

STUDIES ON SPREAD FACTOR, VISCOSITY, DENSITY,  
SURFACE TENSION AND EVAPORATION RATE OF  
FORMULATIONS OF INSECTICIDES AND INSECT  
GROWTH REGULATORS

File Report No. 9

January 1981

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## INTRODUCTION

Efficient spray operations of pesticides, biological or chemical, require correct formulation of the active ingredient in suitable vehicle-solvents and/or liquids in order to produce required droplet sizes. The aim is to transmit the pesticide in such a way as to achieve maximum probability of targeting. This probability is a function of droplet size, formulation properties and external meteorological conditions. It has been shown recently that droplets  $\leq 100$   $\mu\text{m}$  in diameter meet the conditions of a high probability of impaction on spruce foliage, when the spray spectrum is released in forest canopy. This droplet size-range at once dictates the physico-chemical characteristics of spray formulations employed. Therefore, the objective of the present study is to carry out research and develop strategic formulations having optimum physico-chemical properties that would lead to a high probability of impact on target insects and/or foliage. Due consideration should also be given to factors such as economy of the spray operation and compatibility between ingredients.

The following physico-chemical properties of some vehicle oils, chemical insecticides and insect growth regulators were studied and the data are presented in Tables 1 to 21.

### Spread Factor

The spread factor or spreading ability of a liquid formulation is related to the droplet size, droplet momentum of impact, surface tension of the formulation and contact angle between the spread and the surface. Tables 1 to 12 present spread factor data for vehicle oils and spray mixes used in field spray-operations during the summer 1980.

Figures 1 to 12 present the regression line between the drop diameter and stain diameter on the Kromekote card.

### Viscosity

The viscosity ' $\eta$ ' is one of the most important liquid properties that can influence the drop size spectrum. An increase in viscosity physically dampens the natural wave formations which generally delays disintegration and increases the droplet size. One of the recent interesting developments is the introduction of adjuvants to modify the viscosity in order to control the drift potential. These observations indicate the importance of viscosity measurements of spray formulations.

### Surface Tension

The surface tension ' $\gamma$ ' of a liquid represents the force that resists the formation of a new surface area. The minimum energy required for atomization is equal to the surface tension multiplied by the liquid surface area. Thus, it may represent a predominate force for certain types of atomization and affect the droplet size range produced.

### Density

The density ' $d$ ' of a spray formulation has some effect on the atomization due to the relationship between spray pressure, fluid velocity and density. Density data are recorded in Table 13 along with other physico-chemical properties,  $\eta$  and  $\gamma$ .

### Evaporation Rate

The rate of evaporation of a pure liquid is directly related to its vapour pressure; but the evaporation rate of a mixture is more

complex. In the initial stage, the evaporation process can be treated similar to that of a pure liquid drop. At a later stage, the rate decreases rapidly and becomes more or less constant. The evaporation rate of a formulation plays a dominant role in influencing deposition and/or drift of droplets. Tables 14 to 21 and Figures 13 to 20 present evaporation-rate data for some fluids.

#### EXPERIMENTAL PROCEDURE

Viscosity, density and surface tension measurements were for all spray formulations (Table 22) done at different temperatures ranging from 5° to 25°C, whereas the spread factor and evaporation rate studies were carried out at room temperature (22°C). Two types of viscometers, Ostwald and falling-ball types, were used for viscosity measurements. Density was measured using a density bottle. For surface tension, the conventional capillary-rise method was used. For the spread factor determination on the Kromekote card, the rotary device, developed by Rayner and Haliburton (Rev. Sci. Instr. 26, 1124-1127, 1955) was used. For studying the evaporation rates, droplets of different sizes were produced by the rotary device described above, and were captured on to glass fibres mounted on plastic petri dishes containing a saturated solution of potassium nitrite at 22°C, in order to obtain a constant relative humidity of 45%. Size measurements at specified time periods were carried out using a microscope.

Table 1

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> Between  
Spot (X) and Droplet (Y) Diameter for "Insecticide Diluent-585"

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Y <sub>p</sub> ) from equation	Spread factor = $\frac{X}{Y_p}$
1	200.00	66.	70.	2.85000
2	225.00	72.	77.	2.93000
3	309.00	97.	99.	3.11000
4	324.00	102.	103.	3.13000
5	408.00	113.	126.	3.24000
6	402.00	113.	124.	3.23000
7	420.00	130.	129.	3.24000
8	439.00	132.	134.	3.27000
9	408.00	138.	126.	3.24000
10	416.00	140.	128.	3.25000
11	499.00	143.	150.	3.32000
12	482.00	148.	146.	3.31000
13	555.00	182.	165.	3.36000
14	837.00	243.	241.	3.47000
15	895.00	251.	256.	3.49000
16	849.00	259.	244.	3.48000
17	944.00	273.	270.	3.50000
18	978.00	281.	279.	3.51000
19	1278.00	347.	359.	3.56000
20	1332.00	372.	374.	3.57000

<sup>a</sup>Correlation coefficient = 0.995.

<sup>b</sup>For "insecticide diluent-585",  $Y = 16.6 + 0.268 X$

<sup>c</sup>Dye used - Automate-B Red.

FIG. 1

INSECTICIDE DILUENT - 585

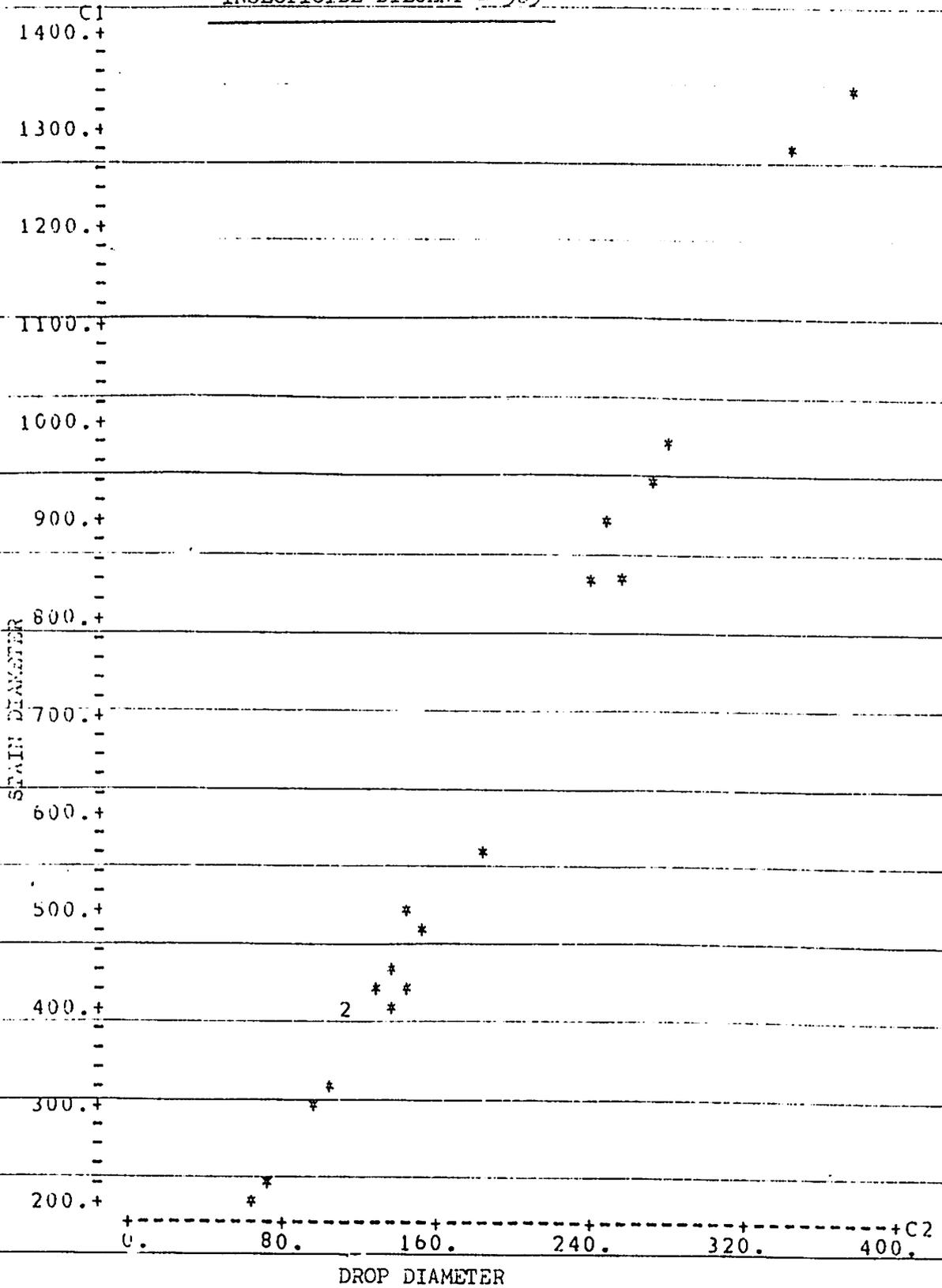


Table 2

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for "Sunspray 7N" Oil

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	230.00	59.	60.	3.83000
2	300.00	73.	77.	3.89000
3	375.00	99.	95.	3.94000
4	525.00	125.	132.	3.99000
5	698.00	182.	174.	4.02000
6	945.00	222.	234.	4.04000
7	1084.00	245.	268.	4.05000
8	1131.00	251.	279.	4.05000
9	1011.00	250.	250.	4.05000
10	1029.00	260.	254.	4.05000
11	1011.00	261.	250.	4.05000
12	999.00	262.	247.	4.05000
13	1035.00	261.	256.	4.05000
14	1077.00	265.	266.	4.05000
15	1227.00	271.	302.	4.06000
16	1083.00	275.	267.	4.05000
17	1068.00	275.	264.	4.05000
18	1092.00	279.	269.	4.05000
19	1110.00	290.	274.	4.05000
20	1440.00	348.	354.	4.07000
21	1461.00	377.	359.	4.07000

<sup>a</sup>Correlation coefficient = 0.985.

<sup>b</sup>For "Sunspray 7N Oil",  $Y = 4.14 + 0.243X$ .

<sup>c</sup>= dye used - Automate B Red.

1  
9  
1

FIG. 2

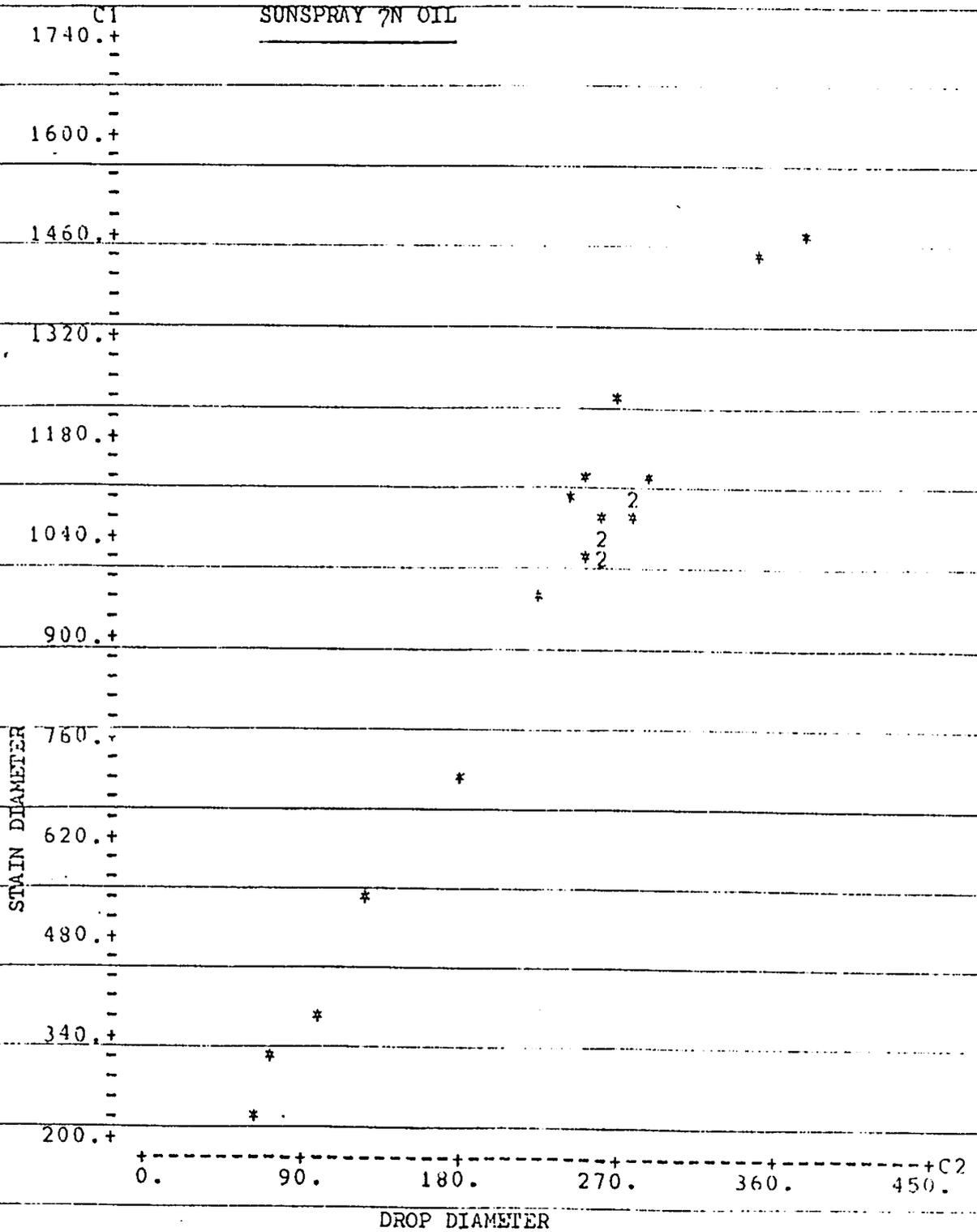


Table 3

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for UC - 62644 in Sunspray 7N Oil (0.5 oz/acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Y_p}$
1	234.00	58.	70.	3.35000
2	285.00	84.	82.	3.49000
3	339.00	108.	94.	3.61000
4	561.00	138.	145.	3.88000
5	750.00	190.	188.	3.99000
6	930.00	225.	229.	4.06000
7	1092.00	282.	266.	4.11000
8	1237.00	284.	299.	4.14000
9	1451.00	351.	348.	4.17000

<sup>a</sup>Correlation coefficient = 0.995

<sup>b</sup>For UC - 62644 in Sunspray 7N oil  $Y = 16.5 + 0.228 X$

<sup>c</sup>Dye used : Automate-B Red.

1  
∞  
1

FIG. 3

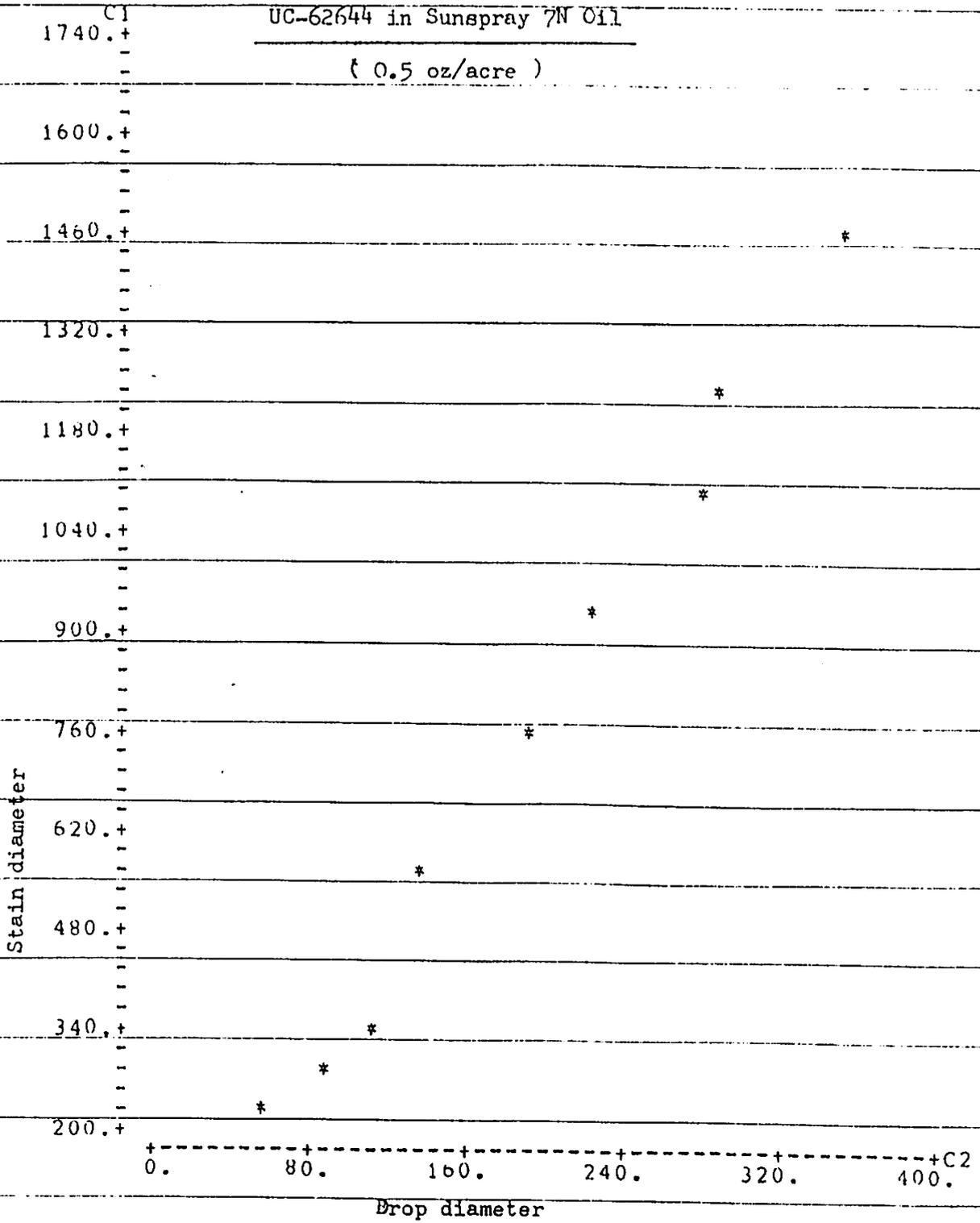


Table 4

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for UC - 62644 in Sunspray 7N Oil (1 oz/acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	205.00	53.	59.	3.47000
2	237.00	66.	67.	3.53000
3	288.00	90.	80.	3.61000
4	432.00	116.	115.	3.74000
5	516.00	134.	136.	3.79000
6	740.00	189.	192.	3.86000
7	1120.00	288.	286.	3.91000
8	1540.00	390.	390.	3.95000

<sup>a</sup>Correlation coefficient = 0.999

<sup>b</sup>For UC - 62644 in Sunspray 7N Oil  $Y = 8.29 + 0.248 X$

<sup>c</sup>Dye used: Automate-B Red.

Fig. 4

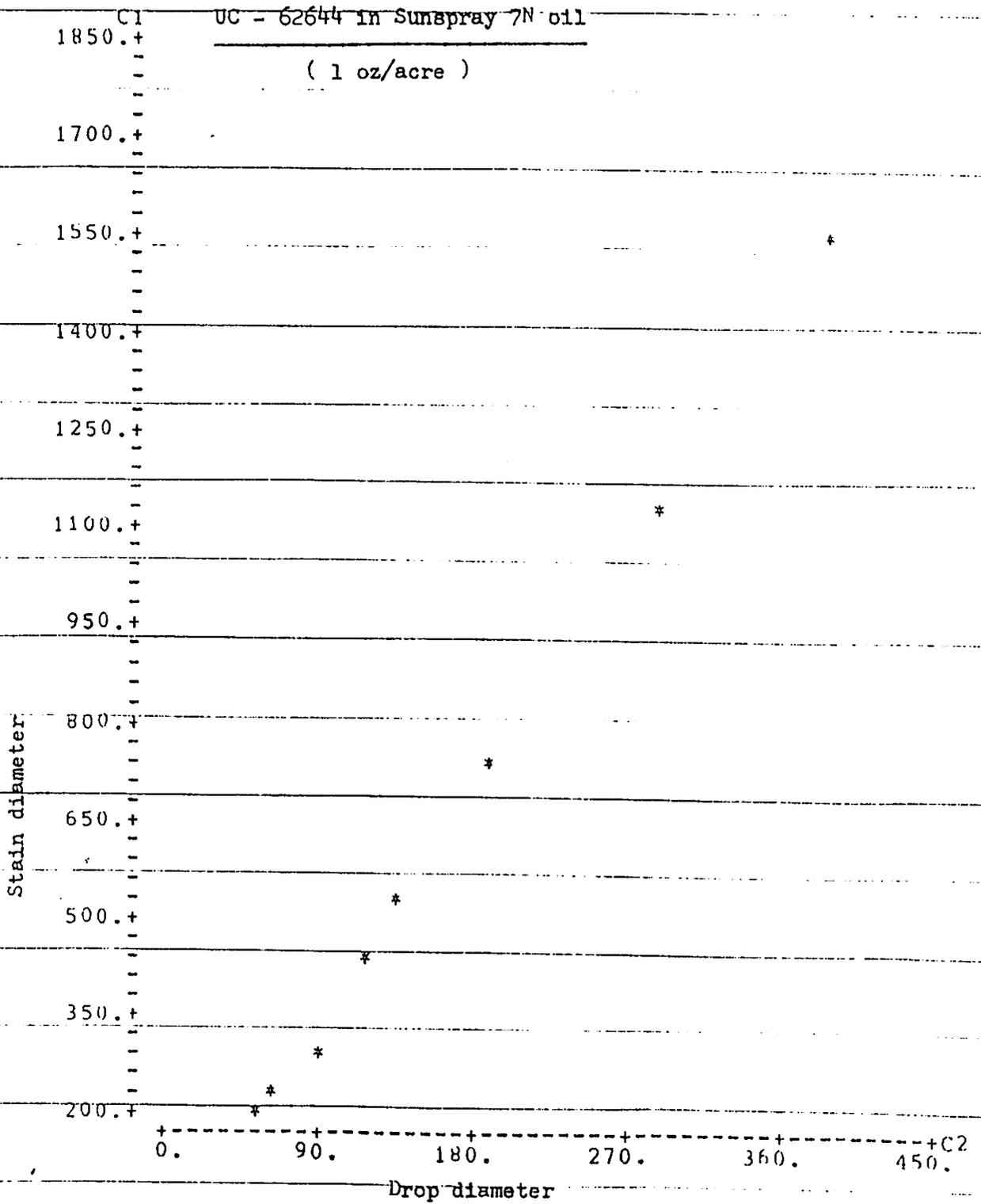


Table 5

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for Vay Sir 8514 in water (2 oz/acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	181.	104.	104.	1.74000
2	267.	119.	130.	2.24000
3	264.	141.	129.	1.87000

<sup>a</sup>Correlation coefficient = 0.5

<sup>b</sup>For Bay Sir 8514 in water, = 50 + 0.3 X

<sup>c</sup>Dye used: Erio Acid Red.

Fig.5

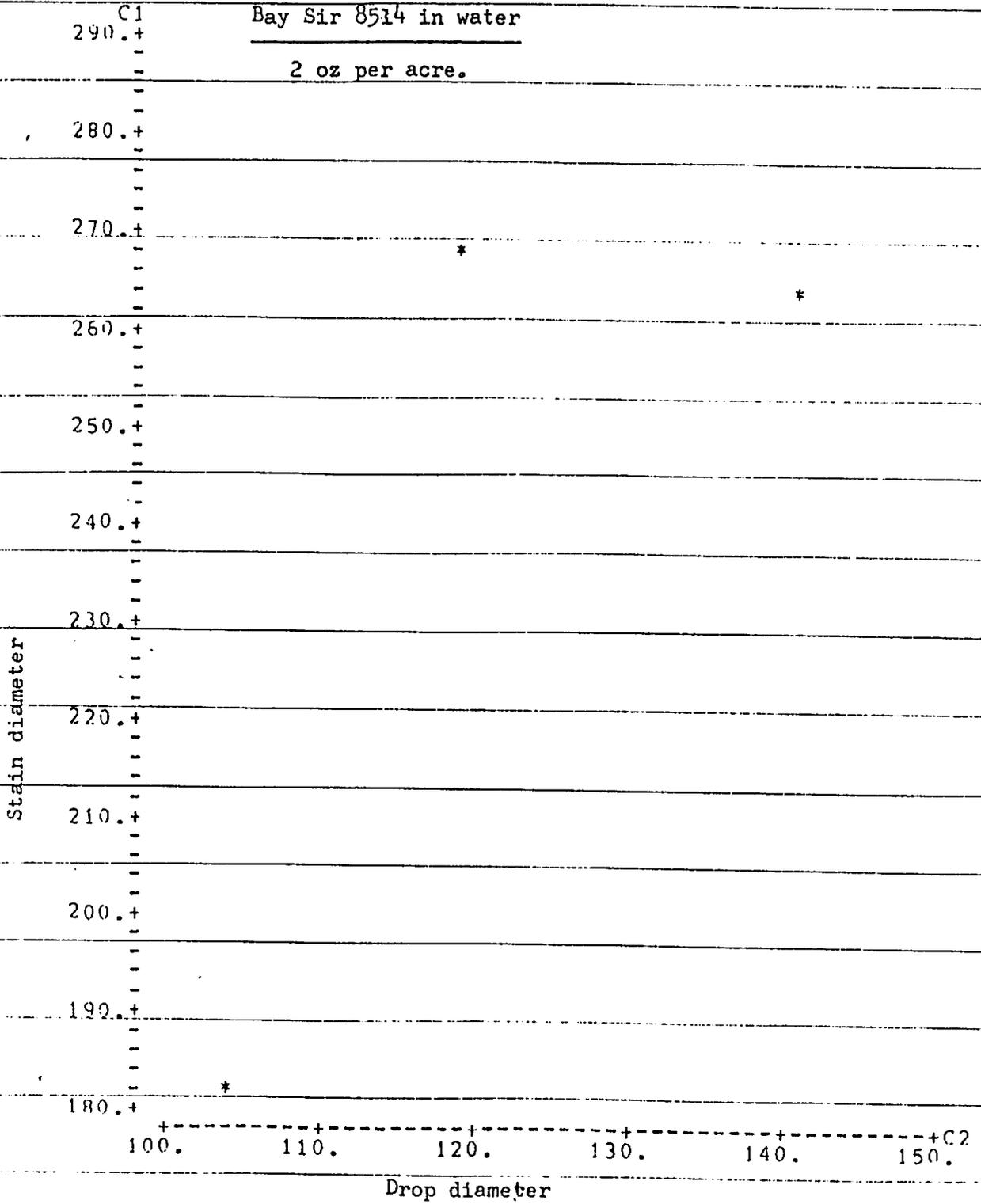


Table 6

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for Bay Sir 8514 in Sunspray 7N oil (3 oz/acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	162.00	47.	42.	3.88000
2	231.00	66.	60.	3.83000
3	345.00	84.	91.	3.79000
4	438.00	113.	116.	3.77000
5	782.00	203.	209.	3.74000
6	1178.00	321.	316.	3.74000

<sup>a</sup>Correlation coefficient = 0.999

<sup>b</sup>For Bay Sir 8514 in Sunspray 7N oil  $Y = - 1.88 + 0.27 X$

<sup>c</sup>Dye used : Automate-B Red

Fig 6

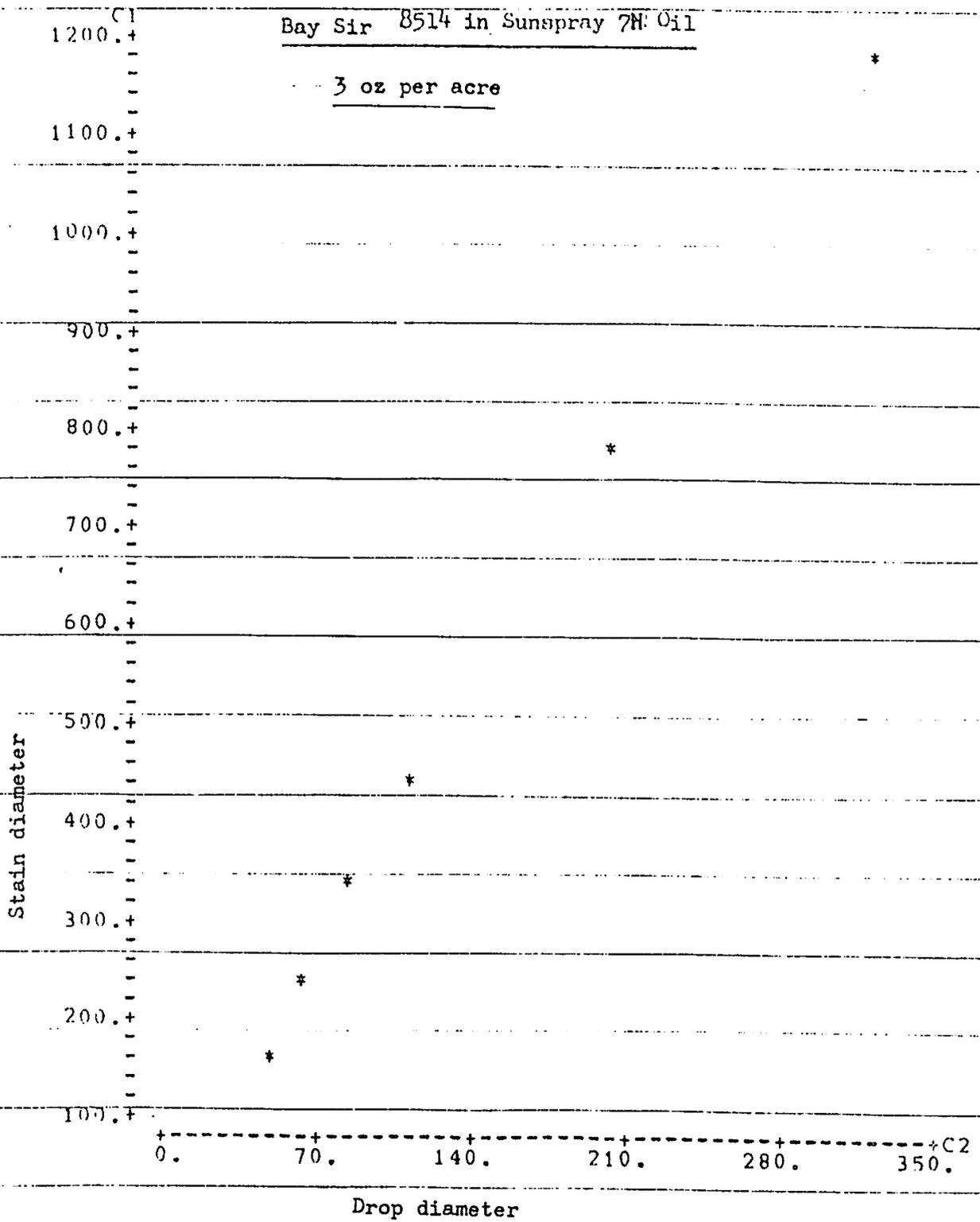


Table 7

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for Bay Sir 8514 in Sunspray 7N oil (2 oz/acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	255.	95.	108.	2.36000
2	258.	111.	109.	2.36000
3	287.	111.	122.	2.36000
4	306.	132.	130.	2.36000
5	298.	134.	126.	2.36000
6	427.	185.	181.	2.36000
7	495.	225.	210.	2.36000
8	836.	347.	355.	2.36000
9	927.	394.	394.	2.36000

<sup>a</sup>Correlation coefficient = 0.998

<sup>b</sup>For Bay Sir 8514 in Sunspray 7N oil  $Y = 0.548 + 0.425 X$

<sup>c</sup>Dye used : Automate-B Red.

Fig. 7

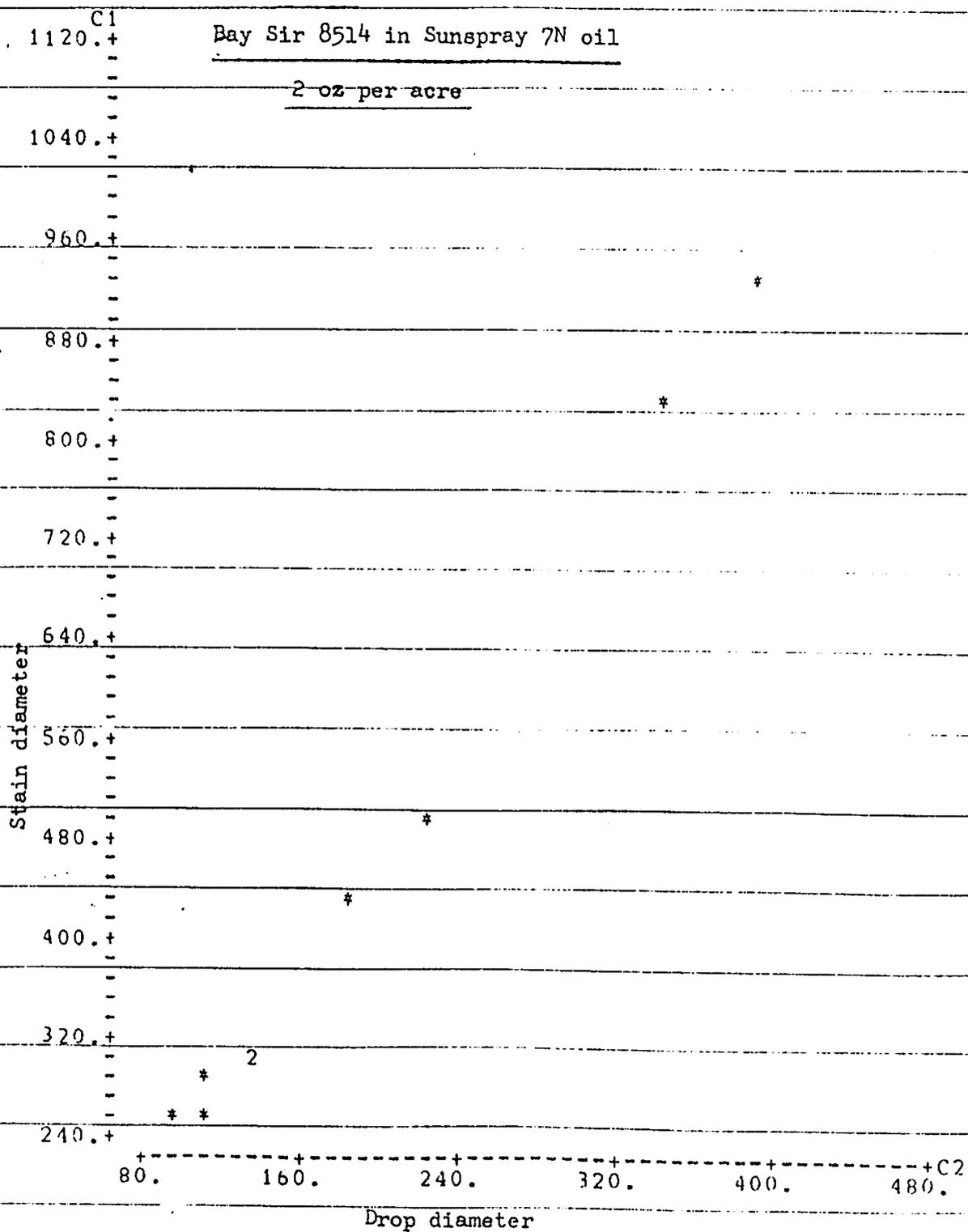


Table 8

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for Bay Sir 8514 in Sunspray 7N oil  
+ Emulsifier (2 oz per acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	192.	81.	72.	2.68000
2	291.	97.	107.	2.72000
3	303.	124.	111.	2.72000
4	432.	150.	157.	2.74000
5	393.	134.	144.	2.74000
6	544.	169.	198.	2.75000
7	696.	258.	252.	2.76000
8	837.	367.	302.	2.77000
9	838.	313.	303.	2.77000
10	993.	311.	358.	2.77000

<sup>a</sup>Correlation coefficient = 0.95

<sup>b</sup>For Bay Sir 8514 in Sunspray 7N oil + Emulsifier (2 oz per acre),  $Y = 2.83 + 0.358 X$

<sup>c</sup>Dye used : Automate-B Red.

Fig. 8

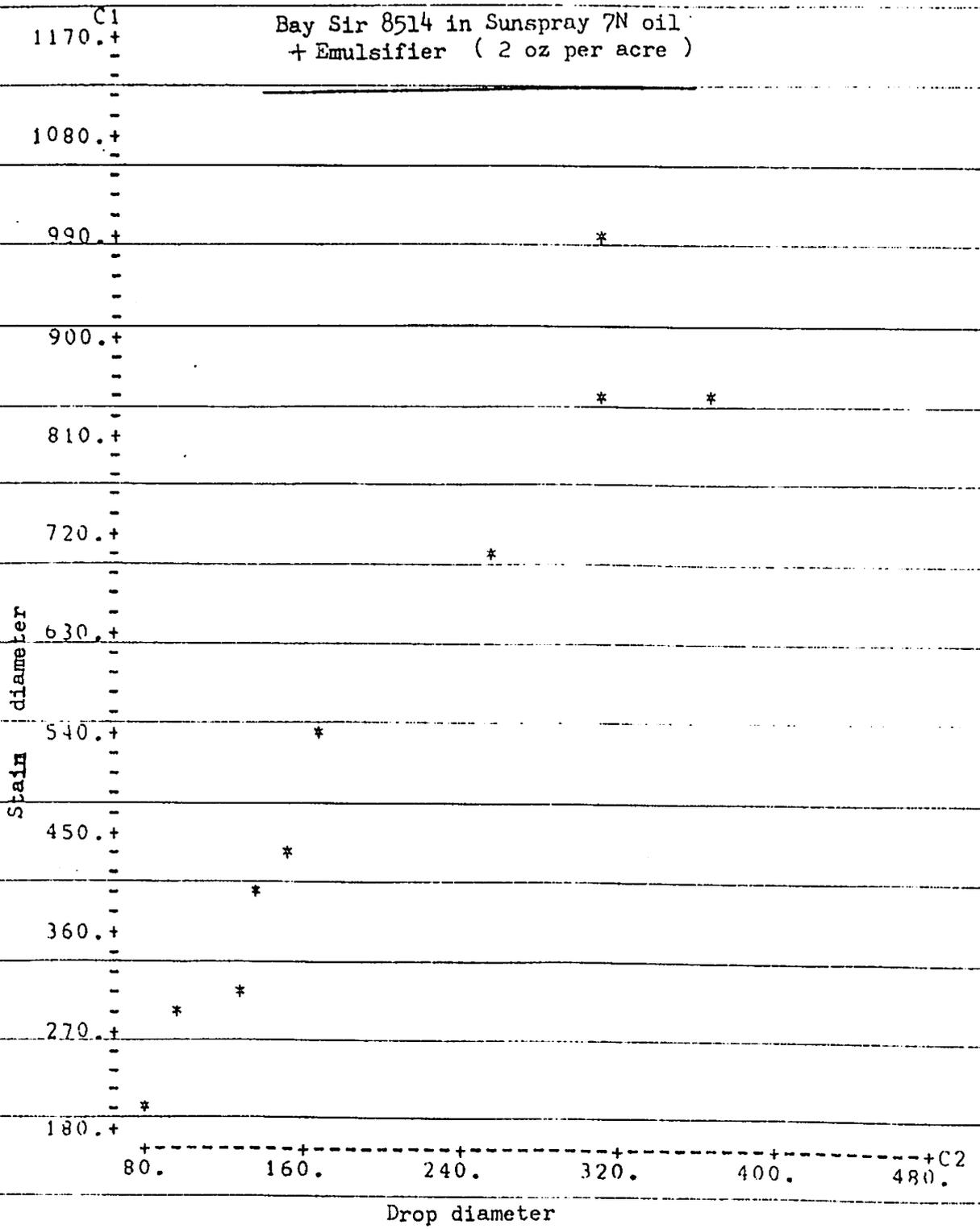


Table 9

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for Bay Sir 8514 in water (3 oz per acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	239.	95.	99.	2.42000
2	365.	147.	140.	2.60000
3	468.	172.	174.	2.69000
4	617.	222.	223.	2.77000

<sup>a</sup>Correlation coefficient = 0.98

<sup>b</sup>For Bay Sir 8514 in water,  $Y = 20.2 + 0.329 X$

<sup>c</sup>Dye used : Erio Acid Red

Fig. 9

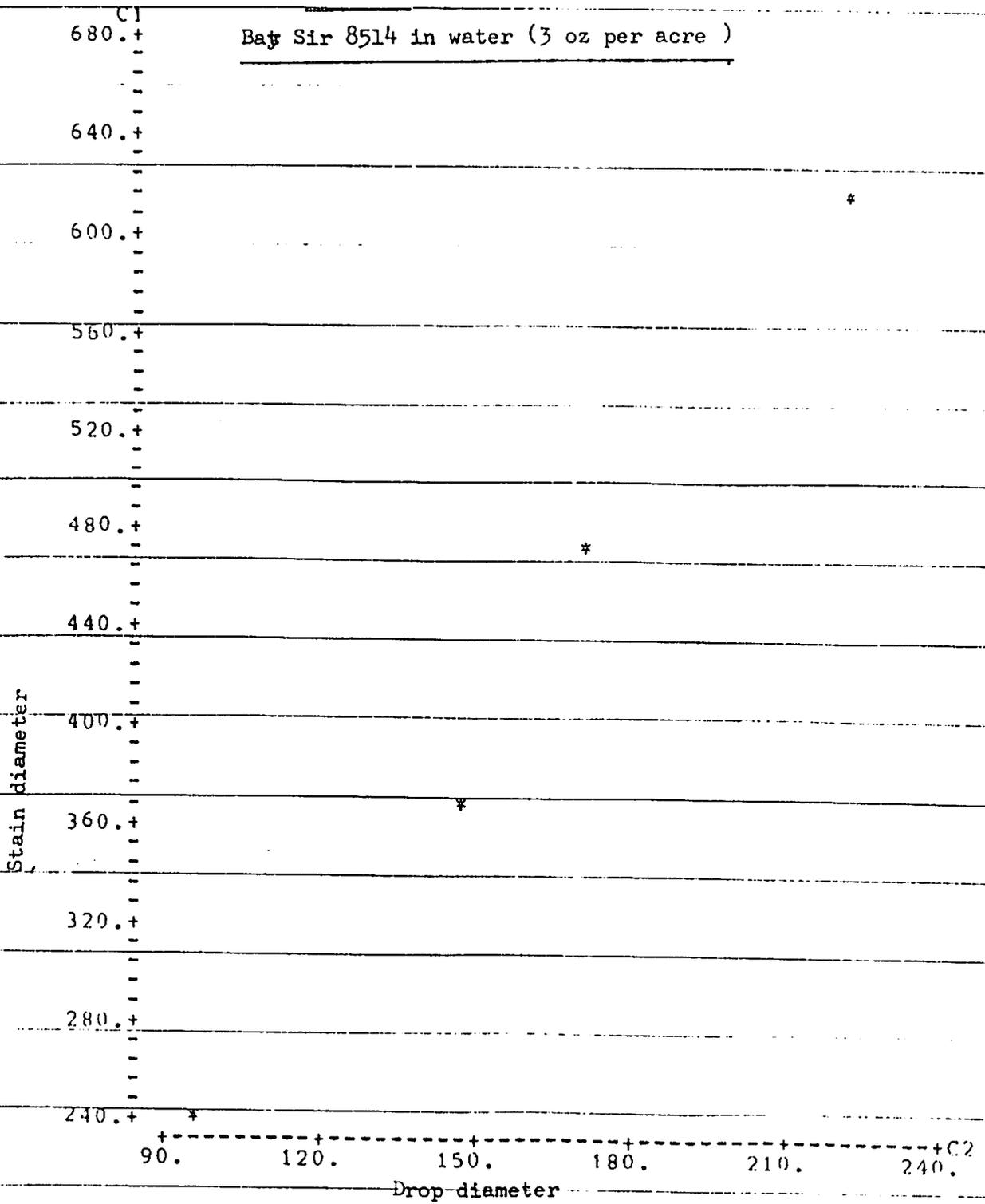


Table 10

Spread Factor and Linear Regression<sup>a</sup> Equation<sup>b</sup> between Spot (X)  
and Droplet (Y) Diameter for Matacil in I.D. 585 Oil (1.0 oz per acre)

No.	Spot <sup>c</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	213.00	95.	111.	1.92000
2	264.00	130.	125.	2.12000
3	408.00	170.	164.	2.49000
4	486.00	195.	185.	2.62000
5	636.00	223.	226.	2.81000
6	799.00	276.	271.	2.95000
7	844.00	288.	283.	2.98000
8	934.00	297.	308.	3.04000
9	1096.00	312.	352.	3.11000
10	1068.00	349.	344.	3.10000
11	1111.00	381.	356.	3.12000

<sup>a</sup>Correlation coefficient = 0.985

<sup>b</sup>For Matacil in 585 Oil,  $Y = 52.4 + 0.273 X$

<sup>c</sup>Dye used : Automate Red.

Fig. 10

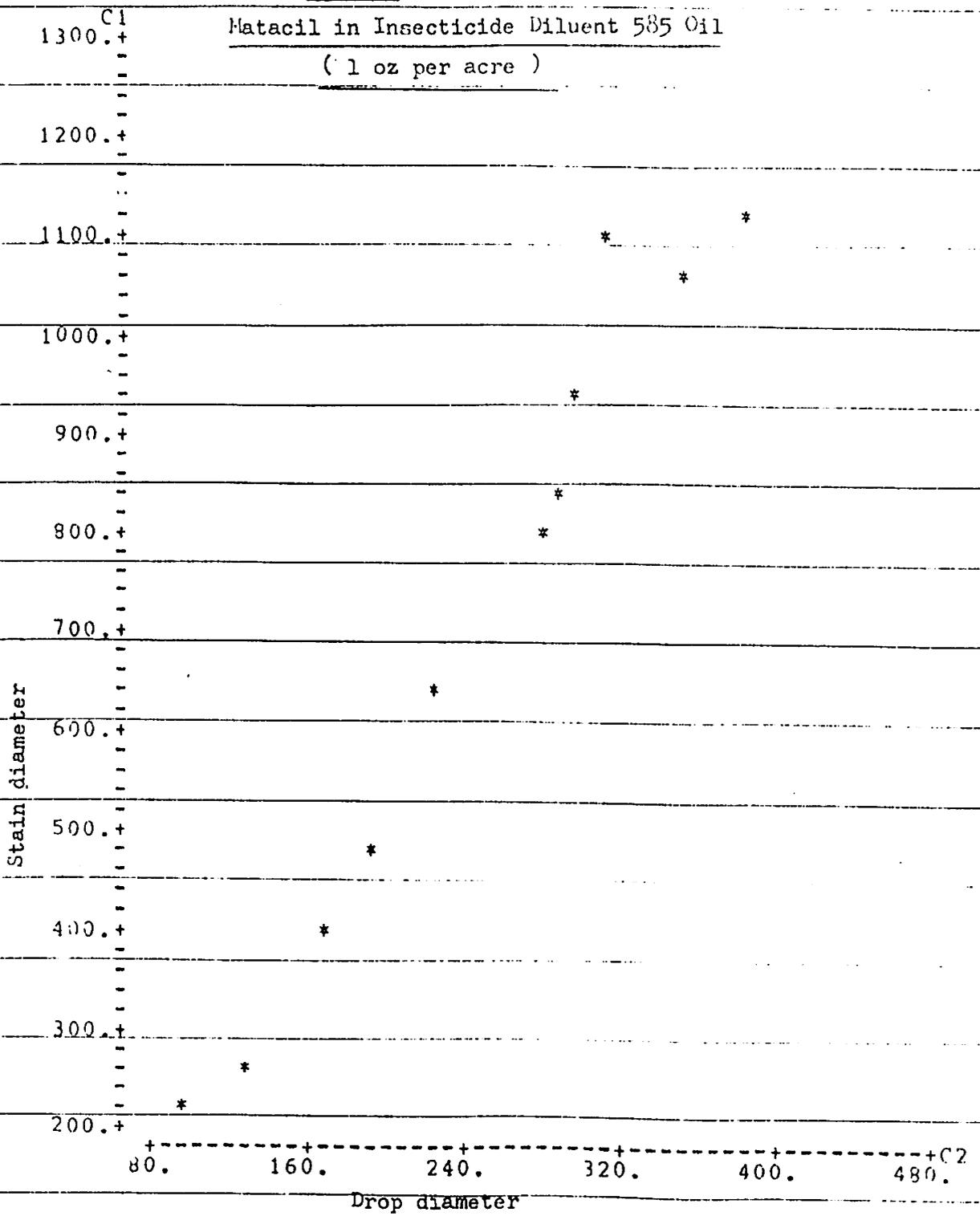


Table 11

Spread Factor and Regression Equation<sup>a</sup> Between Spot (X) and Droplet (Y)  
Diameter For Reldan in I.D. 585 (1.0 oz/acre)

No.	Spot <sup>b</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Y <sub>p</sub> ) from equation	Spread factor = $\frac{X}{Y_p}$
1	135.00	55.	54.	2.50000
2	141.00	60.	57.	2.47368
3	235.00	90.	99.	2.37374
4	300.00	117.	123.	2.43902
5	345.00	134.	138.	2.50000
6	381.00	156.	149.	2.55705
7	453.00	180.	169.	2.68047
8	718.00	232.	230.	3.12174
9	907.00	264.	266.	3.40977
10	1092.00	292.	298.	3.66443
11	1269.00	320.	325.	3.90462
12	1468.00	360.	353.	4.15864

<sup>a</sup>For Reldan in I.D. 585,  $Y = -120 + 22 X^{0.4}$ ; coeff. detn. = 0.996

<sup>b</sup>Dye used : Automate-B Red.

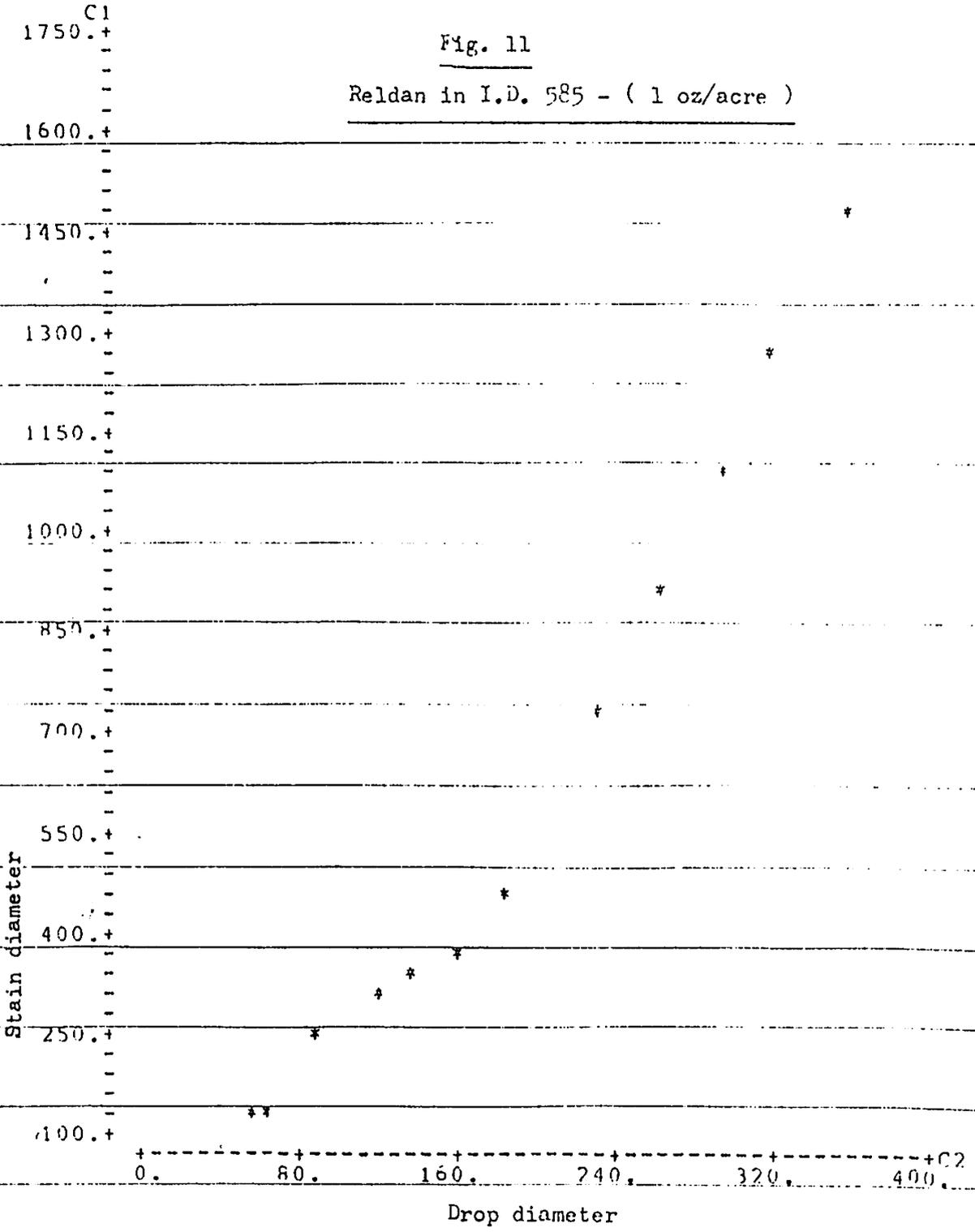


Table 12

Spread Factor and Regression Equation<sup>a</sup> between Spot (X) and Droplet (Y)  
Diameter For Permethrin in I.D. 585 (0.25 oz/acre)

No.	Spot <sup>b</sup> (X) diameter (μm)	Droplet (Y) diameter (μm)	Predicted Y (Yp) from equation	Spread factor = $\frac{X}{Yp}$
1	126.00	50.	35.	3.60000
2	203.00	75.	76.	2.67105
3	243.00	92.	95.	2.55789
4	270.00	100.	106.	2.54717
5	291.00	112.	115.	2.53043
6	324.00	177.	128.	2.53125
7	333.00	125.	131.	2.54198
8	399.00	144.	155.	2.57419
9	417.00	167.	161.	2.59006
10	528.00	194.	196.	2.69388
11	568.00	195.	208.	2.73077
12	534.00	214.	198.	2.69697
13	747.00	263.	256.	2.91797
14	900.00	320.	292.	2.08219
15	1177.00	351.	351.	3.35328
16	1379.00	373.	390.	3.53590

<sup>a</sup>For Permethrin in I.D. 585,  $Y = 0.121 + 14 X^{0.5}$ ; coeff. detn. = 0.986

<sup>b</sup>Dye used : Automate-B Red.

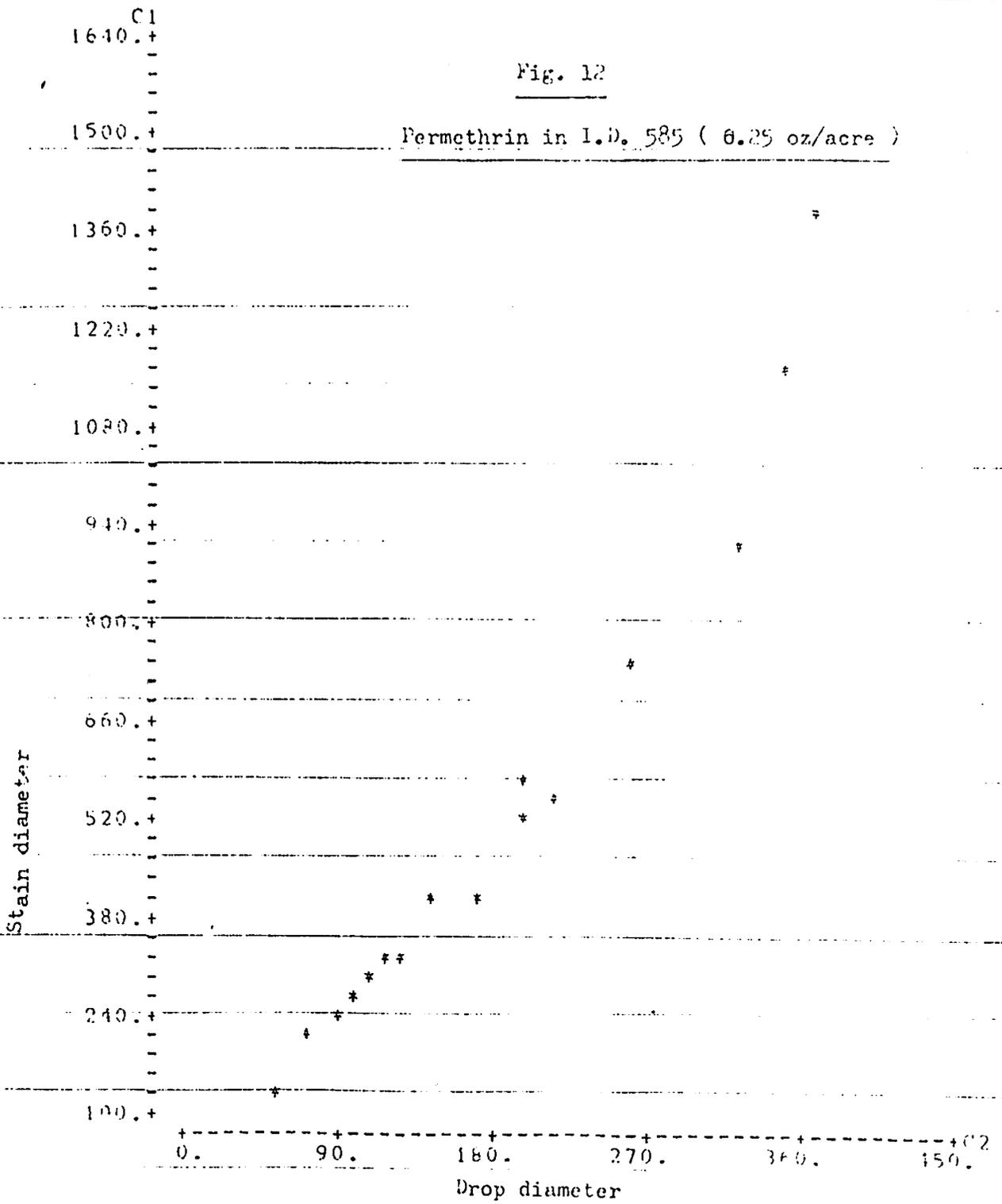


Table 13

Physico-Chemical Properties of Ingradient Oils and Formulations  
of Insecticides and Insect growth regulators

1. Insecticide Diluent - '585'

Temp. °C	Viscosity (cp)	Density (gm/ml)	Surface tension (dyne/cm)
25	1.59	0.841	25.6
20	1.84	0.845	26.0
15	1.97	0.850	26.3
10	2.07	0.852	26.4
5	2.22	0.853	26.8

2. Sunspray 7N oil

25	16.2	0.876	29.2
20	19.7	0.877	29.9
15	26.6	0.878	28.9
10	36.4	0.879	31.0
5	53.2	0.881	30.4

3. UC-62644 in Sunspray 7N oil (insect growth regulator) - (0.5 oz/acre)

25	16.8	0.906	29.0
20	23.3	0.906	29.6
15	29.8	0.907	31.4
10	39.8	0.911	32.0
5	68.5	0.916	31.4

.....continued

Table 13 (cont'd)

4. UC-62644 in Sunspray 7N oil (insect growth regulator) - 1.0 oz/acre.

Temp. °C	Viscosity (cp)	Density (gm/ml)	Surface Tension (dyne/cm)
25	27.6	0.926	34.1
20	30.3	0.927	35.4
15	37.9	0.928	36.8
10	46.6	0.929	38.9
5	72.7	0.930	41.8

5. Bay Sir 8514 in water (2 oz/acre)

25	1.405	1.072	40.5
20	1.410	1.074	42.8
15	1.387	1.076	44.4
10	1.333	1.078	44.2
5	1.304	1.080	45.1

6. Bay Sir 8514 in Sunspray 7N oil (3 oz/acre)

25	-*	0.930	-*
20	-	0.932	-
15	-	0.934	-
10	-	0.936	-
5	-	0.938	-

7. Bay Sir 8514 in Sunspray 7N oil (2 oz/acre)

25	-*	0.928	-*
20	-	0.930	-
15	-	0.932	-
10	-	0.933	-
5	-	0.934	-

\*Settled down too quickly to do measurements

.....continued

Table 13 (cont'd)

8. Bay Sir 8514 in Sunspray 7N oil with emulsifier (2 oz/acre)

Temp. °C	Viscosity (cp)	Density (gm/ml)	Surface Tension (dyne/cm)
25	23.5	0.930	29.5
20	30.9	0.931	31.0
15	44.0	0.933	32.0
10	62.0	0.934	32.9
5	88.0	0.936	34.7

9. Bay Sir 8514 in water (3 oz/acre)

25	1.68	1.072	36.2
20	1.86	1.073	40.2
15	2.05	1.074	41.0
10	2.22	1.074	41.2
5	2.69	1.075	42.9

10. Matacil in I.D. 585 oil - (1 oz/acre)

25	2.03	0.837	64.3
20	2.35	0.838	65.6
15	2.53	0.839	66.5
10	2.86	0.843	66-9
5	3.14	0.847	68.7

.....continued

Table 13 (cont'd)

11. Permethrin in I.D. 585 oil (0.25 oz/acre)

Temp. °C	Viscosity (cp)	Density (gm/ml)	Surface Tension (dyne/cm)
25	1.15	0.787	23.1
20	1.54	0.788	23.3
15	1.80	0.790	23.6
10	2.18	0.791	23.9
5	2.72	0.792	24.0

12. Reldan in I.D. 585 oil (1 oz/acre)

25	1.45	0.840	24.2
20	1.67	0.841	24.5
15	1.77	0.843	24.8
10	1.94	0.848	25.3
5	2.07	0.854	26.7

13. Water

25	0.894	0.9971	72.0
20	1.050	0.9982	72.8
15	1.140	0.9991	73.5
10	1.308	0.9997	74.2
5	1.519	1.0000	74.9

Fig. 13

Evaporation Rate of Water at 22°C and 45% R.H.

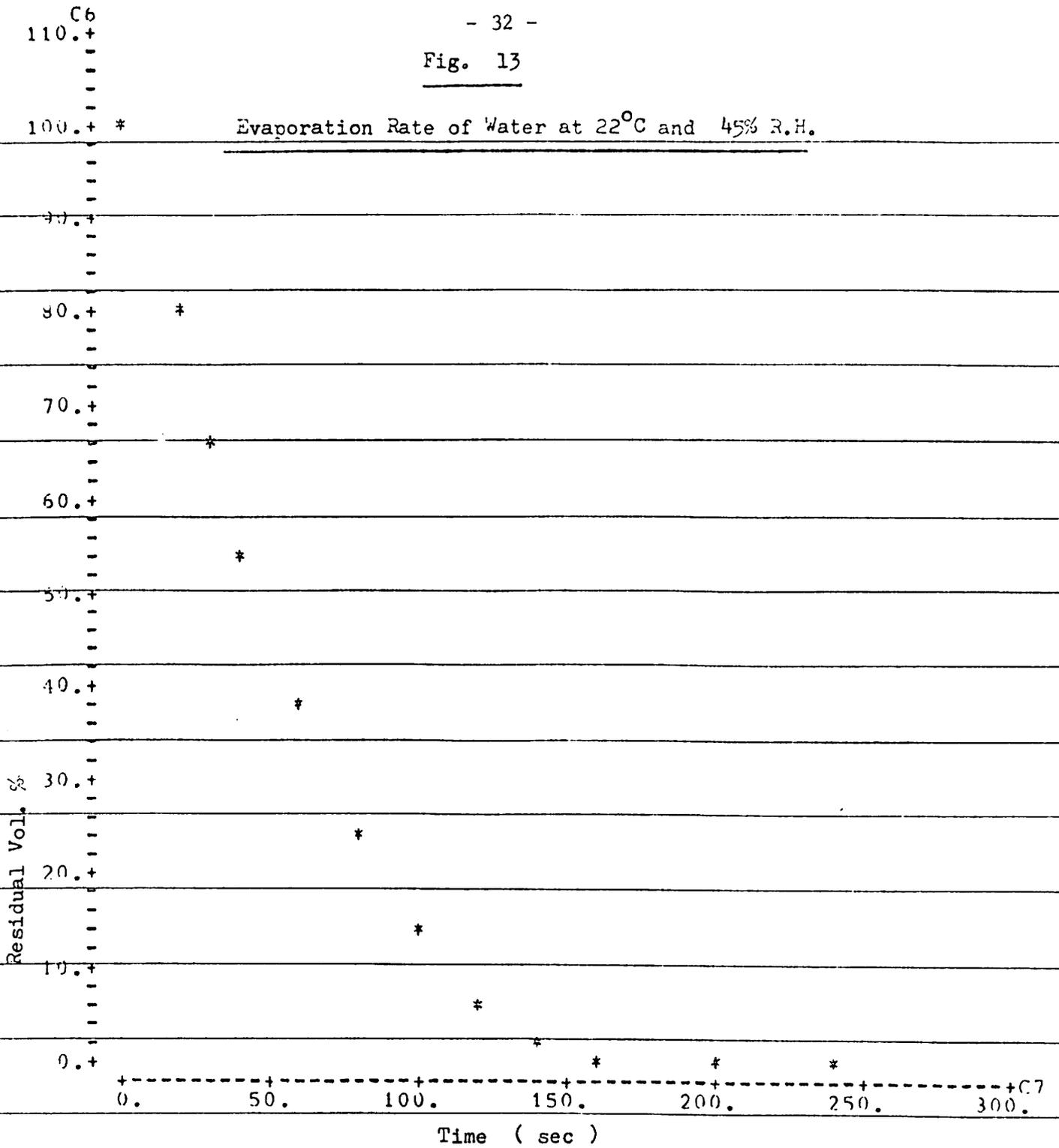


Table 14

Evaporation Rate of Water at 22°C and 45% Relative Humidity

No.	Time (sec.)	Drop diameter ( $\mu\text{m}$ )	Vol. ( $\pi/6$ ) ( $\mu\text{m}^3$ )	Residual Vol. (%)
1	0.	355.	44738876.	100.000
2	20.	330.	35937000.	80.326
3	30.	310.	29791000.	66.589
4	40.	290.	24389000.	54.514
5	60.	255.	16581375.	37.063
6	80.	220.	10648000.	23.800
7	100.	180.	5832000.	13.036
8	120.	140.	2744000.	6.133
9	140.	100.	1000000.	2.235
10	160.	60.	216000.	0.483
11	200.	20.	8000.	0.018
12	240.	0.	0.	0.000

Evaporation Rate of I.D. 585 at 22° C. and 45% R.H.

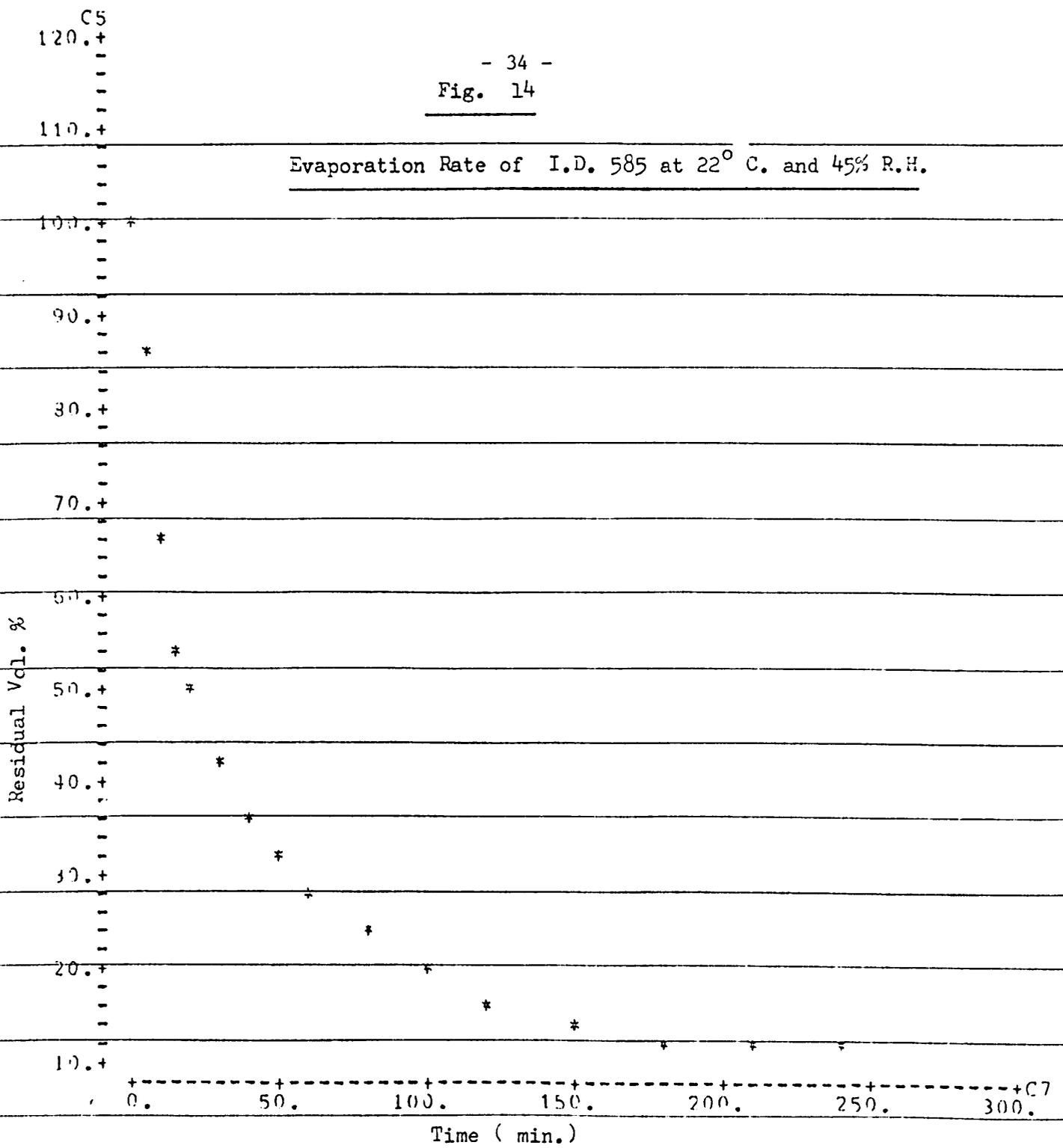


Table 15

Evaporation Rate of I.D. 585 at 22°C and 45% Relative Humidity

No.	Time (min.)	Drop diameter ( $\mu\text{m}$ )	Vol. ( $\pi/6$ ) ( $\mu\text{m}^3$ )	Residual vol. (%)
1	0.	390.	59319000.	100.000
2	5.	370.	50653000.	85.391
3	10.	340.	39304000.	66.259
4	15.	318.	32157432.	54.211
5	20.	310.	29791000.	50.222
6	30.	290.	24389000.	41.115
7	40.	277.	21253934.	35.830
8	50.	268.	19248832.	32.450
9	60.	258.	17173512.	28.951
10	80.	240.	13824000.	23.305
11	100.	227.	11697083.	19.719
12	120.	215.	9938375.	16.754
13	150.	200.	8000000.	13.486
14	180.	196.	7529536.	12.693
15	210.	194.	7301384.	12.309
16	240.	192.	7077888.	11.932

Fig. 15

Evaporation Rate of Matacil in I.D. 585 at 22°C  
and 45 % Relative Humidity.

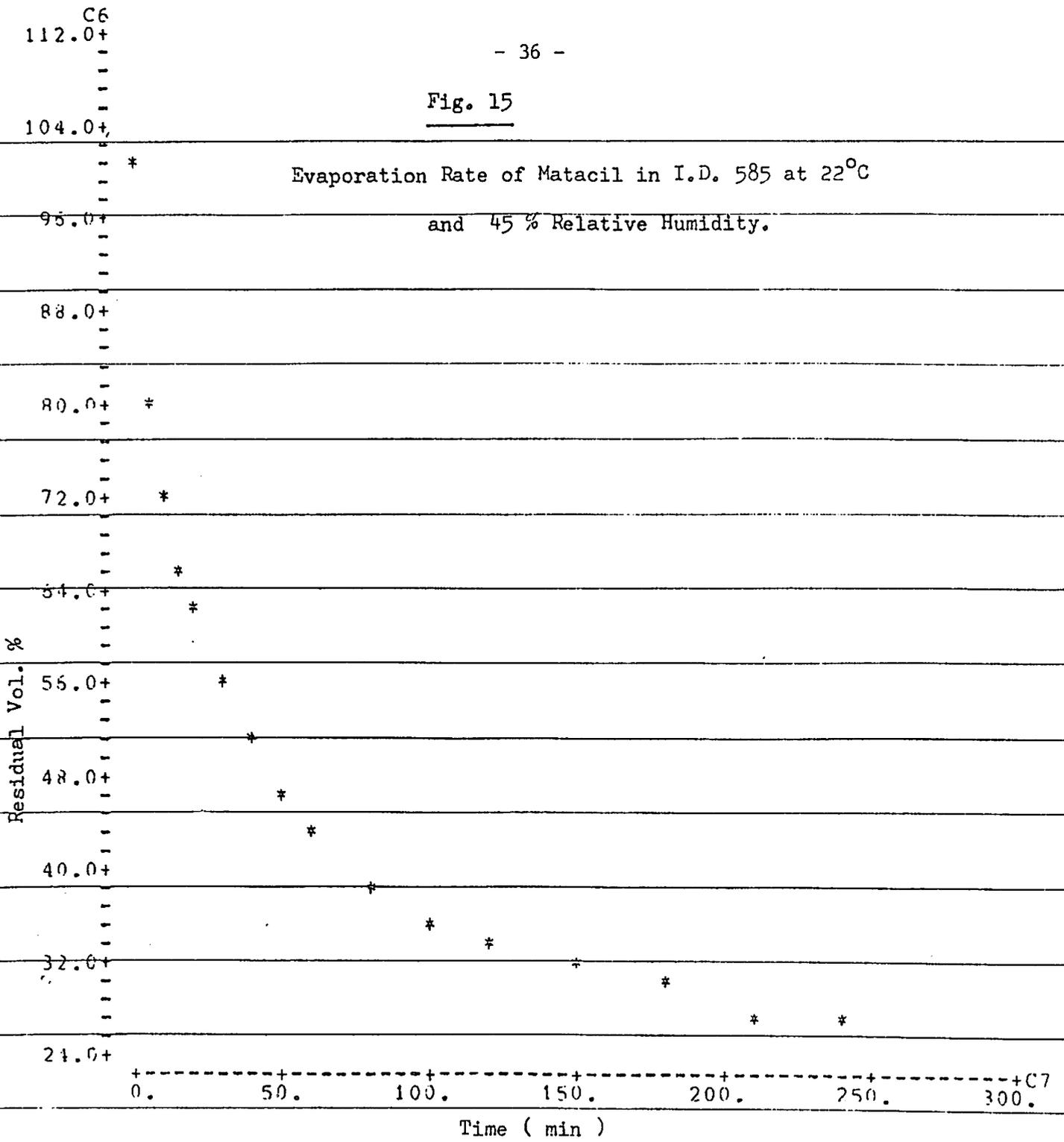


Table 16

Evaporation Rate of Matacil in I.D. 585 at 22°C  
and 45% Relative Humidity

No.	Time (min.)	Drop diameter ( $\mu\text{m}$ )	Vol. ( $\pi/6$ ) ( $\mu\text{m}^3$ )	Residual vol. (%)
1	0.	345.	41063624.	100.000
2	5.	321.	33076162.	80.549
3	10.	310.	29791000.	72.548
4	15.	300.	27000000.	65.752
5	20.	295.	25672376.	62.519
6	30.	285.	23149126.	56.374
7	40.	275.	20796876.	50.645
8	50.	267.	19034164.	46.353
9	60.	260.	17576000.	42.802
10	80.	252.	16003008.	38.971
11	100.	245.	14706125.	35.813
12	120.	240.	13824000.	33.665
13	150.	235.	13977875.	31.604
14	180.	230.	12167000.	29.630
15	210.	225.	11390625.	27.739
16	240.	225.	11390625.	27.739

C6  
120.+

Fig. 16

Evaporation Rate of Reldan in I.D.585 at 22°C  
and 45 % Relative Humidity.

110.+  
100.+ \*  
90.+  
80.+ \*  
70.+ \*  
60.+ \*  
50.+ \*  
40.+ \*  
30.+ \*  
20.+ \*  
10.+

0. 50. 100. 150. 200. 250. 300. C7

Time ( min )

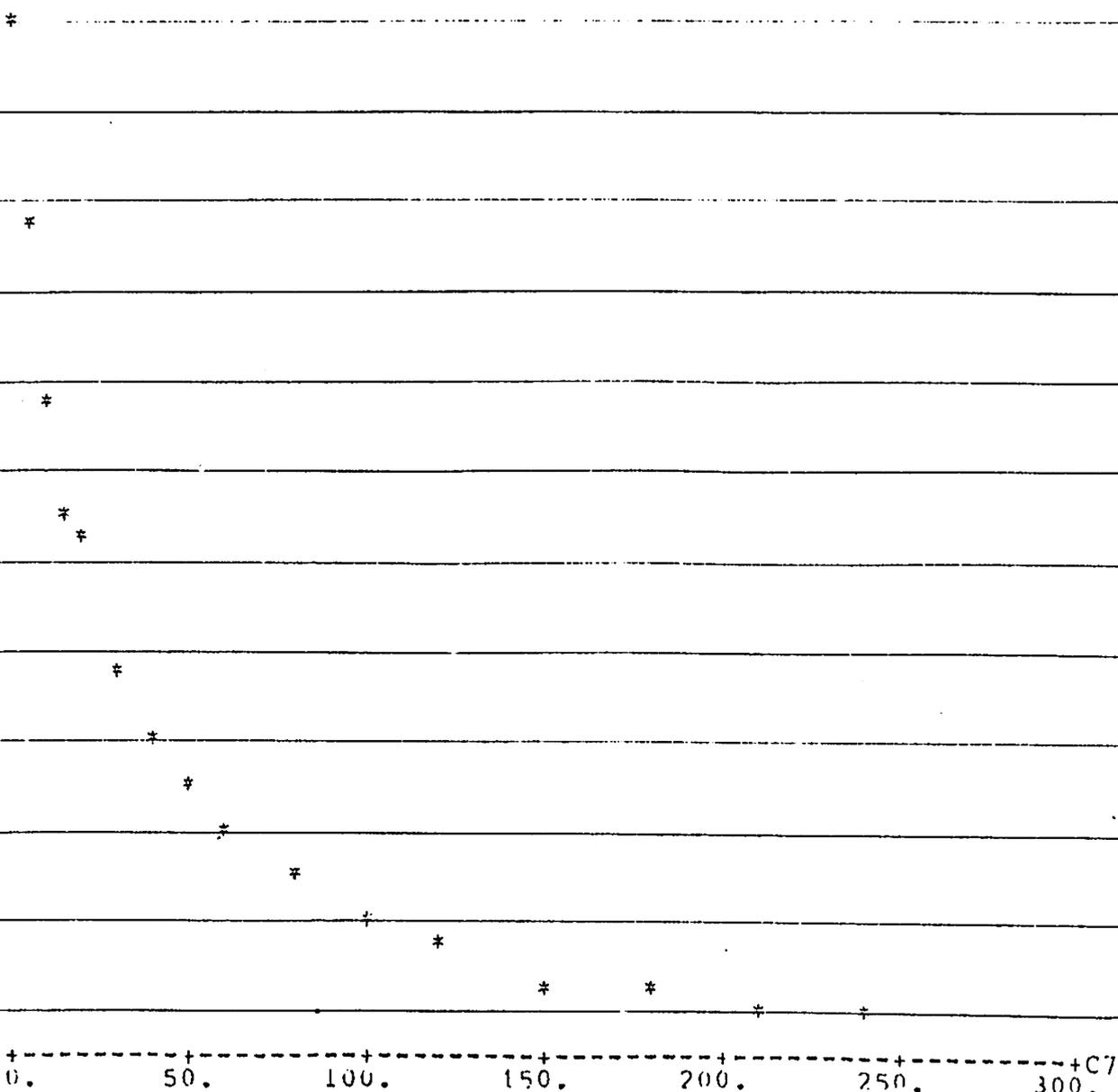


Table 17

Evaporation Rate of Reldan in I.D. 585 at 22°C  
and 45% Relative humidity

No.	Time (min.)	Drop diameter ( $\mu\text{m}$ )	Vol. ( $\pi/6$ ) ( $\mu\text{m}^3$ )	Residual vol. (%)
1	0.	400.	64000000.	100.000
2	5.	375.	52734376.	82.397
3	10.	350.	42875000.	66.992
4	15.	330.	35937000.	56.152
5	20.	325.	34328124.	53.638
6	30.	300.	27000000.	42.187
7	40.	285.	23149126.	36.171
8	50.	275.	20796876.	32.495
9	60.	262.	17984728.	28.101
10	80.	250.	15625000.	24.414
11	100.	237.	13312053.	20.800
12	120.	225.	11390625.	17.798
13	150.	212.	9528128.	14.888
14	180.	206.	8741816.	13.659
15	210.	200.	8000000.	12.500
16	240.	200.	8000000.	12.500

Fig. 17

Evaporation Rate of Permethrin in I.D. 585 at 22°C  
and 45 % Relative Humidity.

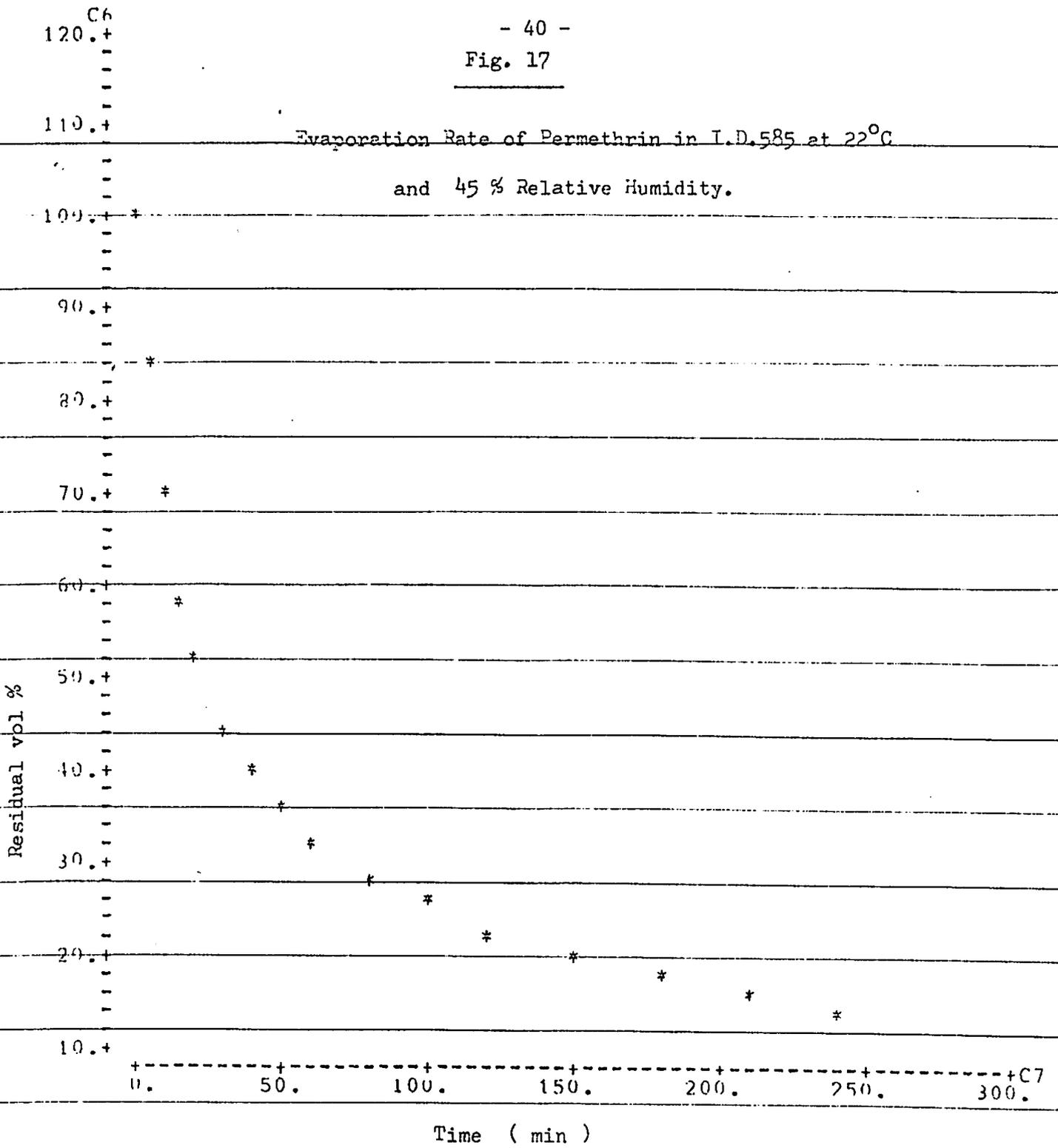


Table 18

Evaporation Rate of Permethrin in I.D. 585 at 22°C  
and 45% Relative humidity

No.	Time (min.)	Drop diameter ( $\mu\text{m}$ )	Vol. ( /6) ( $\mu\text{m}^3$ )	Residual vol. (%)
1	0.	360.	46656000.	100.000
2	5.	340.	39305000.	84.242
3	10.	320.	32768000.	70.233
4	15.	300.	27000000.	57.870
5	20.	288.	23887872.	51.200
6	30.	275.	20796876.	44.575
7	40.	265.	18609626.	39.887
8	50.	255.	16581375.	35.540
9	60.	248.	15252992.	32.692
10	80.	238.	13481272.	28.895
11	100.	228.	11852352.	25.404
12	120.	215.	9938375.	21.301
13	150.	209.	9129329.	19.567
14	180.	202.	8242408.	17.666
15	210.	196.	7529536.	16.138
16	240.	190.	6859000.	14.701

100.0+ \*

Fig. 18

Evaporation Rate of Sunspray 7N Oil at 22°C  
and 45% relative humidity.

Residual Vol. %

95.0+

92.0+

88.0+

84.0+

80.0+

76.0+

72.0+

68.0+

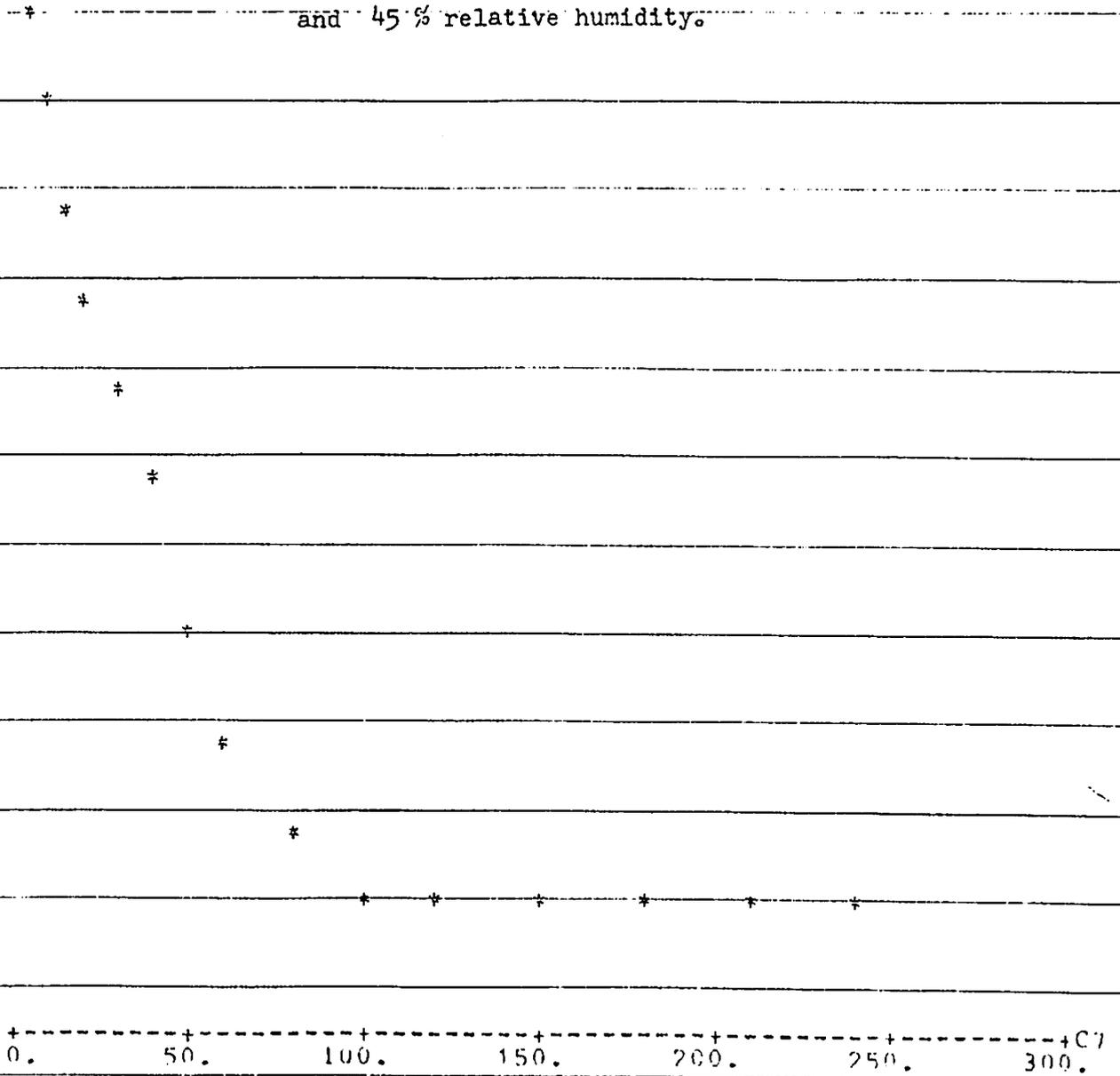
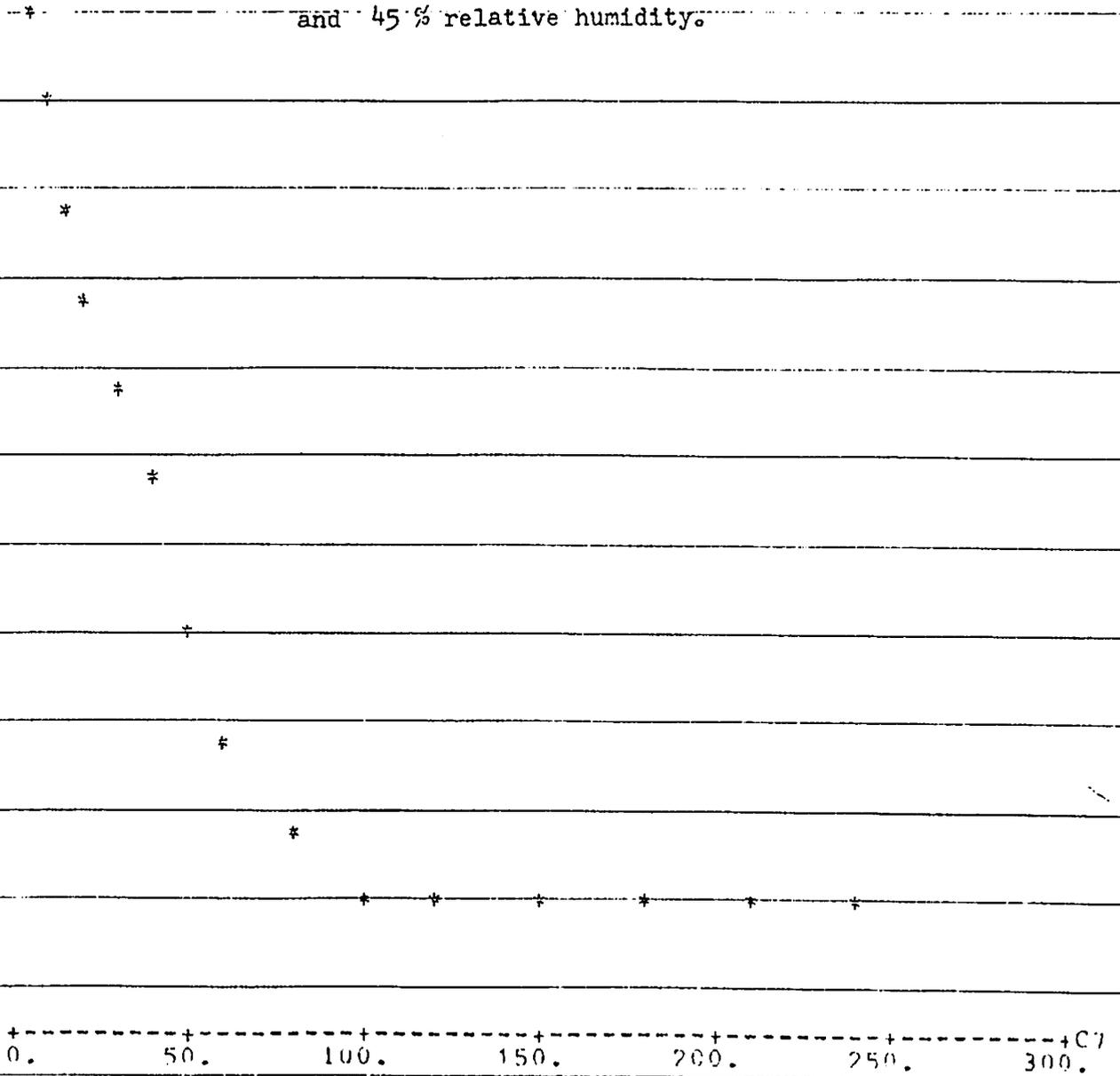
64.0+

60.0+

56.0+

0. 50. 100. 150. 200. 250. 300. (min)

Time (min)



Time (min)	Residual Vol. %
0	100.0
10	95.0
20	90.0
30	85.0
40	80.0
50	76.0
75	72.0
100	68.0
125	64.0
150	60.0
175	60.0
200	60.0
225	60.0
250	60.0
275	60.0

Table 19

Evaporation Rate of Sunspray 7N oil at 22°C  
and 45% Relative humidity

No.	Time (min.)	Drop diameter ( $\mu\text{m}$ )	Vol. ( $\pi/6$ ) ( $\mu\text{m}$ )	Residual vol. (%)
1	0.	380.	54872000.	100.000
2	5.	370.	50653000.	92.311
3	10.	365.	48527124.	88.619
4	15.	360.	46656000.	85.027
5	20.	355.	44738876.	81.533
6	30.	350.	42875000.	78.136
7	40.	345.	41063624.	74.835
8	50.	337.	38272752.	69.749
9	60.	330.	35937000.	65.492
10	80.	325.	34328124.	62.560
11	100.	320.	32768000.	59.717
12	120.	320.	32768000.	59.717
13	150.	320.	32768000.	59.717
14	180.	320.	32768000.	59.717
15	210.	320.	32768000.	59.717
16	240.	320.	32768000.	59.717

Fig. 19

Evapotation Rate of UC - 62644 in Sunspray 7N oil  
at 22°C and 45% Relative Humidity.  
( 0.5 oz/acre )

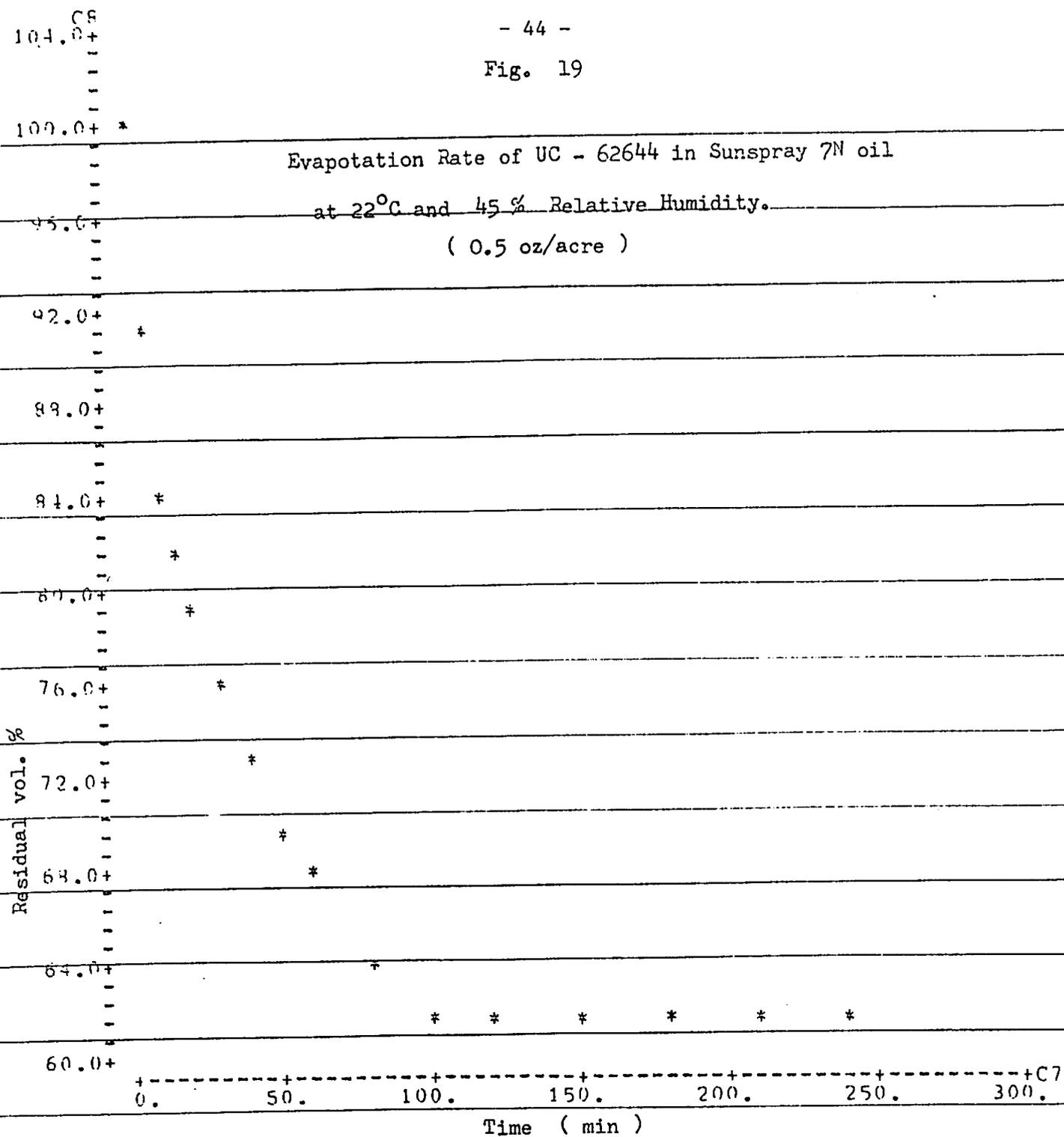


Table 20

Evaporation Rate of UC-62644 in 7N oil at 22°C  
and 45% Relative humidity (0.5 oz/acre)

No.	Time (min.)	Drop diameter ( $\mu\text{m}$ )	Vol. ( $\pi/6$ ) ( $\mu\text{m}^3$ )	Residual vol. (%)
1	0.	400.	64000000.	100.000
2	5.	388.	58411072.	91.267
3	10.	378.	54010152.	84.391
4	15.	374.	52313624.	81.740
5	20.	370.	50653000.	79.145
6	30.	365.	48627124.	75.980
7	40.	360.	56656000.	72.900
8	50.	355.	44738876.	69.904
9	60.	352.	43614208.	68.147
10	80.	345.	41063624.	64.162
11	100.	340.	39304000.	61.413
12	120.	340.	39304000.	61.413
13	150.	340.	39304000.	61.413
14	180.	340.	39304000.	61.413
15	210.	340.	39304000.	61.413
16	240.	340.	39304000.	61.413

Fig. 20

Evaporation Rate of UC - 62644 in Sunspray 7N oil at 22°C  
and 45 % Relative Humidity ( 1.0 oz/acre )

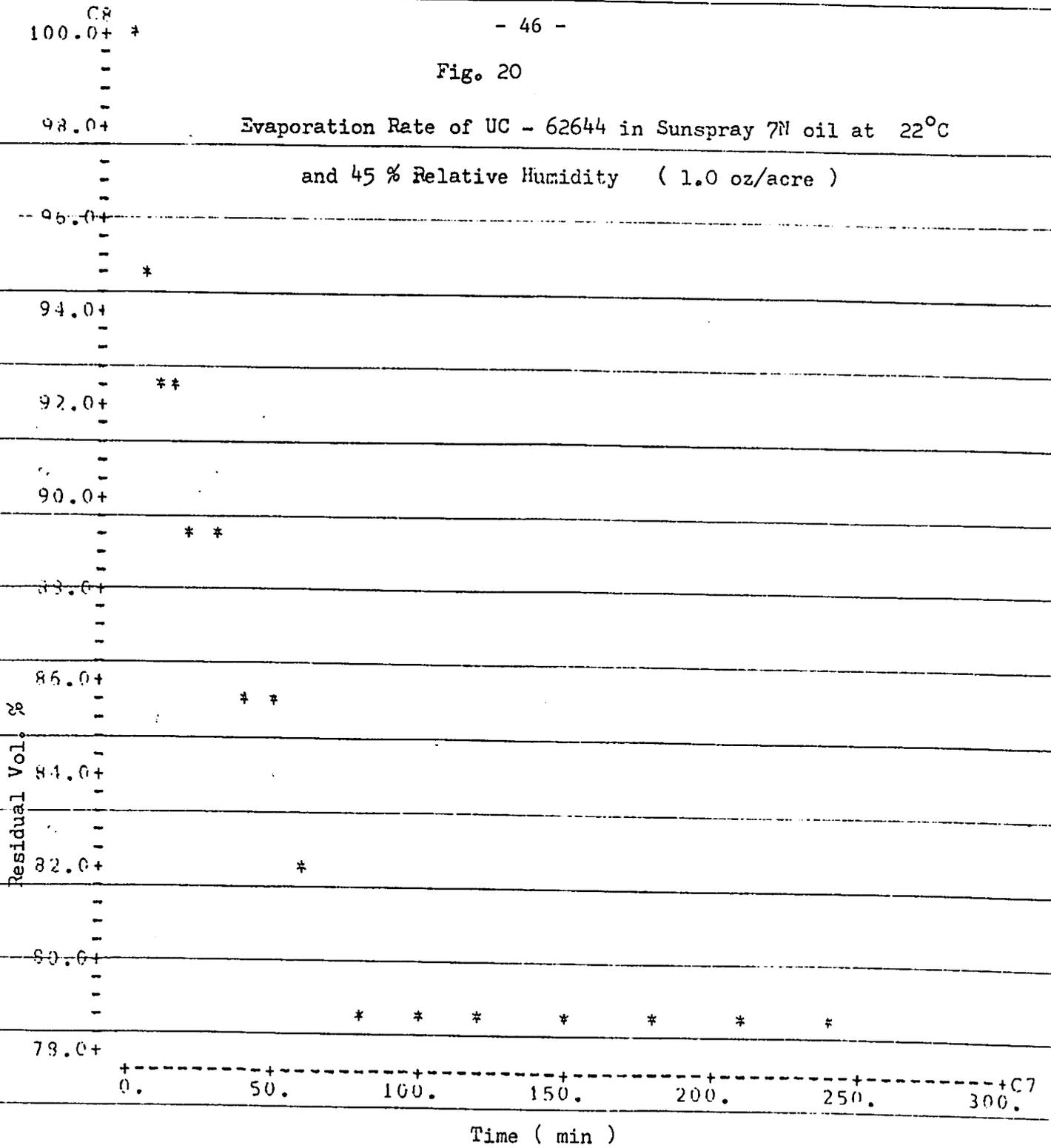


Table 21

Evaporation Rate of UC - 62644 in 7N oil at 22°C  
and 45% Relative humidity (1.0 oz/acre)

No.	Time (min.)	Drop diameter ( $\mu\text{m}$ )	Vol. $(\pi/6)$ ( $\mu\text{m}^3$ )	Residual vol. (%)
1	0.	395.	61629876.	100.000
2	5.	388.	58411072.	94.777
3	10.	385.	57066624.	92.596
4	15.	385.	57066624.	92.596
5	20.	380.	54872000.	89.035
6	30.	380.	54872000.	89.035
7	40.	375.	52734376.	85.566
8	50.	375.	52734376.	85.566
9	60.	370.	50653000.	82.189
10	80.	365.	48627124.	78.902
11	100.	365.	48627124.	78.902
12	120.	365.	48627124.	78.902
13	150.	365.	48627124.	78.902
14	180.	365.	48627124.	78.902
15	210.	365.	48627124.	78.902
16	240.	365.	48627124.	78.902

Table 22

Spray Formulations Used in Summer 1980  
For Determining Physico-Chemical Properties

Plot No.	Dye used	Active ingredient (oz/acre) in 0.5 U.S. gallon
<u>Dr. Retnakaran's Formulations</u>		
1	Automate-B Red	0.5 oz/acre UC-62644 in Sunspray 7N oil
2	Automate-B Red	1.0 oz/acre UC-62644 in Sunspray 7N oil
3	Erio Acid Red	2.0 oz/acre Bay Sir 8514 in water
4	Automate-B Red	3.0 oz/acre Bay Sir 8514 in Sunspray 7N oil
5	Automate-B Red	2.0 oz/acre Bay Sir 8514 in Sunspray 7N oil
6	Automate-B Red	2.0 oz/acre Bay Sir 8514 in Sunspray 7N oil + Emulsifier
7	Erio Acid Red	3.0 oz/acre Bay Sir 8514 in water
8	Automate-B Red	1.0 oz/acre Matacil in I.D. 585 oil

.....cont'd.

Table 22 (cont'd)

Plot No.	Dye used	Active ingredient (oz/acre) in 0.5 U.S. gallon
<u>Mr. Cadogan's Formulations</u>		
A	Automate-B Red	1.0 oz/acre Reldan in I.D. 585
B	Automate-B Red	0.25 oz/acre Permethrin in I.D. 585

## DISCUSSION

The objective of any field application is to provide optimum coverage of the area to be protected. This can be achieved by maximizing the number of target hits and minimizing loss due to environmental drift, and loss due to ground contamination. The type of coverage obtained will depend on several factors which include droplet size spectrum, droplet density (droplets/area) and nature of formulation employed. The physico-chemical properties that affect the drop size range released by the spray nozzle are: viscosity, density and surface tension; the droplet size range at the target site depends not only on the three properties mentioned but also on the vapour pressure of the formulation components. The rate of evaporation in still air under the laboratory conditions is an approximate measure of the rate of evaporation under variable conditions of wind speed and temperature.

From the results obtained for the oil-based spray mixes, it is apparent that there is a definite relationship between viscosity and evaporation rate data; the higher the viscosity of the spray mix, the lower is the tendency to evaporate. For instance the diluent I.D. 585 has a low viscosity but a high evaporation rate. The oil Sunspray 7N has a high viscosity and a low evaporation rate. Moreover, the addition of other ingredients to the oils increased the viscosity but decreased the volatility. With respect to the spread factor data, there seems to be no direct relationship between the spreading ability of an oil and viscosity or surface tension. However, the addition of other ingredients appear to decrease the spreading ability. This is evident with both I.D. 585 and Sunspray 7N.

To understand the spray kinetics during an aerial application and spray dynamics in the environment, a study of the above physico-chemical properties is important. Further work using a variety of nozzles, to test the aerosol generation depending on formulation properties would elucidate on the direct application of the above measured parameters in spray kinetics and physics.

The author wishes to thank Dr. A. Retnakaran and Mr. L. Cadogan for supplying solvents, vehicle oils, emulsifiers and spray formulations and supporting the investigation of the physico-chemical properties.