DISTRIBUTION, PERSISTENCE AND FATE OF MATACIL® FORMULATIONS IN A FOREST ECOSYSTEM

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INTRODUCTION

Aminocarb (Trade name: Matacil®) [4-dimethylamino-m-tolyl N-methylcarbamate] has been used for spruce budworm [Choristoneura fumiferana (Clem.)] control in eastern Canada, first experimentally and then operationally since 1970 and to date ca 1.0×10^6 kg of the material has been sprayed over 10×10^6 ha of forest. Usually the insecticide is applied by aircraft at 2×0.07 kg/ha as a homogeneous oil formulation (Matacil 1.8D*) containing (Wt. %) aminocarb 19.5, Shell insecticide diluent 585 (Shell Canada Ltd., Toronto, Ont., Canada) 30.0, and nonylphenol (Rohm and Hass Canada Ltd., West Hill, Ont., Canada) 50.5. Since nonylphenol, the major adjuvant in the formulation, is found to be toxic to juvenile Atlantic salmon, Salmo salar, Chemagro Chemical Company in Toronto the marketers of Matacil® recently introduced a flowable suspension, Matacil 1.8F®**, containing air-milled particles of aminocarb (2-3 μm D) suspended in oil, which can be used

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* 1.8D = 1.8 lbs of AI (active ingredient)/Imp. gal.
1.0 US gal. = 0.833 Imp. gal. (1 Imp. gal. = 1.2 US gal).
1.8 D = 1.5 D i.e. 1.5 lbs of AI/US gal.

**1.8F = 1.8 lbs of AI/Imp. gal.
1.8F = 1.5 F, i.e., 1.5 lbs of AI/US gal.

Converting to metric from Imp. and US measures using the conversion factors 1 Imp gal. = 4.546 L, 1 US gal. = 3.785 L and 1 lb = 453.6 g.

1.8 lbs AI (1.8D or 1.8F)/Imp. gal. = 1.5 lbs AI (1.5D or 1.5F)/US gal. = 180 g AI/L.

To avoid confusion and to maintain uniformity the nomenclature of the Matacil® formulations in this report are based on metric measures representing the number of grams of AI present per liter of the formulation. So the conventional oil formulation used prior to 1981 is represented as 180D and the new flowable ones as 180FO [180 F (oil)] and 180FE [180F (emulsion)] respectively.

either as a water-based (1.5 F emulsion) or as an oil-based (1.5F oil) formulation for aerial application. During the 1981 field season, a joint experimental spray program was undertaken by the scientists in efficacy and environmental chemistry sections of this Institute, to field test these three formulations viz., 180 D [1.5 D (oil)], 180 FO [1.5F (oil)] and 180 FE [1.5 F (emulsion)] of aminocarb in a forest near Bathurst (N.B.) for studying their distribution, persistence and fate in different compartments of the environment as well as to evaluate their efficacy on spruce budworm. This preliminary report* deals only with the chemical aspects of the spray operation. The results on efficacy will be published separately by the scientists concerned.

MATERIALS AND METHODS

Plot selection

Four 50-ha (1000 m x 500 m) spray plots (PI, PIII, PV and C) located** farther apart from one another, to avoid contamination of the insecticide by drift, were selected in a mixed, mature coniferous

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* A comprehensive and indepth evaluation on the environmental fate of aminocarb present in these three formulations will come out as a journal publication on a later date.

**Plot location:

PI	47° 33' N+, 65° 56' W++	+ Latitude
PIII	47° 33' N, 65° 57' W	++ Longitude
PV	47° 33' N, 65° 59' W	
C	47° 30' N, 66° 01' W	

forest* about 40 km southwest of Bathurst, N.B. (Fig. 1) for the Matacil® treatment. Plots PI, PIII and PV served as treatment plots and plot C served as the control. Most of the trees in the plots showed evidence of moderate to severe defoliation due to spruce budworm outbreak in past years and the crowns were not well developed. Twelve nearly uniform size and shape balsam fir, Abies balsamea (L.) (Mill.) trees ca 14.0 m in height and DBH 16.5 cm with reasonable foliage content were selected randomly in each plot transecting it partly across the centre. They were tagged with plastic ribbon and numbered as 1 to 12 prefixed with the block number to identify the trees selected in each block. Layout of trees in the three spray plots are given in Figs. 2 to 4. Ground vegetation and neighbouring trees surrounding each sampling tree were cleared up to a radius of 5 m to enhance exposure to spray cloud.

Matacil® was applied twice to each experimental plot (PI, PIII and PV) at 70 g AI/ha per application. The composition of each tank mix

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*Plot composition:

PI Mature soft and hardwood stand consisting of 50% balsam fir, 20% spruce (Red/white), 10 sugar maple, 10% red maple and 10% beech. Canopy cover ca > 90%.

PIII Immature soft and hardwood stand consisting of 30% balsam fir, 20% spruce (red/white), 30% red maple, 20% birch (yellow and white). Canopy cover > 90%.

Plot V Mature soft and hardwood stand consisting of 30% balsam, 30% spruce (red/white), 20% red maple and 20% other species. Canopy cover > 90%.

Plot C Softwood mature stand consisting of 70 balsam fir, 20% spruce (red/white) and 10% other species. Canopy cover 90%.

(volume %), dosage of AI/ha, application rate and the plots sprayed with are given in Table 1. Aircraft/spray data, spray parameters and meteorological conditions existed during the spraying are given in Tables 2 and 3 respectively.

Sampling and analysis of Substrates

Sampling, storage, transportation and final sample preparation of foliage, forest litter and soil samples were done according to the established procedure developed in this laboratory. The only difference in foliage sampling has been the collection of the new foliage including the buds of the current season along with the needles of the previous season's growth for the residue analysis. This change in sampling has been necessitated due to the severe defoliation of the trees; consequently sufficient foliage samples from last year's growth alone were not adequate for the residue analysis.

The extraction, cleanup and gas chromatographic analysis of aminocarb residues present in foliage, litter and soil samples were carried out according to the established method developed by the author at this Institute.

Ground spray deposit assessment

Two glass slides (7.5 cm x 5.0 cm) along with a Kromekote® card (10 cm x 10 cm) mounted on a folding aluminum plate (collection unit) were used for droplet size and deposit assessments. Forty-four collection units per plot were placed on aluminum stands ca 15 cm above the ground level for each spray application. The collection units were positioned in the plot 0.5 hr prior to application as follows:

Litter plot	4 collection units (N, S, E and W)
Soil plot	4 collection units (N, S, E and W)
Sampling tree	3 collection units per tree (12 trees) - 1 upwind under tree, 1 downwind under tree, and 1 upwind in open.

Total number of collection units/plot/application = 44.

Care was taken to ensure that ground vegetation did not obscure the surface of the collection units in any way.

The collection units were collected 1 hr after the spray application, transported immediately to the field laboratory where the deposits on the glass plates were removed by washing with 3 x 5 ml of pesticide grade ethyl acetate and the eluates were stored in tightly sealed amber coloured bottles away from heat and sunlight.

In the laboratory, the eluates were first analyzed for the AI by GLC and later flash evaporated them gently to dryness and the residues were taken either in toluene (Automate B Red) or methanol (Rhodamine B) for colorimeteric analysis of the dye tracer.

The Kromekote cards were examined under magnification and the spots recorded. The resulting counts were grouped according to size and from these the droplet size sepctrum was calculated using the spread factor (S.F.) values. From the droplet size spectrum deposit densities (g AI/ha) were calculated.

TABLE 1

Composition of tank mix, dosage and application rate

Formulation	Composition of tank mix (volume %)	Plots sprayed	Dosage AI/ha	Application rate (L/ha)
180 FE	Aminocarb 25.93%, Atlox® 3409F[1] 1.27%, Water 72.27%, Rhodamine B[2] 0.53%	PI	70	1.5
180 FO	Aminocarb 25.93%, Shell I.D. 585[3] 72.07%, Automate B Red[4] 2%.	PIII	70	1.5
180 D	Aminocarb 25.93% Sunspray 6N oil[5] 72.07%, Automate B Red 2%	PV	70	1.5

[1]Atlox 3409F emulsifier supplied by Atlas Chemical Industries, Brantford, Ont., Canada

[2]Rhodamine B (dye tracer) supplied by Allied Chemicals, Morristown, New Jersey, U.S.A.

[3]Shell insecticide diluent 585 supplied by Shell Canada Ltd.; Toronto, Ont., Canada.

[4]Automate B Red (dye tracer) supplied by Morton Williams Ltd., Ajax, Ont., Canada.

[5]Sunspray 6N oil supplied by Sun Oil Co., Philadelphia, Pa., 19103, U.S.A. (Canadian supplier: Shell Canada)

TABLE 2

Aircraft/Spray Data

Aircraft type	:	Cessna 188
Spray speed	:	160 km/hr
Atomiser	:	4 Micronair AU3000 with blade setting at 28°
Spray height (average)	:	25-30 m
Emission rate	:	24.5 L/min.
Swath width	:	60 m
Application rate	:	1.5 L/ha

TABLE 3

Meteorological Data

Parameters	Plots					
	PI		PIII		PV	
	1st Application	2nd Application	1st Application	2nd Application	1st Application	2nd Application
Date of application (1981)	June 12	June 18	June 12	June 18	June 13	June 18
Time of application (hrs)	1945	0622	2100	0720	2035	2023
Wind speed (mean)(km/hr)	0.25	1.0	0	5	0	1.5
Wind direction	E	W	-	W	-	W
Temp (mean)(°C)	13.00	10.25	10.00	13.75	16.50	22.25
Relative humidity (%)	80	100	96	73	73	58
Precipitation	Nil	Nil	Nil	Nil	Nil	Nil
Cloud cover	1/10	0/10	0/10	0/10	0/10	0/10

TABLE 4

Deposit Data for Plots PI, PIII and PV

Studies	PI		PIII		PV	
	1st Application	2nd Application	1st Application	2nd Application	1st Application	2nd Application
Drops/cm^2	6 + 6	0.5 ± 0.4	13 ± 6	3 ± 1	16 ± 6	13 ± 6
Dmin (μm)	7	7	16	4	4	4
Dmax (μm)	73	73	85	85	105	105
Number mode (μm)	30-40	15-35	35-45	10-40	50-60	50-80
N.M.D. (μm)	28 ± 3	23 ± 3	35 ± 6	21 ± 3	50 ± 7	58 ± 8
V.M.D. (μm)	36 ± 5	33 ± 5	41 ± 5	39 ± 6	65 ± 9	68 ± 9
S.F.	3.1 ± 0.1	3.1 ± 0.1	5.0 ± 0.1 - 5.7 ± 0.2	5.0 ± 0.1 - 5.7 ± 0.2	3.8 ± 0.1 - 5.5 ± 0.2	3.8 ± 0.1 - 5.5 ± 0.2
Spot Counting (g/ha)*	0.57 (0.81%)	0.05 (0.07%)	2.2 (3.1%)	0.23 (0.32%)	8.5 (12%)	9.9 (14%)
GLC (g/ha)*	1.98 (2.8%)	0.26 (0.37%)	5.95 (8.5%)	0.87 (1.2%)	11.7 (17%)	13.5 (19%)
Colorimetry (g/ha)*	2.45 (3.5%)	0.91 (1.3%)	7.50 (11%)	1.03 (1.5%)	9.95 (14%)	12.5 (18%)
Dosage (g AI/ha)	70	70	70	70	70	70
Vol. sprayed (L/ha)	1.5	1.5	1.5	1.5	1.5	1.5
Conc. of AI in tank mix (GLC)(Wt/vol) %**	4.73	5.78	4.38	4.69	4.39	4.71

*Values in parenthesis represent the percent of AI reached the forest floor.
**Spray formulation is supposed to contain 4.67 g AI/100 ml.

TABLE 5

Aminocarb Residues in B. fir Foliage from Plot I

Time after spraying	Aminocarb concentration (ppm)					
	1st Application			2nd Application		
	As sampled	% Moisture content	Oven-dry*	As sampled	% Moisture content	Oven-dry*
0.5 h	2.41	60	6.03	0.75	66	2.21
1.0 h	1.86	61	4.77	0.96	65	2.74
4.0 h	1.54	62	4.05	0.85	63	2.30
12.0 h	1.37	66	4.03	0.70	64	1.94
15.0 h	1.12	64	3.11	0.66	58	1.57
1 d	0.88	58	2.10	0.68	59	1.66
2 d	0.48	63	1.30	0.63	61	1.62
3 d	0.35	69	1.13	0.58	60	1.45
4 d	0.27	66	0.79	0.55	58	1.31
5 d	0.20	65	0.57	0.51	60	1.28
6 d				0.45	62	1.18
8 d				0.35	64	.97
10 d				0.29	60	0.73
12 d				0.24	57	0.56
21 d				0.14	59	0.34

*Moisture content was determined as per the A.O.A.C. Offical Methods of Analysis, 8th Edn. 1955 by drying 2 x 10 g duplicates of each sample at 105°C for 16 hrs. in a thermostatic oven.

Detection limit of aminocarb in wet foliage 0.005 ppm.
Trace 0.008 ppm based on wet weight of foliage.

TABLE 6

Aminocarb Residues in B. fir Foliage from Plot III

Time after spraying	Aminocarb concentration (ppm)					
	1st Application			2nd Application		
	As sampled	% Moisture content	Oven-dry	As sampled	% Moisture content	Oven-dry
0.5 h	2.27	61	5.82	0.85	56	1.93
1.0 h	1.98	61	5.08	1.79	57	4.16
4.0 h	1.67	62	4.40	1.44	59	3.51
12.0 h	1.45	66	4.26	1.16	62	3.05
15.0 h	1.36	62	3.58	1.12	62	2.95
1 d	1.31	57	3.05	1.06	63	2.86
2 d	1.14	59	2.78	1.02	64	2.83
3 d	0.79	62	2.08	0.98	66	2.83
4 d	0.57	60	1.43	0.88	64	2.44
5 d	0.38	64	1.06	0.69	65	1.97
6 d				0.58	64	1.61
8 d				0.51	58	1.21
10 d				0.48	60	1.20
12 d				0.44	61	1.13
21 d				0.32	59	0.78

See footnotes in Table 5

TABLE 7

Aminocarb Residues in B. fir Foliage from Plot V

Time after spraying	Aminocarb concentration (ppm)					
	1st Application			2nd Application		
	As sampled	% Moisture content	Oven-dry	As sampled	% Moisture content	Oven-dry
0.5 h	0.77	58	1.83	2.35	56	5.34
1.0 h	1.30	60	3.25	2.76	58	6.57
4.0 h	1.15	61	2.95	2.69	58	6.41
12.0 h	1.01	63	2.73	2.04	62	5.37
15.0 h	0.96	62	2.53	1.92	64	5.33
1 d	0.87	62	2.29	1.68	64	4.67
2 d	0.72	63	1.95	1.59	63	4.30
3 d	0.68	64	1.89	1.43	61	3.67
4 d	0.61	63	1.65	1.36	60	3.40
5 d	0.52	62	1.37	1.23	63	3.32
6 d				1.19	59	2.90
8 d				0.97	63	2.62
10 d				0.92	59	2.24
12 d				0.84	60	2.10
21 d				0.64	61	1.64

See footnotes in Table 5

TABLE 8

Aminocarb Residues in Forest Litter from Plot I

Time after spraying	Aminocarb concentration (ppm)	
	1st application	2nd application
0.25 h	0.018 (0.024)	0.016 (0.021)
0.50 h	0.023 (0.031)	0.018 (0.023)
1.0 h	0.022 (0.029)	0.015 (0.022)
3.0 h	0.023 (0.029)	0.016 (0.021)
5.0 h	0.018 (0.024)	0.016 (0.022)
12.0 h	0.015 (0.021)	0.014 (0.019)
1 d	0.018 (0.024)	0.012 (0.015)
2 d	0.015 (0.022)	0.012 (0.016)
3 d	0.017 (0.024)	0.010 (0.012)
4 d	0.014 (0.020)	0.007 (0.009)
5 d	0.015 (0.020)	0.006 (0.008)
6 d		0.007 (0.008)
8 d		0.005 (0.007)
10 d		0.006 (0.009)
12 d		T
21 d		N.D.

T = Trace 0.005 ppm based on wet weight of litter.
N.D. = Not detectable; detection limit 0.003 ppm based on wet weight in litter.

Values in parentheses are for oven-dry litter samples.

Percent moisture content of litter samples is not given since it can be calculated from the folowing expression:

$$\text{Percent moisture content of litter} = \left[\frac{\left[(\text{Aminocarb in oven-dry litter sample}) - (\text{Aminocarb in wet litter sample})\right] \times 100}{\text{Aminocarb in oven-dry litter sample}}\right]$$

TABLE 9

Aminocarb Residues in Forest Litter from Plot III

Time after spraying	Aminocarb concentration (ppm)	
	1st application	2nd application
0.25 h	0.038 (0.052)	0.042 (0.052)
0.50 h	0.054 (0.072)	0.044 (0.049)
1.0 h	0.086 (0.146)	0.046 (0.060)
2.0 h	0.080 (0.106)	0.044 (0.056)
3.0 h	0.077 (0.100)	0.049 (0.066)
5.0 h	0.074 (0.099)	0.036 (0.044)
12.0 h	0.072 (0.096)	0.040 (0.049)
1 d	0.068 (0.088)	0.026 (0.032)
2 d	0.064 (0.079)	0.019 (0.028)
3 d	0.052 (0.069)	0.017 (0.026)
4 d	0.045 (0.060)	0.017 (0.024)
5 d	0.034 (0.046)	0.016 (0.021)
6 d		0.015 (0.022)
8 d		0.014 (0.019)
10 d		0.013 (0.018)
12 d		0.010 (0.014)
21 d		N.D.

See footnotes in Table 8

TABLE 10

Aminocarb Residues in Forest Litter from Plot V

Time after spraying	Aminocarb concentration (ppm)	
	1st application	2nd application
0.25 h	0.132 (0.175)	0.126 (0.172)
0.50 h	0.159 (0.211)	0.144 (0.188)
1.0 h	0.178 (0.227)	0.206 (0.269)
2.0 h	0.188 (0.240)	0.216 (0.269)
3.0 h	0.160 (0.199)	0.215 (0.263)
4.0 h	0.146 (0.181)	0.196 (0.246)
12.0 h	0.098 (0.128)	0.180 (0.245)
1 d	0.085 (0.108)	0.126 (0.157)
2 d	0.078 (0.098)	0.110 (0.141)
3 d	0.074 (0.094)	0.098 (0.138)
4 d	0.069 (0.086)	0.081 (0.108)
5 d	0.061 (0.077)	0.074 (0.101)
6 d		0.061 (0.084)
8 d		0.049 (0.068)
10 d		0.035 (0.046)
12 d		0.029 (0.037)
21 d		0.013 (0.017)

See footnotes in Table 8

TABLE 11

Aminocarb Residues in Forest Soil from Plot I

Time after spraying	Aminocarb concentration (ppm)	
	1st application	2nd application
0.25 h	0.004 (0.007)	T
0.50 h	0.008 (0.013)	0.003 (0.005)
1.0 h	0.006 (0.011)	T
2.0 h	0.005 (0.008)	N.D.
3.0 h	0.006 (0.009)	N.D.
5.0 h	T	N.D.
12.0 h	N.D.	-
1 d	N.D.	-
2 d	-	-
3 d	N.D.	N.D.
4 d	-	-
5 d	N.D.	N.D.
6 d		
8 d		
10 d		
12 d		
21 d		

T = Trace < 0.003 ppm based on wet mass of soil

N.D. = Not detectable; detection limit 0.001 ppm based on wet mass of soil

Values in parentheses are for oven-dry soil samples

TABLE 12

Aminocarb Residues in Forest Soil from Plot III

Time after spraying	Aminocarb concentration (ppm)	
	1st application	2nd application
0.25 h	0.008 (0.013)	0.004 (0.007)
0.50 h	0.014 (0.024)	0.005 (0.008)
1.0 h	0.018 (0.029)	0.010 (0.017)
2.0 h	0.016 (0.025)	0.005 (0.009)
3.0 h	0.010 (0.016)	0.004 (0.007)
5.0 h	0.011 (0.018)	T
12.0 h	0.007 (0.011)	N.D.
1 d	0.004 (0.006)	N.D.
2 d	N.D.	N.D.
3 d	N.D.	N.D.
4 d	-	-
5 d	N.D.	N.D.
6 d		
8 d		
10 d		
12 d		
21 d		

See footnotes in Table 11

TABLE 13

Aminocarb Residues in Forest Soil from Plot V

Time after spraying	Aminocarb concentration (ppm)	
	1st application	2nd application
0.25 h	0.024 (0.039)	0.008 (0.014)
0.50 h	0.032 (0.053)	0.016 (0.028)
1.0 h	0.050 (0.086)	0.034 (0.057)
2.0 h	0.051 (0.089)	0.044 (0.076)
3.0 h	0.046 (0.075)	0.038 (0.064)
5.0 h	0.037 (0.063)	0.030 (0.052)
12.0 h	0.024 (0.039)	0.022 (0.036)
1 d	0.011 (0.019)	0.017 (0.027)
2 d	0.007 (0.011)	0.011 (0.018)
3 d	0.004 (0.007)	0.006 (0.010)
4 d	T	0.004 (0.007)
5 d	T	T
6 d		T
8 d		N.D.
10 d		N.D.
12 d		N.D.
21 d		-

See footnotes in Table 11

TABLE 14

Half-life of aminocarb in fir foliage

Plot and formulation	1st Application			2nd Application		
	Max. Concn. (ppm)	Concn. at $T_{1/2}$(ppm)	$T_{1/2}$(d)	Max. Concn. (ppm)	Concn. at $T_{1/2}$(ppm)	$T_{1/2}$(d)
PI-180FE	2.41	1.21	0.5	0.96	0.48	5.5
PIII-180FO	2.27	1.14	2.0	1.79	0.90	3.8
PV-180D	1.30	0.65	3.5	2.76	1.38	3.8

Results are presented in Tables 4 to 13.

RESULTS AND DISCUSSION

Spray deposition

The deposit data in Table 4 clearly demonstrate the influence of solvents and additives in spray formulations on droplet size and deposit levels. Within a sampling station, no significant difference was observed in droplet density between cards placed in forest opening under the sampling tree in the upwind side or in the downwind side probably due to uniform turbulence under the canopy. Usually the droplets of emulsion formulation (180 FE), due to its rapid evaporation during a fall of 25-30 m from its release to ground level not only gave a narrow spectrum of droplets (7-73 μm) but also the amount that reached the ground (droplet density, i.e., drops/cm^2) (6 $\pm$ 6 and 0.5 $\pm$ 0.4) was much smaller compared to the two oil formulations 180 FO and 180 D. The latter containing the viscous sunspray 6N oil as an additive, gave a wider drop size spectrum (V.M.D., 65 $\pm$ 9 and 68 $\pm$ 9 μm) with a larger droplet density (16 $\pm$ 6 and 13 $\pm$ 6) which resulted in maximum deposition on the forest floor. The formulation 180 FO containing the volatile ID 585 oil as an additive was intermediate in its droplet size (V.M.D. 41 $\pm$ 5 and 39 $\pm$ 6 μm) and deposition (13 $\pm$ 6 and 3 $\pm$ 1) characteristics. Therefore it appears that the amount of chemical that reached the forest floor was relatable to the drop size spectrum, larger the drops the lower the impaction efficiency on the target, consequently the greater the concentration on the forest floor. High ground concentration could also mean low efficiency in spray application because of the high rate of sedimentation of larger droplets due to gravitational pull, they were not readily available either to the fir needles or the budworm.

Results of the spray deposit data also indicate that generally the first application was more successful in producing a comparatively better droplet density and heavier concentration on the forest floor than the second application. Usually the amount of aminocarb reaching the ground level was found to be rather low, probably due to the dense canopy cover. Since the ground concentration was low, it is normal to expect that apart from the bulk of the material trapped by the forest canopy, a fraction of the sprayed material could have drifted outside the target areas. So far no study has been undertaken to examine critically the airborne spray drift and its consequences in an experimental spray program. This is an area that we should pay some attention in future spray operations.

Among the three methods (spot counting, GLC and colorimetry) used to evaluate the deposit concentration on the forest floor, the gas chromatographic technique alone is reliable because it measures directly the AI whereas in the other two, the dye additive acted as the tracer for aminocarb. The lower recovery of deposits by the spot counting is attributable to the errors involved in magnifying and measuring the diameter of finer sprays, i.e., drops < 40 μm and in the determination of spread factor (S.F.) values for them. Considerable difficulties were also encountered during the colorimetric analysis due to interference and solvent effects as well as the extremely low absorbance observed for many eluates for which Beer-Lambert law (absorbance is proportional to concentration) was not strictly obeyed. These factors introduced noticeable deviations in deposit (Table 4) compared to the GLC technique.

In conclusion, assessment of deposits on the forest floor in random locations over the entire plot using the three techniques (GLC, colorimetry and spot counting) indicated that only a fraction of the insecticide released over the canopy descended to the collection units kept on the forest floor. Various physical and environmental factors at the site of each collection unit could prevent spray released over the canopy reaching the ground. Temperature inversions above the canoy, temperature gradients between the canopy and the ground, channelization of winds within the forest canopy and the micrometeorological conditions existed between the air/ground interphase, are some of the factors that could influence greatly the amount of deposit on the forest floor.

Aminocarb residues in balsam fir foliage

The dissipation of aminocarb in balsam fir foliage appeared to be biphasic (Tables 5 to 7). From the data it is apparent that the residue levels in fir foliage varied according to the formulations sprayed. Usually higher values were found with the oil formulations 180D and 180FO compared to the emulsion formulation 180FE. In all cases, the active material was lost rapidly and curvilinearly with time, primarily due to physical processes, having low half-lives (Table 14) of less than 5.5 days, showing that the material does not persist for appreciable time at toxic levels in foliage endangering any potential non-target species.

Low levels of the residues persisted in the foliage even on 21 d after the second application, ranging from 0.14 ppm (Plot I), 0.32 ppm (Plot III) to 0.64 ppm (Plot V). This is primarily due to the dissolution of the chemical into the lipophilic substances such as

terpenoids contained in the fir foliage forming solid solutions which are imbedded in the cuticular waxes thereby resisting rapid physical and biodegradations with time.

Aminocarb residues in forest litter

Concentrations of aminocarb residues found in the forest litter after the first application were generally higher than those after the second application (Tables 8 to 10). This was in agreement with the spray deposits collected on the glass slides discussed in the earlier section. The influence of additives on deposition levels were again apparent. The oil formulation (180D) containing the Sunspray 6N as the additive gave the highest deposition (maximum concentration, 0.188 ppm 1st application) and persisted on the litter surface when compared to the emulsion (180FE) formulation (maximum concentration, 0.023 ppm 1st application). The value in Plot III sprayed with I.D.585 as the solvent was intermediate between these two extremes. The $T_{1/2}$ obtained for the liter samples in the three plots for the 2nd application were low and ranged from 3.1 (Plot I) to 2.6 (Plot V) days.

The surface additions of fallen needles, twigs, stems, flowers, cones and bark are gradually compressed and eventually degraded by soil microorganism forming a flat overlapping layer over the soil layer which is known as forest litter. This organic matter consists of carbohydrates (cellulose, hemicellulose-polyglucuronic and xylan units), humin, humic acid, fulvic acid, phenolic and carboxylic compounds, lignins, nitrogeneous compounds (proteins, amino acids etc.) and lipids. It (litter) is not only acidic (pH of aqueous suspension 5.4) but also provides strong adsorptive surface for various molecules. It

is apparent then, that aminocarb molecules not only form a cation through protonation but also adsorbed strongly onto liter particulates persisting for a long time (21 days) in detectable levels. Adsorption to litter particulates is enhanced by the lipophilic components present in formulations 1.8D and 1.8FO; consequently the persistence of aminocarb in these litter samples, although not significant, were higher compared to Plot I samples.

Residues of aminocarb in forest soil

The forest floor is usually considered a major receptor of aerially applied spray materials, but the maximum aminocarb content found in the soil samples (sandy loam, pH 6.3) from plots PI, PIII and PV (Tables 11 to 13) were extremely low ranging from (following lst application) 0.008 (PI) to 0.051 (PV) ppm. Half-lives ranged from ca 2 (PI) to 6 (PV) hours. The insecticide concentration decreased rapidly, the rate of decrease as well as the deposition levels were influenced by the additives present in the formulations. The highest residue levels (0.051 ppm) and longer persistence (ca 5 days) were found in Plot V. After 5 days following second application, the aminocarb concentration decreased to trace levels (< 0.003 ppm). Therefore it appears that under experimental or operational conditions of forest protection, no significant amount of the insecticide persisted in soil for a considerable length of time.

Mechanism of disappearance of aminocarb from forest floor included volatilization, leaching through soil profile by water, degradation by various physicochemical processes including sunlight and biological means. Among these, a combination of chemical and bacterial

degradations and volatilization from the soil surface probably played vital parts.

SUMMARY AND CONCLUSIONS

Newly introduced aminocarb flowable (suspension concentrate) formulation 180F as an aqueous emulsion (180FE) and in Shell I.D.585 (180FO) and the conventional oil soluble concentrate containing nonylphenol diluted with Shell Sunspray 6N oil (180D) were applied separately to different plots twice at 70 g AI/ha by means of a fixed-wing aircraft to a mixed coniferous forest near Bathurst, N.B.

Distribution, persistence and enviroinmental fate of aminocarb residues in fir foliage, forest litter and soil collected at intervals of time, were studied by GLC analysis after solvent extraction and necessary cleanup.

Residues in balsam fir foliage were usually low but varied according to the formulations sprayed. Usually higher values were found with the oil formulations 180D and 180FO compared to the water formulation 180FE. In all three cases, the active material was lost rapidly and curvilinearly with time showing low half-lives.

Aminocarb residues were extremely low in soil compared to forest litter and persisted longer in detectable levels in the latter.

The additives in the formulation played a significant role in droplet spectrum and deposition characteristics of the material.

Findings from this study are in good agreement with those reported in 1976 by the author thereby confirming that the aminocarb insecticide was lost rapidly and has low persistence in some of the forestry substrates studied. It could be considered as an acceptable

insecticide to control spruce budworm. The data also indicate that under the experimental conditions discussed here, aminocarb 180F in both water and I.D.585 appears to be environmentally safe and acceptable as a satisfactory formulation to be used in forestry spray programs.

ACKNOWLEDGEMENTS

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The technical assistance of Joe Feng, Dave MacTavish, Reg Nott, Sharon Beith and Joe DeGraw is acknowledged with thanks.

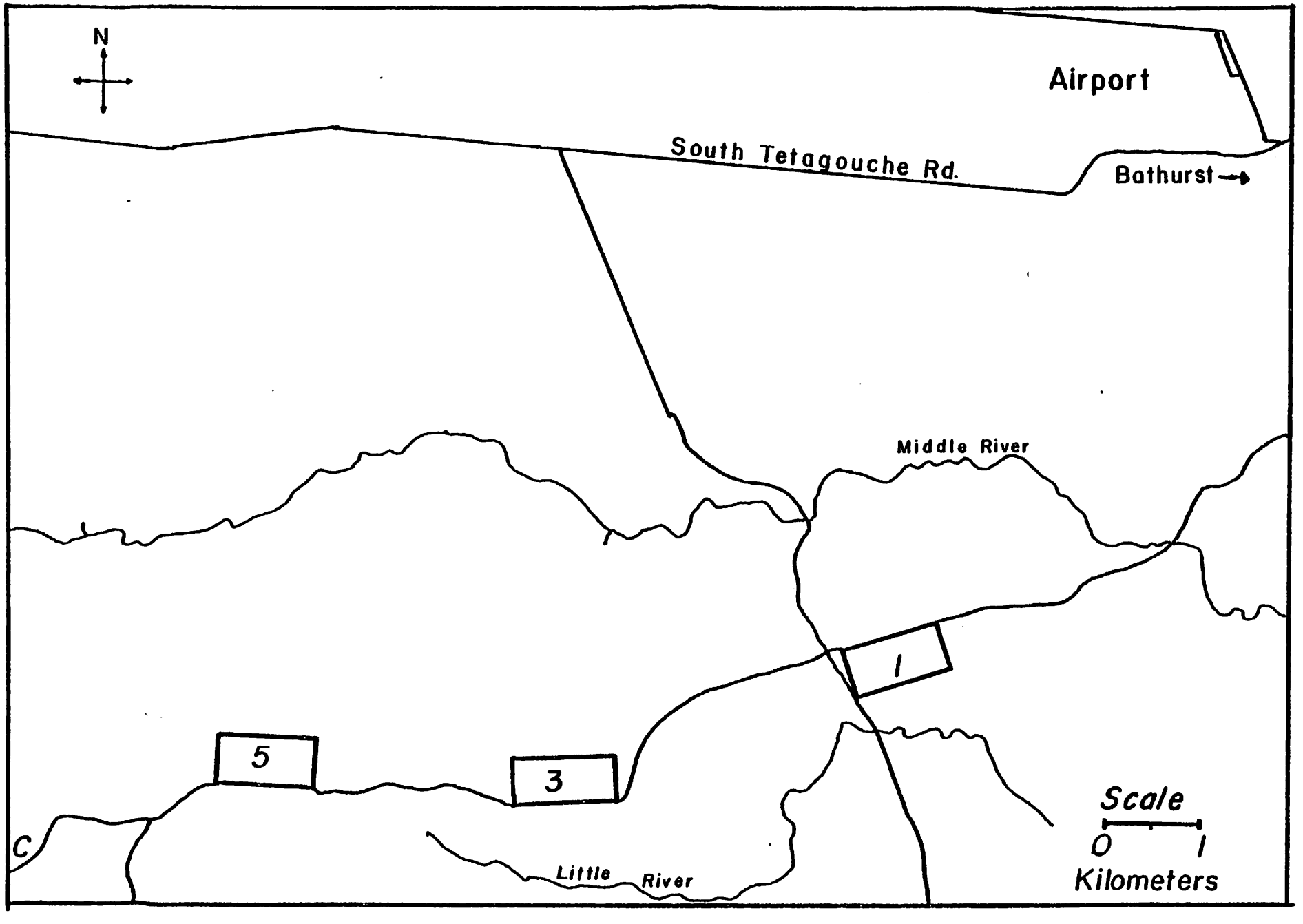
N
Airport
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Fig. 1

A-Litter and Soil
Plots
1-12-Sample Trees

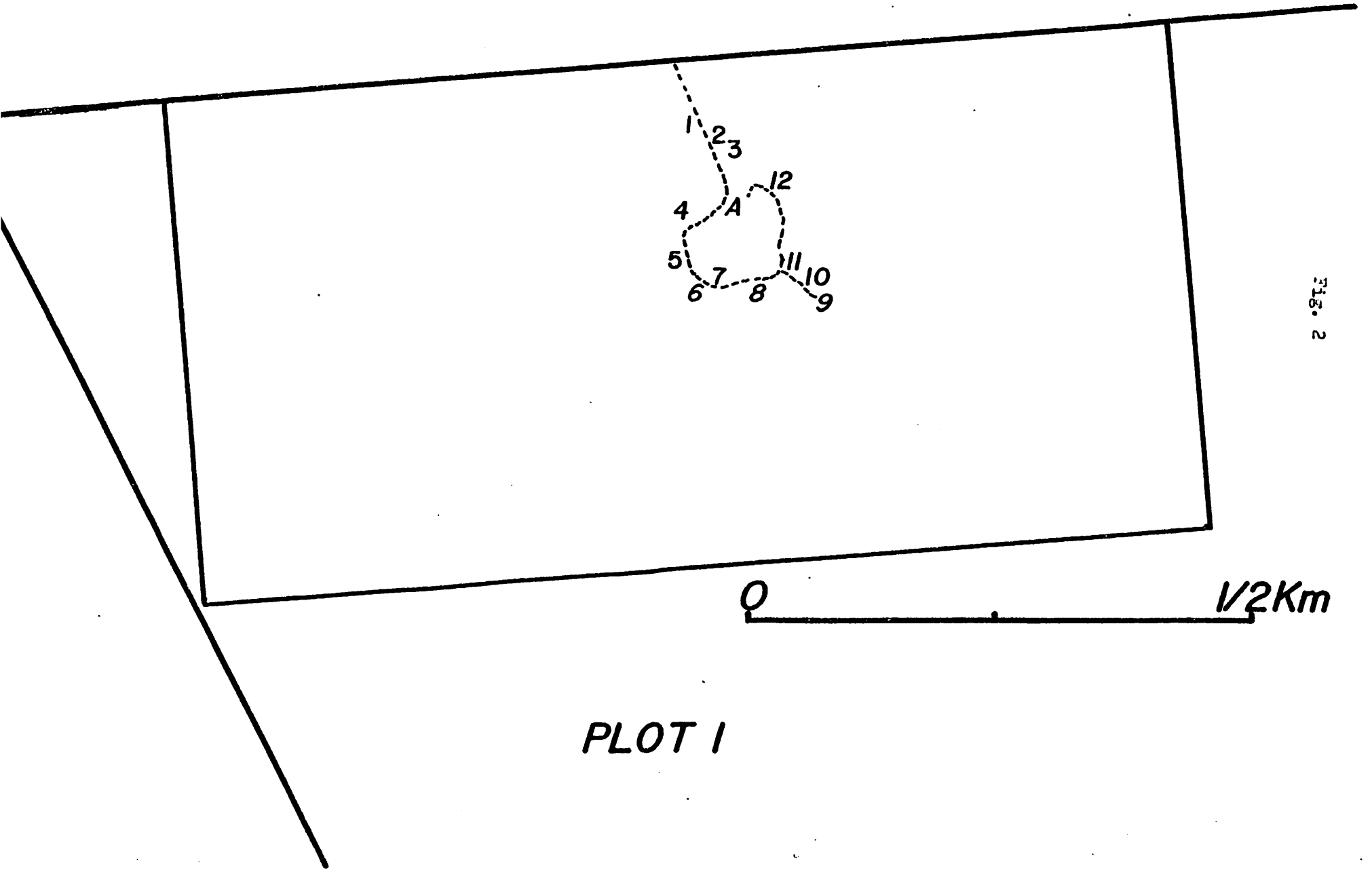


Fig. 2

A-Litter and Soil
Plots
1-12-Sample Trees

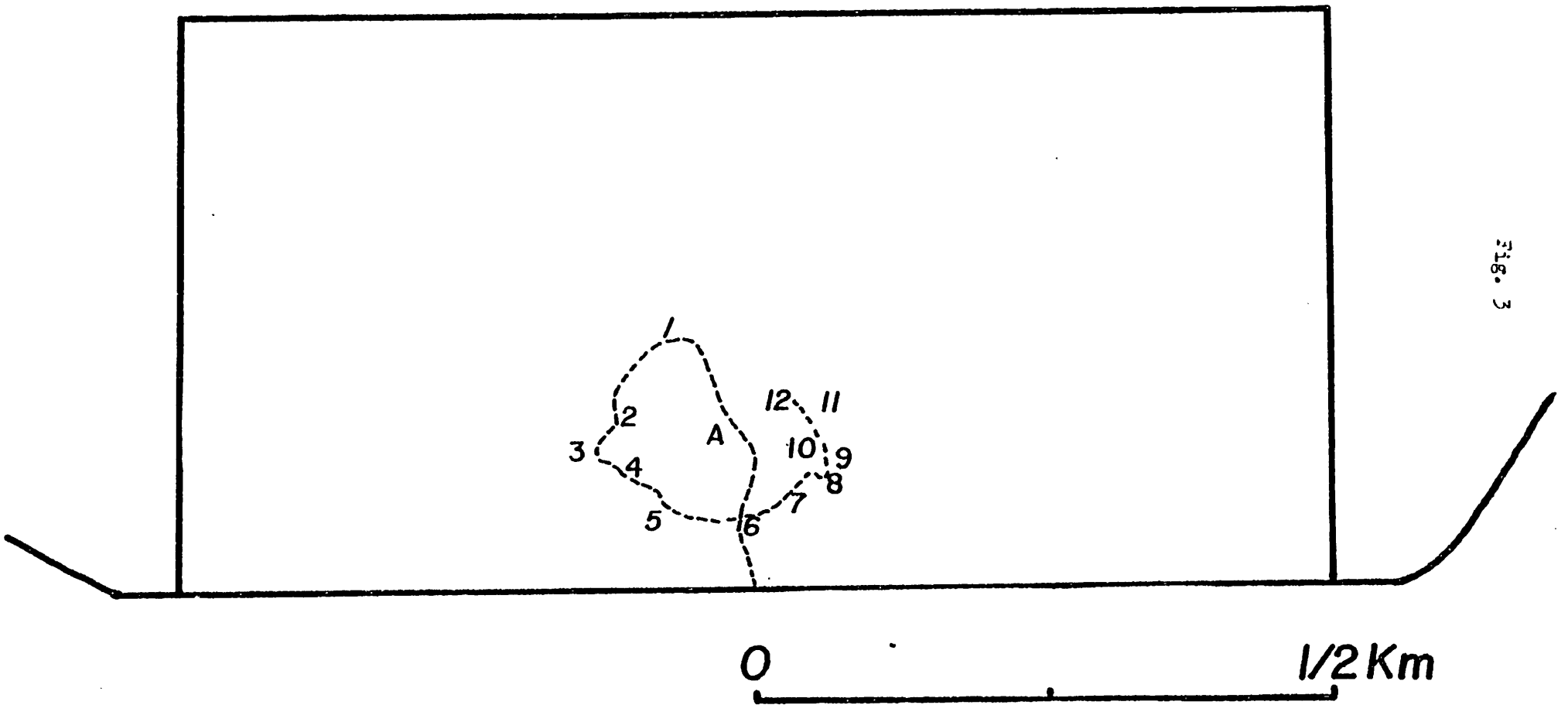


Fig. 3

PLOT 3

A- Litter and Soil
Plots
1-12-Sample Trees

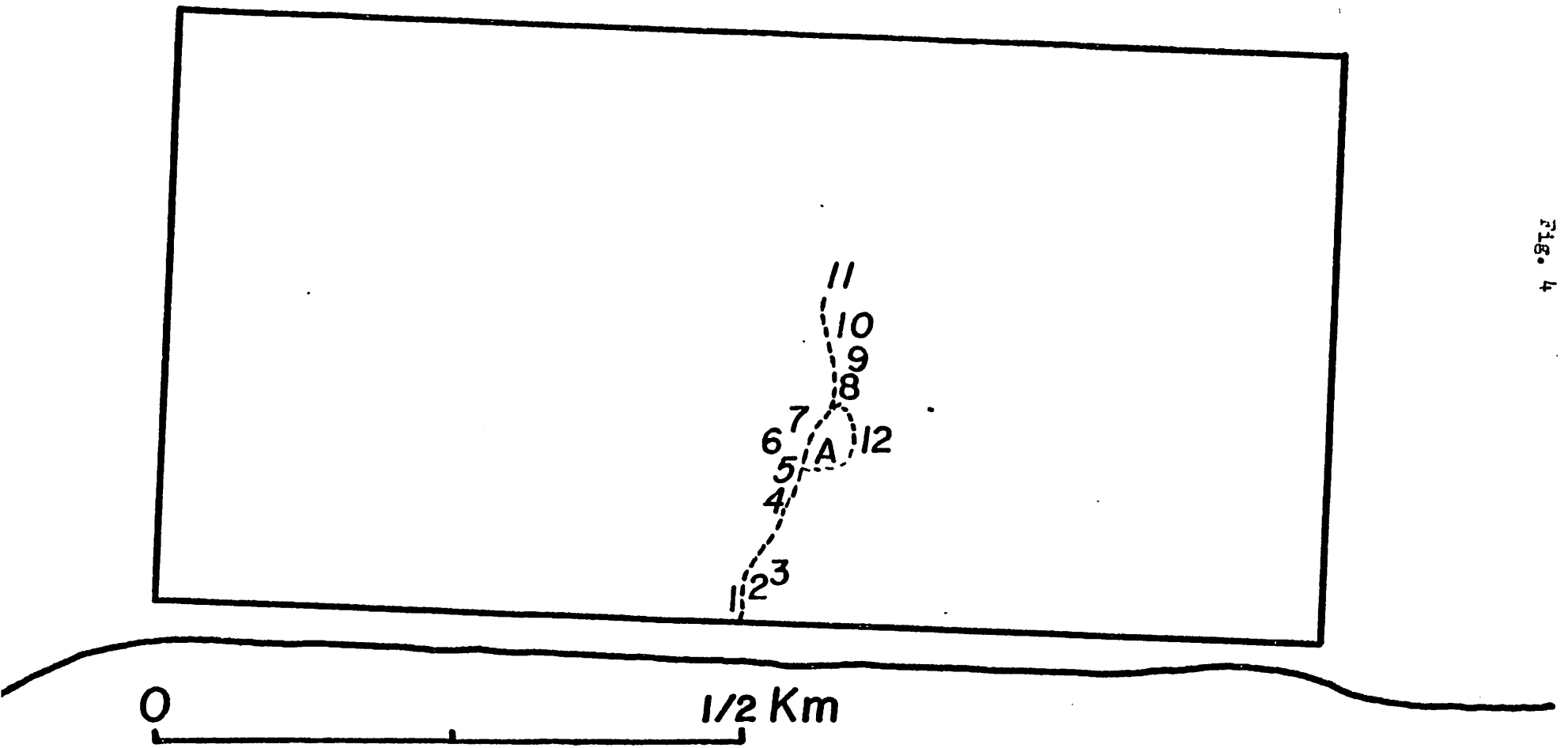


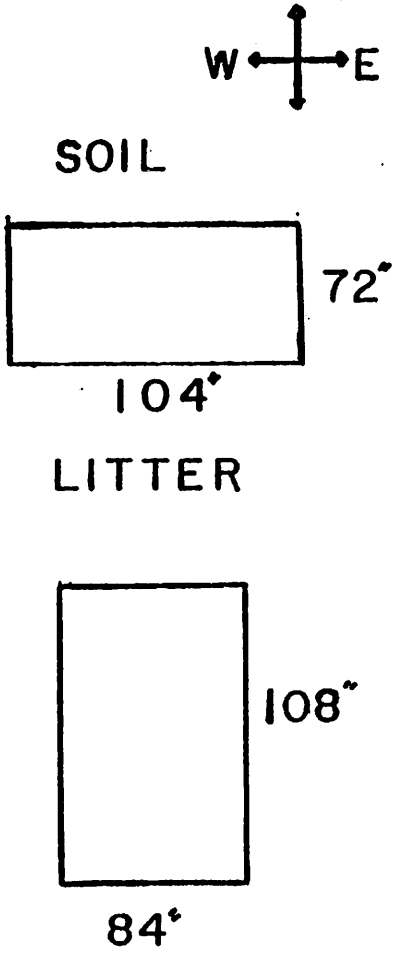
Fig. 4

Plot 5

PLOT I

TREE NUMBER	AVERAGE HEIGHT ft.	CROWN HEIGHT ft.	SAMPLING HEIGHT ft	DBH in.	No of TREES
1	35	15	35	6	2
2	35	12	28	5.5	1
3	40	15	30	5.5	3
4	30	12	25	3.8	3
5	35	15	30	6	3
6	42	15	30	7.5	1
7	38	18	28	5.5	2
8	45	15	30	6.5	1
9	32	12	28	5.5	2
10	34	10	22	6	3
11	45	10	30	9	1
12	45	10	30	6.5	1

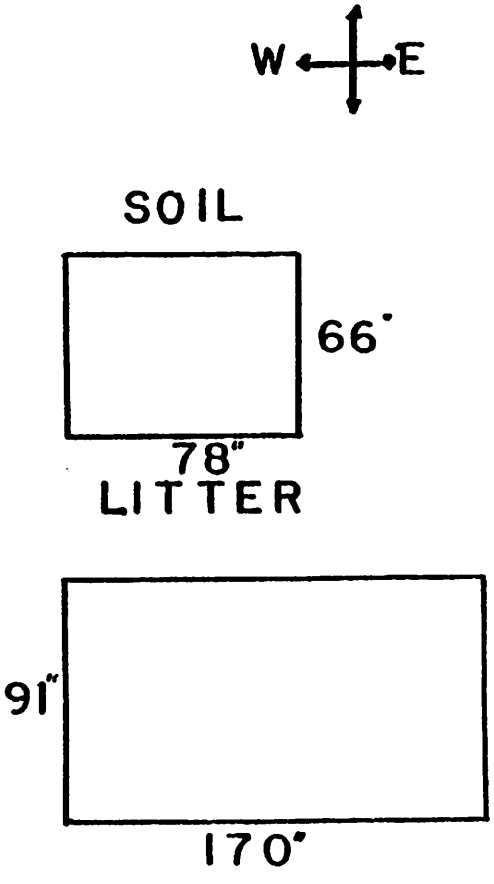
SOIL and LITTER PLOTS



PLOT 3

TREE NUMBER	AVERAGE HEIGHT ft	CROWN HEIGHT ft.	SAMPLING HEIGHT ft.	DBH in.	No of TREES
1	42	24	35	5	1
2	38	12	30	5.5	1
3	42	24	35	5.5	3
4	45	24	35	5.5	3
5	45	24	35	65	3
6	45	24	37	7	1
7	42	12	35	6.5	3
8	40	18	30	6.5	3
9	40	15	30	5.5	3
10	38	15	30	5	3
11	35	15	30	4.5	9
12	35	12	30	5	2

SOIL and LITTER PLOTS in.



PLOT 5

TREE NUMBER	AVERAGE HEIGHT ft	CROWN HEIGHT ft.	SAMPLING HEIGHT ft.	DBH in.	No. of TREES
1	50	12	30	7.5	1
2	40	12	30	6	3
3	42	12	35	7	1
4	42	15	35	7	3
5	25	10	20	4	2
6	54	18	40	7	3
7	50	12	35	8.5	1
8	60	18	35	9.5	1
9	48	15	35	5.8	2
10	48	12	35	7	2
11	60	18	35	8	1
12	45	15	30	5	2

SOIL and LITTER PLOTS in.