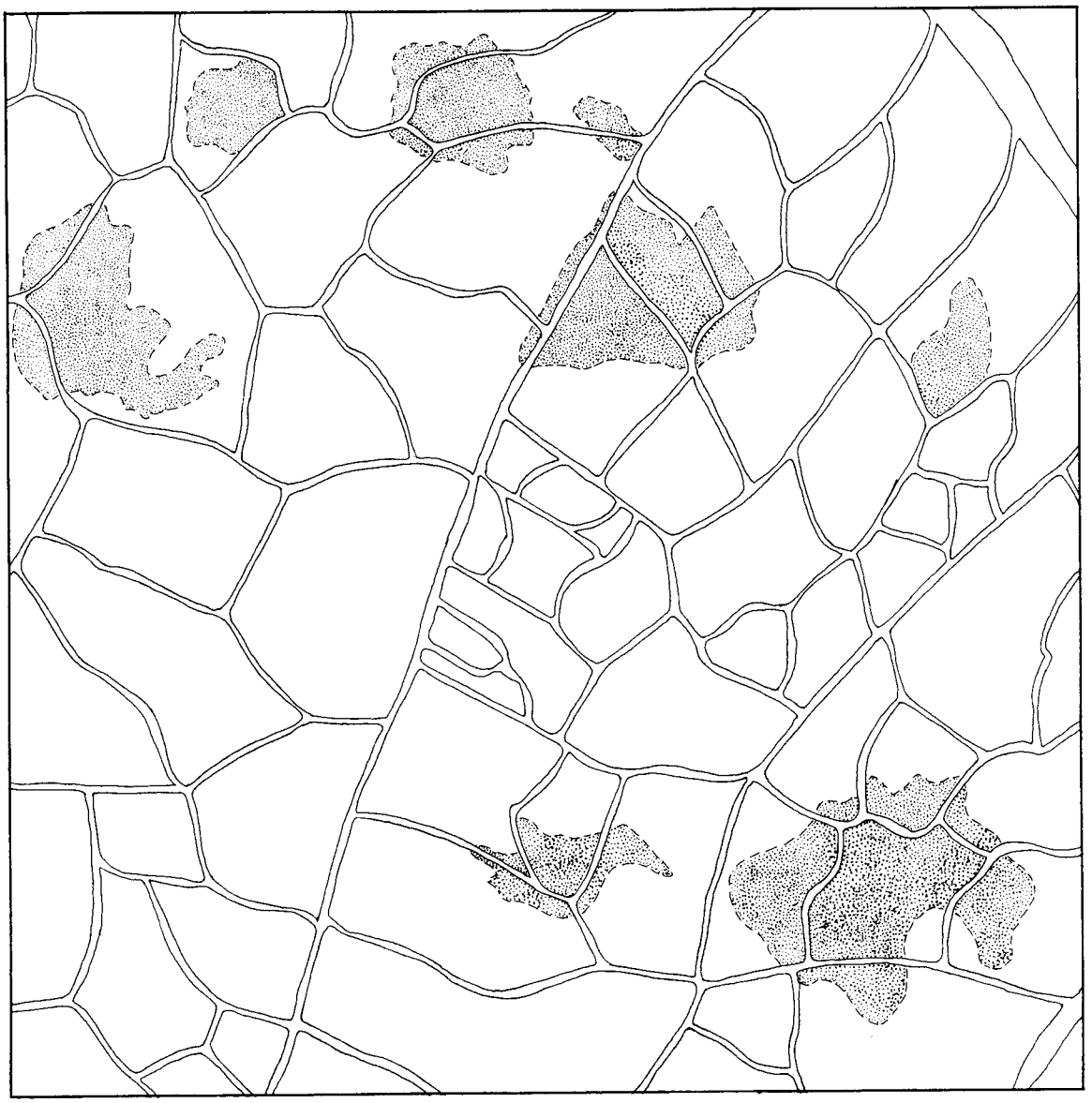

Figure 6. Diagrammatic representation of distribution of VOLCK Supreme Oil on a 9/16 x 9/16 inch section of a bean leaf on the second day after spraying. Shaded sections represent oil deposits.)