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NEW BRUNSWICK COMPARATIVE BRUSH TRIAL

- status report -

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TABLE OF CONTENTS

	Page
ABSTRACT	1
INTRODUCTION	1
GOALS and OBJECTIVES	3
BACKGROUND	4
METHODS	6
a) Pre-treatment	6
1) site selection and preparation	6
2) silvicultural assessments	8
3) experimental design	9
4) sprayer calibration	10
5) preparation for environmental fate and persistence studies	14
b) Treatment	16
1) chemical application	16
2) manual control	17
3) meteorological measurements	17
4) deposit evaluation	18
5) environmental fate and persistence determination	19
c) Post-treatment	22
1) environmental fate activities	22
2) silvicultural activities	22
RESULTS TO DATE	22
a) Pre-treatment Weed and Crop Data	22
b) Chemical Applications and Initial Deposit	27
c) Meteorology	34
d) Environmental Fate and Persistence	34
BUDGET STATUS	35
REFERENCES	35

ABSTRACT

Methods and preliminary results are provided for a study designed to compare five different strategies for controlling deciduous brush in conifer release and site preparation roles. Four different herbicides, each applied at 5 application rates, are evaluated in terms of efficacy, crop tolerance, crop growth response, environmental fate, and economics. Proposed silvicultural data will provide a dose-response guide for each herbicide tested (VISION, RELEASE, TOUCHDOWN, and MON14420) on a broad range of eastern Canadian brush species. Environmental fate data being generated, including foliar and soil dissipation and soil leaching, will provide valuable registration data specific to the Acadian forest region. Manual weed control will provide a bench-mark comparison to chemical treatments.

Pre-treatment weed and crop data suggest adequate statistical interspersion and no treatment bias following treatment randomization. Brush density on the site averaged 40,000 stems/ha, with sugar maple accounting for 43% of this total. Black spruce planted in 1987 averaged 57cm in height at the time of release. Similar stock planted immediately following treatment averaged 14cm. Herbicides were applied in a total of 100 L/ha. In general, calculated application rates, based on measured residual tank-mix volumes and tank-mix concentrations, deviated from nominal rates by less than 10%. Resulting deposit of active ingredient on sugar maple foliage showed generally high precision for replicate treatments and well-defined correlation of mean on-target deposit to calculated application rates for each product. Post-treatment weed and crop evaluations will be conducted in July and August 1990, with chemical analysis continuing throughout 1990.

INTRODUCTION

The number of vegetation management tools available to the Canadian forest manager is limited. The only herbicide currently available for aerial forestry application is VISION (formerly ROUNDUP). VELPAR L (liquid hexazinone) was recently granted a registration for ground-based applications only. The phenoxy herbicide 2,4-D still holds an aerial forestry label, but its use is rather limited and it is currently under federal regulatory review.

Aside from manual methods, non-chemical means of weed control are largely experimental and are not likely to be available operationally for a decade or more.

The herbicides that are currently registered for forestry use in Canada leave serious gaps in our abilities to control certain weed species. VISION provides extremely effective control of grass, raspberry, and aspen, but only marginal control of species like maple, beech, ash, elderberry and hazel. VELPAR L has been demonstrated as an effective site preparation tool, but only where grass, raspberry, and aspen are of concern. The phenoxy herbicides, while often exacerbating grass and raspberry competition, did provide some degree of brush control. The de-registration of 2,4,5-T, has seriously hampered our abilities to control deciduous brush competition on forest sites (Reynolds, 1988).

Perhaps the problem is most evident in the more than 30 million ha of backlog forest lands that we currently have not satisfactorily regenerated in Canada (Manville, 1983). The majority of these areas are heavily brushed in and will require an effective brush-control tool in order to bring back into softwood production. The lack of efficacious and cost-effective options for brush control in silvicultural programs will eventually result in higher production costs and loss of productive forest lands.

This status report outlines methods and preliminary results for a 1989 study designed to compare several herbicides and manual weeding as brush-control tools in both conifer release and site preparation capacities. The herbicides evaluated in this study include VISION and three other products currently being developed for forestry use in Canada; RELEASE, TOUCHDOWN, and MON14420. Silvicultural comparison of these vegetation management tools will be based on evaluations of efficacy, crop tolerance, crop growth response, and economics. In addition, the tools will be compared from an environmental fate perspective, through an analysis of foliar and soil dissipation, as well as soil leaching.

GOALS and OBJECTIVES

For the most promising of candidate herbicides, this research takes a pro-active role in generating data that are required for both Canadian forestry registration and efficacious, cost-effective, and environmentally-sound use. Prior to registration, federal and provincial regulatory officials require comprehensive data packages documenting efficacy, toxicological, and environmental fate characteristics of herbicide compounds under conditions typical of their proposed use. Registration of any one of these new products will require generation of the data produced in this study at some point in time. Conducting separate experiments to address silvicultural questions first and environmental questions later, results in higher total research costs and delayed registration reviews. In this regard, both the silvicultural and environmental fate data generated in this study will significantly contribute to the registration data packages of the herbicides tested and could, in some cases, speed registration.

Study results will provide operational foresters in eastern Canada with increased knowledge required for the selection of biologically efficacious, cost effective, and environmentally acceptable tools for brush-control problems. Information generated from the manual control treatments will provide a better understanding of how this weed control method performs relative to chemical methods, for a range of weed species. Dose-response relationships will provide a guide to the minimum levels of deposit necessary for threshold levels of control. These relationships will be defined for all four products and include the major eastern Canadian competitors. Reduced costs and chemical burden on the environment will be the ultimate benefits.

Further, there has never been a comparative field study, undertaken anywhere in Canada, designed to identify herbicides and application rates that are most capable of efficiently controlling brush in both conifer release and site preparation situations. On an individual basis, the following information will be gained for the products tested :

* VISION
  - the first side-by-side comparison of a range of rates on hard-to-kill species.
  - the first replicated study of terrestrial environmental fate

in the Acadian forest region.

* RELEASE - information specific to the New Brunswick situation; one of the largest areas of potential use.

* TOUCHDOWN - the first comprehensive forestry study and the first solid comparison to VISION on broad range of brush species.
 - the first comparison of environmental behavior of VISION and TOUCHDOWN.

* MON14420 - the first comprehensive forestry study and the first solid comparison to VISION on broad range of eastern brush species.
 - the first replicated study of terrestrial environmental fate in the Acadian forest region.
 - the first comparison of environmental behavior of VISION and MON14420.

Finally, the trial offers the opportunity to obtain growth-response data that are currently non-existent and will become of increasing importance for herbicide-use substantiation in the future.

BACKGROUND

VISION (by Monsanto) is a liquid formulation containing the IsoPropylAmine (IPA) salt of glyphosate as the active ingredient (480g salt/L, 356g a.e./L). From the point of contact with the foliage, this herbicide translocates throughout the plant and its root system, killing it by inhibiting the synthesis of essential amino acids. VISION is a broad-spectrum herbicide that controls annual and perennial broad-leaved weeds and grasses, as well as brush species like aspen, pin cherry, and birch. Species like the maples, alder, ash, beech, and oak show some resistance and conifers can be damaged if application is made before bud-set and hardening. Glyphosate is inactivated upon contact with the soil so it does not provide residual weed control. Glyphosate is degraded primarily by microbial processes and is non-persistent in soils and foliage. Due to its strong sorption to organic matter and cation-saturated clays, it is virtually immobile in soils.

To be effective, VISION must be applied a minimum of 6 hours before rainfall. Surfactants that will reduce this time period are currently being experimented with by Monsanto and FPMI.

VISION currently has full registration for conifer release and site preparation uses in forestry, for both air- and ground-based applications.

RELEASE (formerly GARLON 4) (by DowElanco) is an emulsifiable concentrate containing the low-volatile butoxyethyl ester of triclopyr (480g/L), the active ingredient. RELEASE is primarily a foliar herbicide and, like other auxin-type herbicides, translocates readily within the target plant, accumulates in meristematic tissues, and causes excessive cell elongation. It provides effective control of alder, ash, aspen, beech, birch, hazel, maple, pin cherry, oak, willow, and raspberry, but does not effect grass.

RELEASE is similar to VISION with respect to application timing and crop phytotoxicity, however, RELEASE is more effective than VISION on hardwoods (i.e., sugar maple and beech), and less effective on raspberry and aspen (Moore, 1985). Triclopyr does not readily persist, as it breaks down rapidly in the soil (Stephenson and Solomon, 1987) and exhibits limited leaching and off-site mobility under Canadian boreal forest field conditions.

GARLON 4 is currently registered for both industrial and forestry uses in the U.S. and now has a temporary registration for ground applications to rights-of-way in Canada. A date for forestry registration is estimated at 1990-91.

TOUCHDOWN (by Chipman) is a new product that is currently being developed for both agricultural and forestry uses in Canada . It is a water soluble liquid that contains the Trimethyl-Sulphonium salt (TMS) of glyphosate as the active ingredient (480g salt/L or 330g a.e./L). Tests so far have revealed that the product behaves in a fashion similar to ROUNDUP and it is expected that it will have similar weed control, crop tolerance spectra, and environmental fate characteristics to VISION, when applied in a silvicultural role.

MON 14420 (by Monsanto) is a glyphosate formulation registered in the U.S. for industrial uses. Forestry use is currently experimental. The formulation contains the MonoAmmonium salt of glyphosate (74.4% salt, 68% a.e.) as water soluble granules, pre-measured in water soluble packets. One 500g packet of water soluble granules is the equivalent of (340g a.e./356g a.e.) 0.96 L of VISION. Obvious advantages of this formulation include simplicity and safety in mixing, ease in handling, and reduced transportation costs.

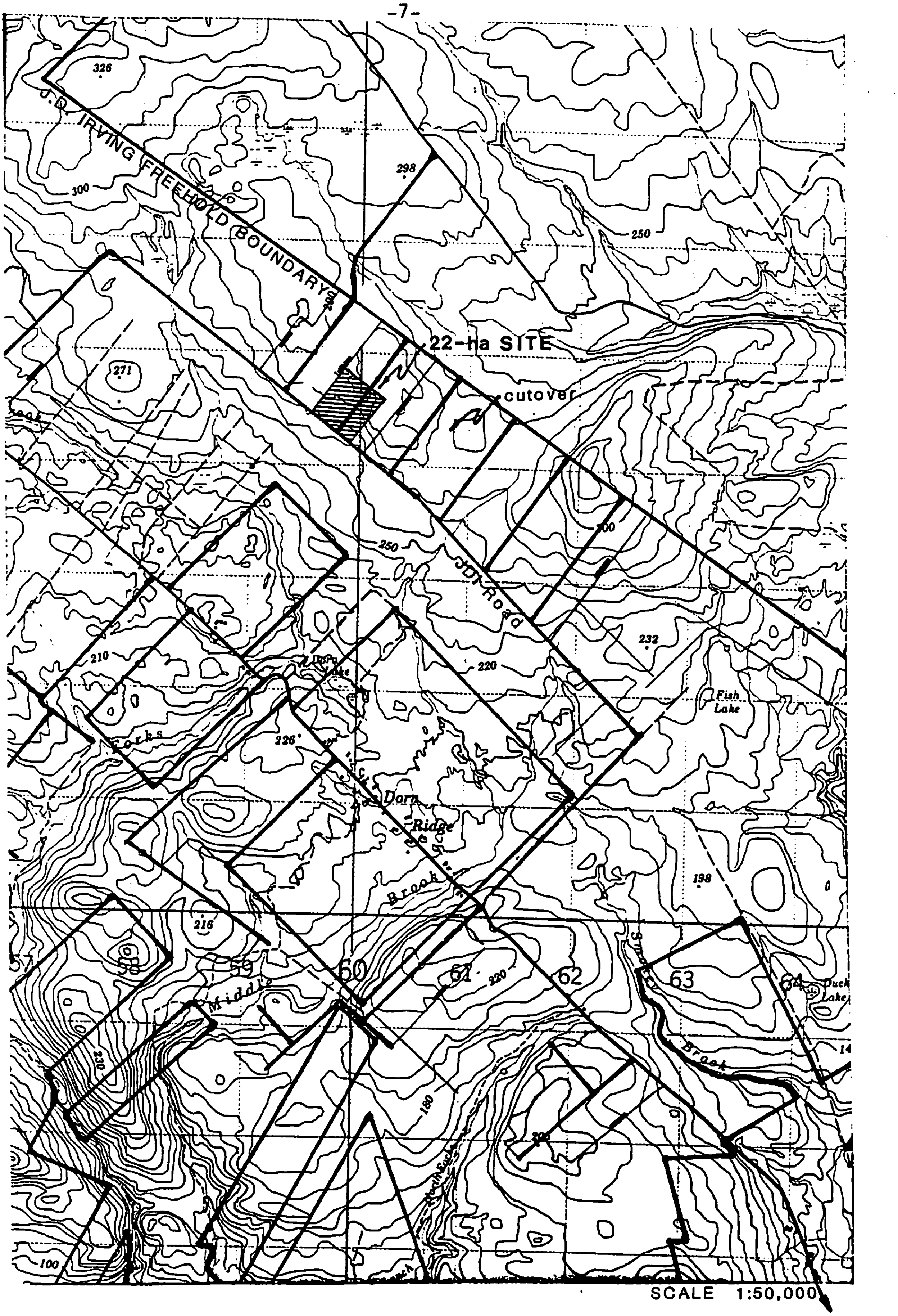
METHODS

a) Pre-treatment

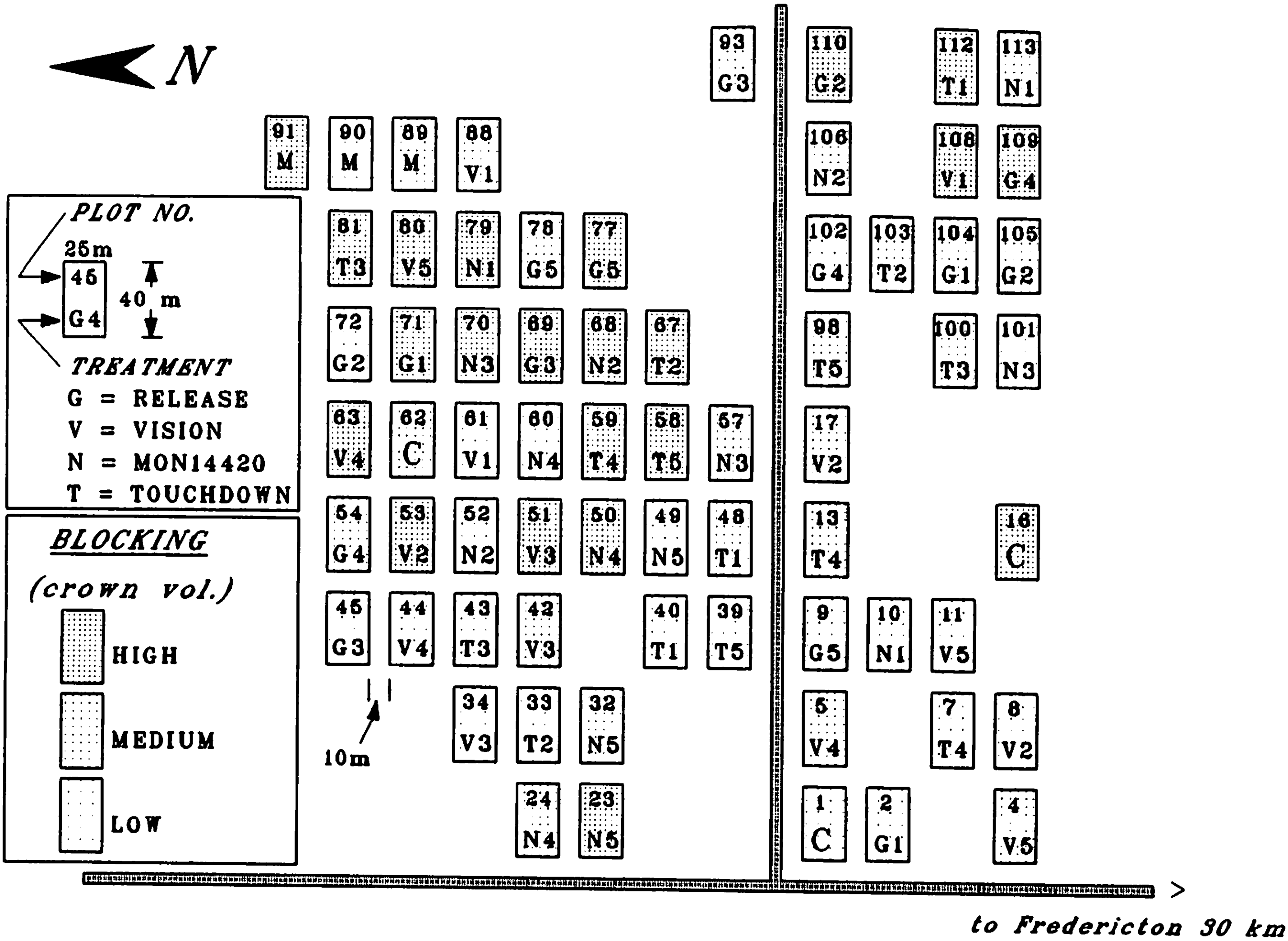
1) site selection and preparation:

Site selection for this study took place in June 1987. In this process, several cutovers across New Brunswick were inspected and considered before a 22-ha site, located on J.D. Irving freehold land near Fredericton (Map 1), was chosen. This site had been included in a 300-ha area that was full-tree logged during the fall and winter of 1986. The use of Koehring feller-forwarders allowed the site to be left relatively free of logging debris and plantable without any site preparation. Existing on the site was a relatively uniform cover of young hardwood seedlings, saplings, and stump sprouts. Species included sugar, red, mountain, and striped maple, white ash, beech, yellow and white birch, hazel, elderberry, and hobble bush. This particular site was chosen because its uniformity suited the planned experimental design and its species diversity offered the potential for results to extend to virtually all major eastern Canadian competitors.

In August 1987, the site was divided into sixty-six 40 x 25m plots, with 10-m vegetation buffers between each (Map 2). Buffer width was chosen to allow treatment in $\leq$ 5 kph winds without the risk of cross-plot contamination. Within the center of each plot, twelve sample locations were established at 2.1-m intervals in a cross pattern, the center of each marking the future planting location of a crop tree and focus for future weed sampling. Black spruce container stock (Multipot 45) was planted in the inner 4 of the 12 sample locations in each plot at the end of August 1987. These trees will



Map 1. Location of research site.



Map 2. Layout of treatment plots.

provide release data. For site-prep data, 24 additional black spruce container stock (Multipot 45) were planted immediately following treatment (including the remaining 8 subsample locations and 16 surrounding locations at 2.1 x 2.1m spacing).

2) silvicultural assessments:

Pre-treatment vegetation sampling took place in mid August 1989. Brush data included evaluations of stem density, crown area, crown volume, stem diameter, basal area, and health, by species. Data for herbaceous and non-arborescent woody species included estimates of height and percent cover.

Crop data included evaluations of height, stem and crown diameter, and health.

Major brush species were sampled with a horizontal point sampling technique (Husch, Miller, and Beers, 1972). An individual rootstock was considered "in" the sample if its crown diameter was greater than an angle of 30.5° projected from the subsample center. The sampling angle (Θ) was chosen for each plot such that approximately 5 individual rootstocks were included in each subsample. Alternative angles of 36.1°, 42.3°, and 48.3° were used in plots with higher brush densities. Two crown diameter measurements were recorded for each rootstock; one along a line projected from the subsample center, through the center of the crown, and a second at 90° to the first. Stem diameter was recorded at 10cm above ground line, with the average diameter being recorded in the case of multi-stemmed rootstocks. Total height and height of live crown were also recorded. Each rootstock in the sample was numbered and tagged for future identification.

Herbaceous and non-arborescent species were evaluated within a 1-m radius of each subsample center. Percent cover was visually estimated and total height was estimated to the nearest 10cm.

Health of individual crop trees and brush rootstocks was rated on a scale of 1 (vigorous) to 5 (dead). A value of 1 was assigned to a specimen with no visible imperfections, good morphological characteristics, and obvious good growth. A stem showing visible signs of only one minor health ailment (insect damage, disease, mechanical damage, etc.,), but otherwise healthy, was assigned a value of 2. A tree in mediocre condition (3) had a sufficient amount of morphological, physiological, or mechanical damage that it could be considered to have a 50% chance of survival. Significant health problems (top-kill, severe chlorosis, or necrosis, serious insect damage, etc.,) warranted a rating of 4 (moribund).

3) experimental design:

Treatments consisted of 5 rates of each herbicide, one manual control treatment, and an untreated control. Each treatment was replicated 3 times in a randomized complete block design. Specific rates (kg a.e./ha) tested were:

	1	2	3	4	5
RELEASE	0.400	1.260	2.120	2.980	3.480
VISION	0.250	0.722	1.193	1.665	2.136
MON14420	0.250	0.722	1.193	1.665	2.136
TOUCHDOWN	0.232	0.669	1.106	1.543	1.980

Blocking of treatments took place on total crown volume of brush species. Crown volume estimates were generated from the pre-treatment data using the following formula:

[1] $$V = a * D_1 * D_2 * HLC,$$

where V = individual rootstock crown volume (m^3), a = Π ($1.67*10^{-7}$ m^3/cm^3), D_1 and D_2 = crown diameter measurements (cm), and HLC = the height of live crown (cm). This equation defines an ellipsoid, the shape of which approximates the crown forms of the species sampled. Total crown volume (m^3/ha) estimates were made from the subsample data in each plot and plots were ranked from lowest to highest according to this estimate. Three blocks were then defined in terms of the crown volume strata; LOW (1115-2829 m^3/ha), MEDIUM (2890-4145 m^3/ha), and HIGH (4230-7228 m^3/ha) (Table 1).

The 33 plots in each block were then assigned treatments in the following manner. The plot of median crown volume was assigned the control treatment. One plot was chosen for manual treatment (strict rules of randomization were not applied to the selection of this plot; rather, species composition and site were considered). Remaining plots were then divided into 5 groups of 4 and application rates (1 through 5) were randomly assigned to each group. Within each group of 4 plots, the 4 herbicides in each rate were then randomly assigned. In this manner, herbicides at a given rate were assigned, as close as possible, plots with similar crown volumes, and adequate interspersion was ensured.

4) sprayer calibration:

Herbicide treatments were applied with three backpack CO_2 sprayers (R & D Sprayers, Inc., Model 4F). Sprayer calibration and characterization was

Table 1. Randomization of treatments based on total crown volume (m^3/ha).

RANK	PLOT No.	BLOCK	TREATMENT	VOLUME
1	34	LO	V3	1114.55
2	43	LO	T3	1373.20
3	101	LO	N3	1628.40
4	45	LO	G3	1825.56
5	9	LO	G5	1919.72
6	11	LO	V5	1978.52
7	49	LO	N5	2136.48
8	39	LO	T5	2158.77
9	2	LO	G1	2222.57
10	61	LO	V1	2304.81
12	10	LO	N1	2421.65
13	40	LO	T1	2478.14
14	60	LO	N4	2504.28
15	7	LO	T4	2593.44
16	102	LO	G4	2687.99
17	44	LO	V4	2780.61
18	33	LO	T2	2785.41
19	8	LO	V2	2805.98
20	52	LO	N2	2807.83
21	72	LO	G2	2828.65
22	42	ME	V3	2890.07
23	100	ME	T3	2925.12
24	93	ME	G3	2942.41
25	57	ME	N3	2962.40
26	88	ME	V1	2982.00
27	104	ME	G1	3059.25
28	48	ME	T1	3108.78
29	113	ME	N1	3206.45
30	4	ME	V5	3269.09
31	32	ME	N5	3284.80
33	78	ME	G5	3328.66
34	98	ME	T5	3336.73
35	106	ME	N2	3387.08
36	103	ME	T2	3394.77
37	17	ME	V2	3560.03
38	105	ME	G2	3570.02
39	24	ME	N4	3753.15
40	13	ME	T4	3840.20
42	54	ME	G4	4112.14
43	5	ME	V4	4144.59
44	53	HI	V2	4230.03
45	68	HI	N2	4257.23
46	110	HI	G2	4374.03
47	67	HI	T2	4419.39
48	50	HI	N4	4457.26
49	59	HI	T4	4597.55
50	63	HI	V4	4665.30
51	109	HI	G4	4666.36
52	112	HI	T1	4682.26
53	108	HI	V1	4698.37
55	79	HI	N1	5069.58
56	71	HI	G1	5090.97
57	58	HI	T5	5204.18
58	23	HI	N5	5281.93
59	77	HI	G5	5397.23
62	80	HI	V5	6188.67
63	51	HI	V3	6502.06
64	70	HI	N3	6954.74
65	81	HI	T3	7145.57
66	69	HI	G3	7227.85
11	1	LO	CONTROL	2400.51
32	62	ME	CONTROL	3301.37
54	16	HI	CONTROL	4715.44
41	90	LO	MANUAL	3963.31
60	89	ME	MANUAL	5638.08
61	91	HI	MANUAL	5665.57

conducted prior to treatment application. Table 2 details the application methodology chosen for use in this study.

Table 2. Application methods.

Nozzle	FLOODJET ¼KLC-9
- orientation	0° straight up
- height (AGL)	4.5 m
Tank pressure	40 psi
Boom pressure	27 psi
Volume	4.32 L/min
Track spacing	9.5 m
Deposit-pattern width @ 2m AGL	9.5 m
Walking speed	0.76 m/s
Application volume	100 L/ha
VMD	1089 μm
NMD	456 μm
DV.1	618 μm
DV.9	1739 μm

Volume distribution across the swath, as produced by the ¼KLC-9 nozzle with the above settings, is illustrated in Fig. 1. These data were generated by placing 4.54-cm diameter petri dishes at 0.5-m intervals across the swath. The sprayer was held stationary over the dishes for 30 seconds. Comparison of pre- and post-spray mass of the dishes produced the volume data.

Droplet VMD's across the swath are shown in Fig. 2. These data were produced by applying a single pass (at calibrated speed) over 64.72-cm² petri dishes, placed at 1-m intervals across the swath. Dishes contained 50-weight motor oil, allowing drops to be measured directly in suspension.

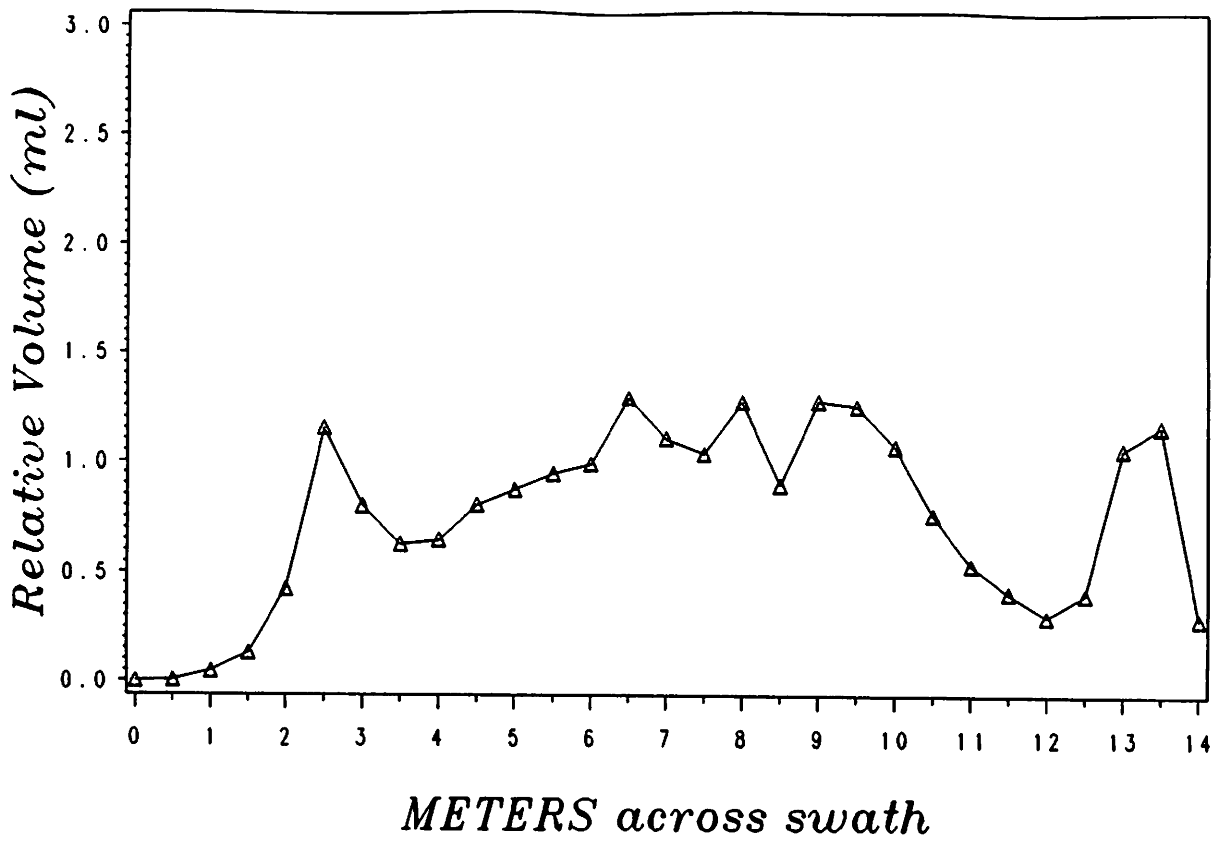


FIG. 1. Relative volume deposited across swath width (¼KLC-9 nozzle at 4.5m, 40 psi).

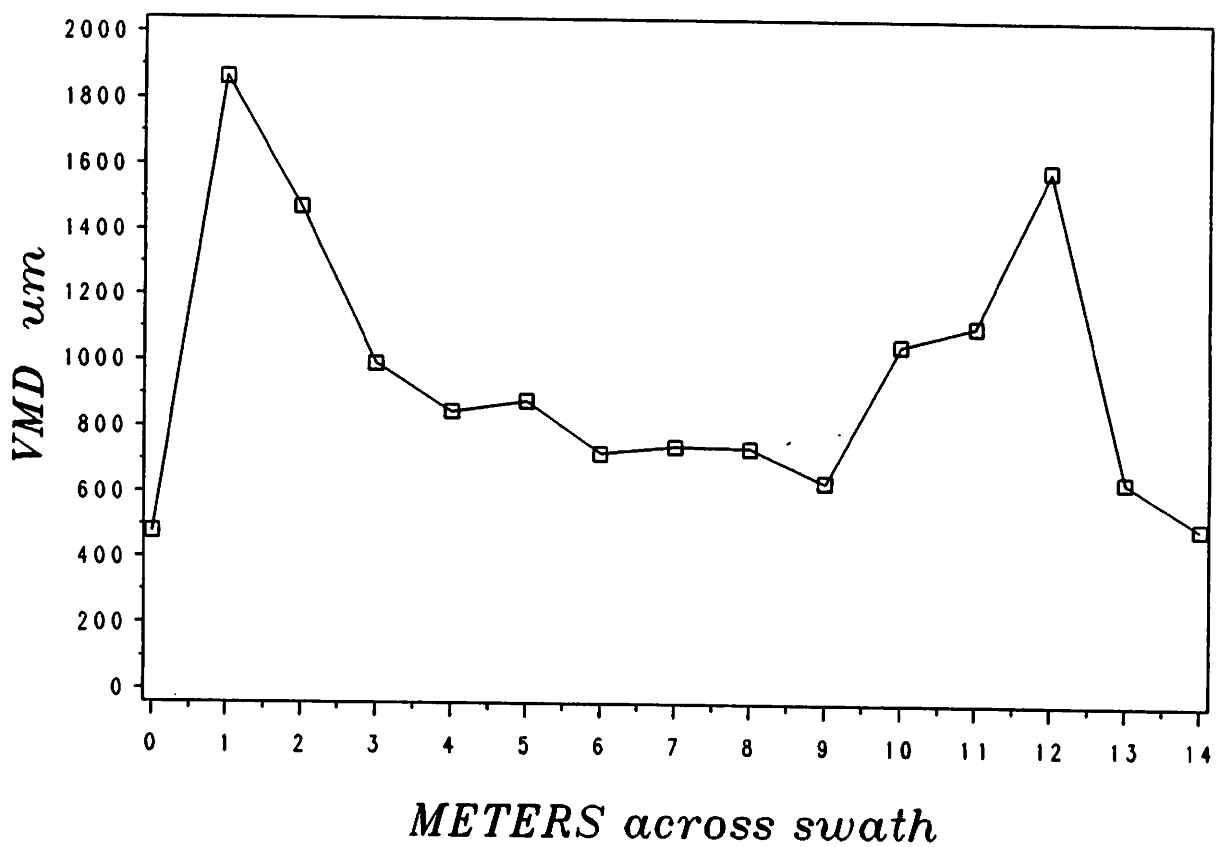


FIG. 2. VMD across swath width (¼KLC-9 nozzle at 4.5m, 40 psi, and 0.76 m/s).

5) **preparation for environmental fate and persistence studies:**

Environmental fate studies were conducted by superimposing a randomized complete block design with subsampling over the experimental layout used for efficacy testing. Experimental units took the form of plots (40m x 25m) as shown previously (Map 2). Those plots receiving the highest rate of each chemical treatment (3 replicates per treatment) were used for determination of chemical fate (deposition with leaf-fall and leaching) and persistence in each of the sampled substrates (foliage, litter and soils). In addition, initial deposit on sugar maple foliage was determined for each treated plot.

Prior to initiation of the study, method development and validation tests were conducted for each analyte/matrix combination. Methods were optimized and validated by fortifying blank matrices with analytical grade and/or 14C-radiolabeled chemicals at a range of rates equivalent to those expected in the field samples. Validation test samples were replicated a minimum of three times and analyzed to determine, percent recovery and precision for the analytical method.

A diagonal transect line, containing 8 uniformly spaced subsamples, was established in each plot (Fig. 3). At each of these subsamples, a representative individual of the major competitive species (sugar maple) was selected and flagged for initial foliar deposit sampling. Sampling along a transect in this manner, provided a pooled sample which integrated the natural variation resulting from chemical application and site characteristics within each experimental unit (40m x 25m plot). Analyzing an aliquot of the pooled subsamples (8) for each replicate provided an accurate estimate of the average initial deposit in each substrate for each experimental unit. Pre-spray sampling was conducted to detect any prior herbicide contamination and to serve as a blank matrix for analytical method validation and quality control.

Within each plot receiving the high, medium and low rates of each chemical (4 treatments x 3 rates x 3 reps = 36 plots) one artificial deposit collector support rod was placed in the efficacy sampling quadrat (Fig. 3). Immediately prior to application, two artificial deposit collectors (a glass-fibre filter paper attached to a flexible wire (GFF) and a glass-fibre filter paper placed

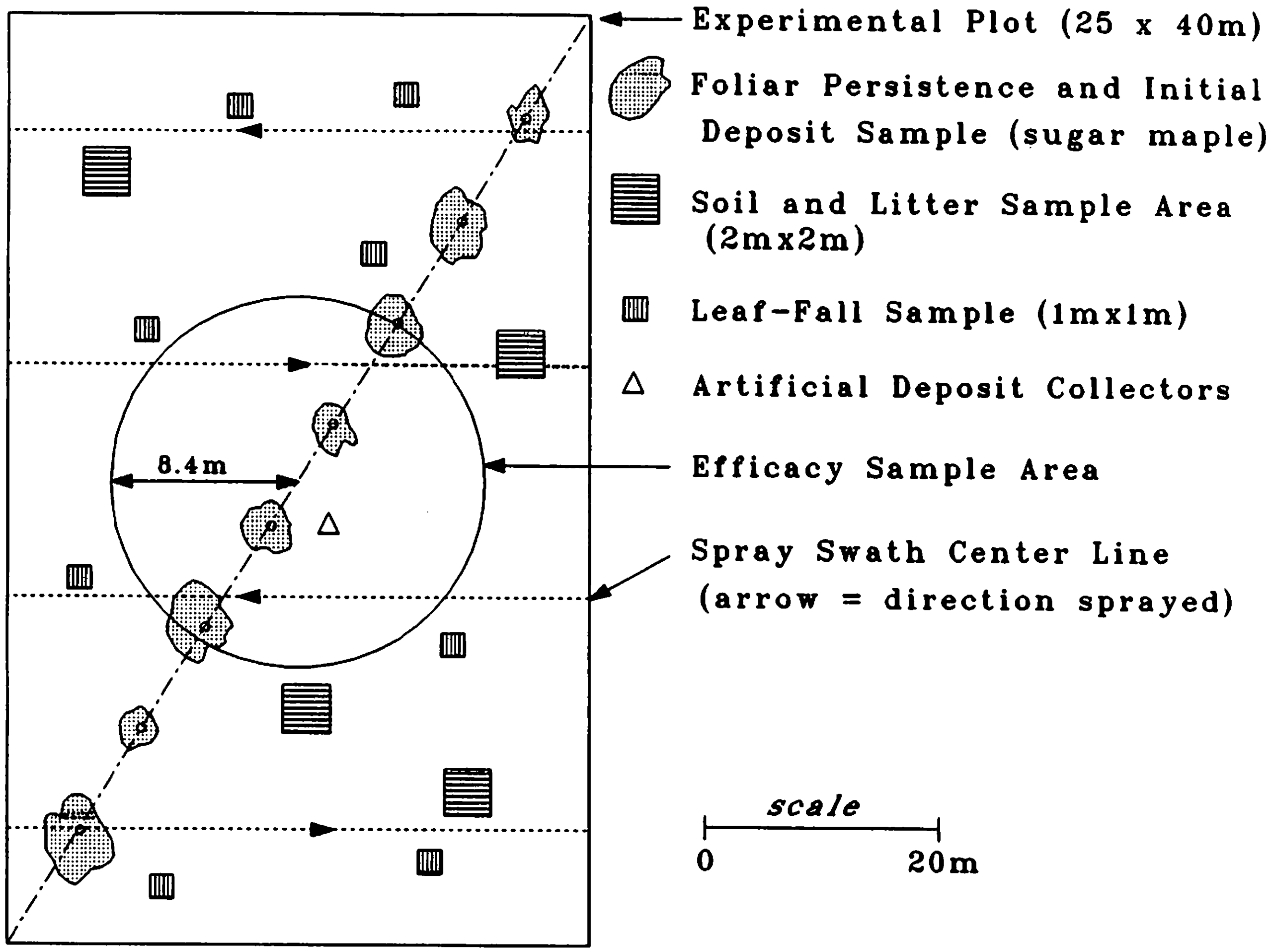


FIG. 3. Experimental plot layout for environmental fate and persistence studies.

in a petri dish (PDF)) with known area were affixed to the support rod at a point equivalent to the average mid-canopy height of the sugar maple.

In each plot receiving the highest rate of application for an individual chemical (4 treatments x 3 reps = 12 plots), four soil sampling stations (2-m^2 area) were chosen in relatively open areas. Soil sampling plots were staked and cordoned off with flagging tape subsequent to removing all above ground herbaceous and brush vegetation with a Husqvarna brush saw. In this manner, full deposit of the chemical to the undisturbed forest floor material was ensured. Pre-spray sampling of the litter, organic and mineral soil horizons was conducted to detect any prior herbicide contamination and to serve as a blank matrix for analytical method validation and quality control.

In the week prior to chemical application, chain saws and brush saws were used to cut access trails throughout the experimental site. Provision of access trails was required to facilitate spraying and ensure all treatments for a given block could be applied within the expected time window of 2 hours post-dawn. In addition, spray lines marking the swath center for of each swath were measured, flagged and cleared of slash to enhance uniformity and accuracy in chemical application.

Finally, a meteorological monitoring station Campbell Scientific (CR-21X) was established (11-09-89) to provide continuous monitoring (24 hr averages) of soil and air temperature, rainfall and relative humidity from the time of chemical application to freeze-up.

b) <u>Treatment</u>

1) chemical application:

Herbicide treatments were applied to the three blocks during the morning spray sessions of September 4, 5, and 6, 1989, respectively. Water for each spray mix was pre-measured into individual 12L-jerry cans (each dedicated to a particular treatment for the duration of the study) each night prior to spraying. Appropriate volumes of each herbicide were mixed with the pre-measured water volumes immediately prior to treatment. A total of 12L was mixed for each treatment. After the completion of each plot, a 10mL subsample was obtained from the residual spray mixes in order to quantify actual tank-mix concentrations. Residual volumes were also measured in order to quantify the actual volume applied to each plot (10L was the target). Herbicides were applied in sequence of increasing rate in order to avoid tank rinses between treatments and potential for cross contamination. For each block, applicators were randomly assigned to the three sprayers which were, in turn, randomly assigned to each of the 4 herbicides.

Plots were treated with a total of four passes spanning the plot width (Fig. 3), following pre-measured and marked swath center lines and using metronomes to maintain calibrated ground speed.

2) manual control:

Manual treatments are scheduled for June 14, 1990. This time was chosen to coincide with full leaf-out (and minimum root carbohydrate stores) in order to minimize re-sprouting and thereby provide the fairest possible comparison of manual and chemical treatments. This time will also coincide with the oncoming effects of the herbicide treatments applied the previous fall.

Treatments will involve the removal of all woody competition (at 10cm above ground line) with a Husqvarna brush saw. An experienced operator will be used for this procedure and time records will be kept.

3) meteorological measurements:

On-site meteorological measurements were made throughout herbicide spray applications, and for the ensuing period ending in late October 1989. Two different sets of measurements were recorded, the first for use in relation to the spray applications, the second for use in relation to herbicide dissipation. During the herbicide applications, wind speed and direction were measured at 4.5m above ground level using a cup anemometer (threshold speed 1.2 km/h) and wind vane (Heathkit Digital Weather Computer model ID 4001, Heath Co., Benton Harbour, MI). Instantaneous values were manually recorded at 5 min time intervals. Air temperatures were measured at 1.5 and 4.5m agl using thermocouples shaded to prevent radiative heating, and soil temperature was measured with a thermocouple buried at a depth of 20cm. Relative humidity was measured at 1.5m agl using a wet/dry bulb psychrometer (Campbell Scientific Inc., Logan, UT), and rainfall was measured using a tipping bucket rain gauge that provides a contact closure for every 1mm of rainfall (RG 2501, Campbell Scientific Inc., Logan, UT). These measurements were made at 5 min time intervals and recorded on a data logger as 24 h averages (CR 21X, Campbell Scientific Inc., Logan, UT). In addition, a visual estimate of leaf wetness was made during the herbicide applications, to determine when spray deposit samplers were sufficiently dry to be collected.

4) deposit evaluation:

Immediately subsequent to application, each residual tank mix was transferred from the spray tank to its respective jerry can and transported back to roadside. Following thorough mixing, a subsample (10mL) of each tank mix was transferred to a 50mL dram vial with screw-cap closure using a 10mL graduated pipet. Tank mix samples were stored frozen and transported to the analytical lab immediately subsequent to completion of the experiment for determination of acid equivalent content using appropriate analytical methods. The residual volume for each tank mix was measured and recorded. The data were used to calculate the volume and active ingredient applied to each plot.

Within each of the 66 plots, 2 foliar samples (leaf area and initial foliar deposit) were taken within 3 hrs post-application for determination of actual initial deposit to sugar maple foliage. From each tagged individual, a constant number of leaves (15) of intermediate size were harvested from all sides of the tree at random heights within the canopy. Initial foliar deposit samples were pooled in a large, pre-labeled plastic bag to form a single composite foliage sample for subsequent residue analysis. In addition, smaller samples (5 leaves per tree) were taken and stored in a separate plastic bag for subsequent use in estimation of mean leaf surface area. Composite leaf surface area samples for each plot were kept flat in large plastic bags, transferred to the lab, and laid out for drying and storage in a large press, to facilitate subsequent area measurement.

Foliage residue samples were stored in the field in coolers containing ice-packs and transported to FORCAN-Maritimes for frozen storage within 12 hrs of collection. To provide homogeneous laboratory samples for residue analysis, foliage samples were macerated and homogenized using an inverted Mason jar fitted to an Osterizer blender. Two sub-samples (mass analyte-dependant) were taken from each laboratory sample, one sample extracted and processed for quantification of residues, while the second was used to determine moisture content. Residue levels in foliage were calculated in ug/g (dry mass) based on moisture content derived from concurrent sub-samples. Leaf areas of approximately 40 representative leaves from each plot were determined using an ARCTEC image analyzer and averaged to calculate the initial on-target deposit on foliage in terms of (ug/cm^2).

As a secondary measure of on-target deposit, artificial deposit collectors (1 of each type per plot) established in each plot receiving the lowest, middle and highest application rate were collected and analyzed for chemical residues. The 2 artificial collectors from each plot were recovered at the same time as initial foliage samples, (i.e. when treated plots were dry to the touch on day of treatment). GFF samples were transferred into PMP sampling bottles with a clean tweezer, PDF samples were covered with the top of the petri dish and taped along the seam. Stabilized samples were stored and transported as described for initial foliage samples. Results for artificial deposit collectors were calculated and reported as ug a.e./cm^2 for comparison to nominal application rates and initial foliar deposit results.

5) environmental fate and persistence determination:

Monitoring for fate and persistence studies began on the day of application and continued until freeze-up (October, 1989). For each product, plots treated at the highest rate of active ingredient were used for environmental fate and persistence determination. Foliar, litter and soil samples were taken from their respective sampling stations according to predetermined schedules. Foliar samples were obtained, as described above for initial deposit, until leaf-drop was estimated to be 90% complete. Litter and organic soil samples were obtained using a 10cm x 10cm x 10cm steel box corer driven into an undisturbed portion of each of four subsampling sites within each plot. The litter fraction was defined as the loosely associated leaf litter, thatch, and non-decomposed organic material above the root zone of herbaceous growth (approx. 5cm). Litter was separated from the underlying true organic soil fraction (approx. 5-10cm) using a clean gardening trowel. A 2.5cm (inside dia.) by 10cm stainless steel bucket auger, was subsequently used to obtain a mineral soil core (approx. 10-20cm) by inserting the auger within the area from which the overlying soil horizons had been removed. Composite samples (4 subsamples/plot) of each layer were placed in individual, pre-labeled plastic bags. Litter, organic and mineral soil samples were stored and transported as described for foliage samples. Soil corers, trowels and other sampling equipment were cleaned exhaustively between replicates using soapy water, distilled water, and acetone to prevent cross-contamination.

At the estimated time of 90% leaf-drop, fresh leaf litter from eight representative 1-m^2 sampling areas within each plot receiving a high-rate treatment were collected. The leaf litter material was collected and pooled in a single large plastic bag and frozen until analyzed. Residue analysis will provide an estimation of the average amount of chemical transported to the ground surface via leaf-drop.

Residue analyses for products containing glyphosate as the active ingredient were conducted using various modifications of the HPLC-VIS analytical technique published previously (Thompson, et al. 1989). Method development and validation for glyphosate residue analysis in tank mix, artificial deposit collectors, and sugar maple foliage have been completed. A capillary GLC-ECD technique modified from packed column techniques supplied by DowElanco has been developed and validated for triclopyr analyses in tank mix and artificial deposit collectors. Further development of this technique for residue analyses in environmental matrices is currently ongoing. Results of the validation trials conducted to date indicate the following:

a) Mean recovery of glyphosate applied to artificial deposit collectors as VISION was greater than 100% with less than 3% coefficient of variation. Recovery was independent of rate and collector type.
b) Mean recovery of glyphosate applied to artificial deposit collectors as TOUCHDOWN was greater than 97% with less than 3% coefficient of

variation. Recovery was independent of rate and collector type.

c) Mean recovery of glyphosate applied to artificial deposit collectors as MON14420 was greater than 96% with less than 3% coefficient of variation. Recovery was independent of rate and collector type.

d) Mean recovery of glyphosate applied to sugar maple foliage as VISION ranged from 79-95% with less than 6% coefficient of variation. Recovery appeared to be independent of rate applied.

e) Mean recovery of glyphosate applied to sugar maple foliage as TOUCHDOWN ranged from 77-79% with less than 10% coefficient of variation. Recovery appeared to be independent of rate applied.

f) Mean recovery of glyphosate applied to sugar maple foliage as MON14420 ranged from 79-92% with less than 6% coefficient of variation. Recovery appeared to be independent of rate applied.

g) Mean recovery of triclopyr (applied as the triclopyr butoxyethyl ester) from artificial deposit collectors ranged from 99.10 - 118% with less than 8% coefficient of variation.

The final conclusion from the validation trials is that the analytical methods meet the acceptability criteria of >80% recovery efficiency, <10% coefficient of variation (good precision) and good chromatographic behaviour (well resolved chromatographic peaks with acceptable limits of detection) in all cases.

Quality control (QC) check sample programs are conducted concurrently with analyses of field samples for all analyte/matrix combinations. Results of the QC check samples indicate excellent recovery efficiency (range 88 - 99%) from fortified deposit collectors with excellent precision (<3% coefficient of variation, with exception of RELEASE on glass fiber filter collectors (6%)). The results indicate that analyses of field samples for these matrix/analyte combinations will be highly accurate when corrected for slight losses in analytical recovery. Similarly, QC samples results for sugar maple foliage fortified with various glyphosate formulations exhibit good mean recovery efficiency and precision (CV) (VISION of 78 ± 5%; TOUCHDOWN 79 ± 3%; and MON14420 81 ± 2%).

c) Post-treatment

1) environmental fate activities:

Sampling of foliar, litter and soil substrates for determination of persistence and fate continued from time of application to freeze-up in late October, 1989. Final sampling of litter and soil substrates will be completed in June, 1990. All soil and litter samples are being stored at -10°C in Forestry Canada - Maritimes facilities prior to shipment for analysis. Foliar residue samples have recently been shipped to FPMI and analyses of these samples is currently on going. Target completion dates for foliar residue samples is April, 1990, with soil and litter samples targeted for completion by December, 1991.

2) silvicultural activities:

Post-treatment weed and crop assessments will be conducted during July and August of 1990 through 1994. Sampling procedures used in the pre-treatment assessment will be repeated.

RESULTS TO DATE

a) Pre-treatment Weed and Crop Data

Estimates of crown area, crown volume, basal area and stem volume were made from the pre-treatment brush data. Crown area [CA(m^2)] was estimated for each tree by calculating the geometric mean of its two crown diameter measurements [D_1 and D_2 (cm)]:

[2] $$CA = a * D_1 * D_2,$$

where $a = \Pi(2.5*10^{-5}\ m^2/cm^2)$. Crown volume was estimated using [1]. Basal area [BA(m^2)] was estimated for each tree from measurements of its stem diameter [D10 (cm)] and number of stems per rootstock (S):

[3] $$BA = a * D10^2 * S,$$

where a = Π(2.5*10-5 m^2/cm^2). Individual stem volumes [SV (m^3)] were estimated from measurements of stem diameter [D10 (cm)], total height [H (m)], and number of stems per rootstock (S):

[4] $$SV = a * D10^2 * H * S,$$

where a = Π($8.3*10^{-6}$ m^2/cm^2). Table 3 provides the experimental means for these parameters, by species.

Table 3. Summary of mean brush parameters for the experimental site, by species.

SPECIES	ROOTSTOCKS (no./ha)	CROWN AREA (m^2/ha)	CROWN VOLUME (m^3/ha)	BASAL AREA (m^2/ha)	STEM VOLUME (m^3/ha)	n plots
Sugar maple	17126.8	1999.67	1445.79	1.78936	1.00256	64
Striped maple	4466.6	648.05	343.20	0.65653	0.27158	62
Yellow birch	5037.5	525.83	333.95	0.47773	0.17753	61
Mountain maple	2777.3	438.57	222.20	0.46176	0.15015	60
Hazel	957.2	480.20	303.28	0.77282	0.27158	57
White ash	2548.6	424.61	260.45	0.38291	0.20489	55
Beech	1493.7	400.08	217.73	0.55725	0.20536	54
Elderberry	1113.5	213.58	101.10	0.17839	0.06780	50
Red maple	2780.9	383.62	348.43	0.42169	0.27650	32
Aspen	355.8	20.70	12.06	0.03448	0.01021	16
Willow	177.5	26.39	14.89	0.01705	0.00622	16
White birch	685.3	97.78	64.86	0.07590	0.03206	16
Pin cherry	51.1	8.87	4.15	0.00450	0.00126	8
Choke cherry	67.5	18.24	10.05	0.01521	0.00537	5
Service berry	11.7	3.49	2.29	0.00407	0.00139	3
Mountain ash	3.5	1.21	0.55	0.00220	0.00070	1
TOTALS	39654.5	5690.87	3684.99	5.85000	2.69000	66

A total of 16 brush species were present on the site prior to treatment. Eight species (sugar maple, striped maple, yellow birch, mountain maple, hazel, white ash, beech, and elderberry) were present in at least 50 (75%) of the research plots. Sugar maple was, by far, the most dominant species on the site, representing 43% of total stem density, 35% of crown area, 39% of crown volume, 30% of basal area, and 37% of stem volume.

Since the experiment was blocked on pre-treatment crown volume, randomization of the treatments should, if adequate interspersion was obtained, minimize pre-treatment differences in crown volume between the treatments. Analysis of variance of total pre-treatment crown volume verifies this eventuality (Table 4). A very low F value (0.61) indicates that pre-treatment variation among treatments did not differ from pre-treatment variation within treatments (P=0.8910).

Table 4. ANOVA of pre-treatment crown volume (all species combined).

SOURCE OF VARIATION	DF	SS	F	P > F
TREATMENTS	21	8025585.8864	0.61	0.8910
BLOCKS	2	94180802.2572		
TREATMENT*BLOCKS (ERROR)	42	26494889.1556		
TOTAL	65	128701277.2992		

Since sugar maple is the most predominant species on the site, and obviously the species of primary interest, the randomization should result in adequate interspersion with respect to this species as well. ANOVA (Table 5) shows this to be true (P=0.3656).

Crop trees planted in August of 1987 averaged 14.45cm in height (CV=13.5%, n=66 plots). All had a health-class rating of 1 at the time of planting. The same trees, measured in August 1989, averaged 56.92cm in height (CV=20.11%, n=66 plots). Analysis of variance of the pre-treatment heights of these trees (Table 6) does not suggest any height differences between treatments.

Table 5. ANOVA of pre-treatment crown volume (sugar maple only).

SOURCE OF VARIATION	DF	SS	F	P > F
TREATMENTS	21	14976656.1904	1.12	0.3656
BLOCKS	2	10740845.0083		
TREATMENT*BLOCKS (ERROR)	40	25399409.5884		
TOTAL	63	51116910.7871		

Table 6. ANOVA of pre-treatment height of 1987 crop trees.

SOURCE OF VARIATION	DF	SS	F	P > F
TREATMENTS	21	3093.4189	1.14	0.3458
BLOCKS	2	9.7174		
TREATMENT*BLOCKS (ERROR)	42	5410.2317		
TOTAL	65	8513.3680		

Mortality during the two year establishment period prior to treatment was minimal (4%, Fig. 4). Flooding was the suspected cause in all cases. In general, the majority (78%) of these trees were healthy (classes 1 and 2) prior to release.

Seedlings planted immediately following treatment averaged 14.39cm in height (CV=8.85%, n=66 plots). While no effort was made to ensure that these trees were identical (i.e., same seed source) to the 1987 trees, they were of the same stock type and mean heights and health characteristics were similar. Table 7 outlines ANOVA results for height of the 1989 trees at the time of planting. As expected, there were no treatment biases evident (P=0.4157).

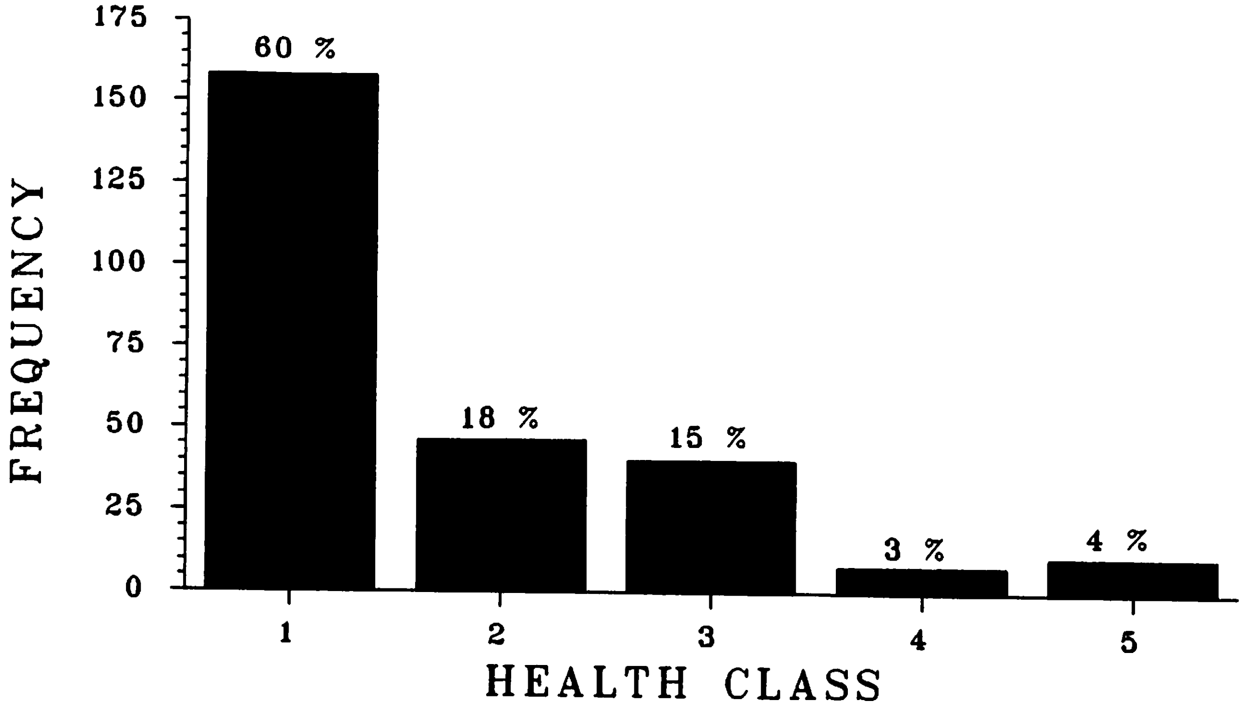


FIG. 4. Frequency of black spruce in each of 5 health classes prior to release. (1 = vigorous, 2 = healthy, 3 = mediocre, 4 = moribund, and 5 = dead).

Table 7. ANOVA of pre-treatment height of 1987 crop trees.

SOURCE OF VARIATION	DF	SS	F	P > F
TREATMENTS	21	35.7291	1.07	0.4157
BLOCKS	2	2.6783		
TREATMENT*BLOCKS (ERROR)	42	66.9693		
TOTAL	65	105.3767		

b) Chemical Applications and Initial Deposit

Residual tank mix volumes and tank mix concentration analyses are presented in Table 8. In short, the data indicate that overall applied volumes averaged 99 L/ha, very close to the target volume rate of 100 L/ha. In terms of the accuracy of spray volume applied for each product/rate combination, the mean volume applied (n=3) was accurate to within 8%. The largest errors occurred on 05-09-90, during application of TOUCHDOWN, for which low volumes applied resulted from partial blockage of the KLC-9 spray nozzle. Low application volume for the second lowest rate of RELEASE resulted from excessive ground speed during application to the second replicate on 05-09-90.

In general, tank mix concentrations were also highly accurate and precise (standard deviation < 0.08). Exceptions to this generalization were observed for 3/5 RELEASE preparations. Significant errors in calculated rate for the two lowest and the highest rates of RELEASE are attributed to separation of the RELEASE formulation in the jerry cans prior to subsampling. Subsequent laboratory tests have confirmed that this hypothesis is plausible, however, there is no means by which to verify that this phenomenon actually occurred during field subsampling. With the exception of the three anomalies described above, calculated rates deviated from nominal rates by factors of -8 to +9%, suggesting that overall application of the various chemical treatments was very accurate.

Quality control check sample results for initial deposit on sugar maple foliage are presented in Table 9.

Residue analysis conducted on field samples of sugar maple foliage taken from plots treated with glyphosate are presented in Table 10, in terms of both ug/g dry mass of foliage and in terms of mean deposit in ug/cm². A clear correlation of deposit in relation to calculated rate applied was observed, as shown in Figs. 5, 6, and 7. Standard deviations about the mean deposit indicate that in general, application to the various replicates was uniform with exceptions being the high rate application of TOUCHDOWN and MON14420. Readers should note that the mean deposit in terms of ug/cm² for the various treatments should be considered only in relative terms. Since the leaves have

Table 8. Residual tank-mix volumes and concentrations.

CHEMICAL	RATE	REP 1 -		low	REP 2 -		med	REP 3 -		high	VOL	APPL	CONC	APPL	CALC	% OF
	kg/ha	RSD	RATE	CONC	RSD	RATE	CONC	RSD	RATE	CONC	MEAN	STD	MEAN	STD	RATE	RATE
		mL	L/ha	ug/mL	mL	L/ha	ug/mL	mL	L/ha	ug/mL	L		ug/mL		kg/ha	
RELEASE	0.400	1950	101	0.029	1750	103	0.017	1475	105	0.018	103	1.947	0.021	0.005	0.315	78.72
RELEASE	1.260	1700	103	0.021	3675	83	0.008	2050	100	0.019	95	8.605	0.016	0.006	0.859	68.21
RELEASE	2.120	2100	99	0.018	2100	99	0.019	1875	101	0.022	100	1.061	0.020	0.001	2.126	100.27
RELEASE	2.980	1250	108	0.020	1725	103	0.023	1725	103	0.022	104	2.239	0.022	0.001	3.260	109.39
RELEASE	3.480	1750	103	0.024	1500	105	0.029	2125	99	0.027	102	2.569	0.027	0.002	4.900	140.79
MON14420	0.250	2200	98	2.544	1850	102	2.582	1650	104	2.664	101	2.273	2.597	0.050	0.262	104.91
MON14420	0.722	2075	99	1.461	1675	103	1.542	2850	92	1.485	98	4.858	1.496	0.034	0.732	101.44
MON14420	1.193	2600	94	2.369	1700	103	2.566	2200	98	2.449	98	3.682	2.461	0.081	1.210	101.43
MON14420	1.665	2450	95	1.661	1850	102	1.684	2125	99	1.630	98	2.664	1.658	0.022	1.632	98.03
MON14420	2.136	2350	96	2.129	2050	100	2.169	1425	106	2.213	100	4.033	2.170	0.034	2.179	102.04
TOUCHDOWN	0.230	1500	105	2.248	2900	91	2.263	1400	106	2.135	101	6.848	2.215	0.057	0.223	96.96
TOUCHDOWN	0.669	1700	103	1.296	3675	83	1.286	1080	109	1.280	98	11.065	1.287	0.007	0.634	94.75
TOUCHDOWN	1.106	2250	97	2.138	3300	87	2.253	850	112	2.100	99	10.058	2.164	0.065	1.066	96.35
TOUCHDOWN	1.543	1800	102	1.478	3100	89	1.563	1475	105	1.570	99	7.021	1.537	0.042	1.518	98.37
TOUCHDOWN	1.980	2300	97	1.921	3850	82	2.072	2050	100	1.936	93	7.962	1.976	0.068	1.831	92.50
VISION	0.250	1650	104	2.449	3025	90	2.436	1550	105	2.632	99	6.730	2.506	0.089	0.249	99.47
VISION	0.722	2450	95	1.433	1950	101	1.404	1900	101	1.404	99	2.718	1.414	0.014	0.699	96.76
VISION	1.193	2275	97	2.373	3550	85	2.388	1475	105	2.444	96	8.530	2.402	0.031	1.148	96.21
VISION	1.665	2000	100	1.657	1350	107	1.657	2300	97	1.643	101	3.965	1.652	0.007	1.672	100.40
VISION	2.136	1900	101	2.069	2150	99	2.081	2125	99	2.194	99	1.124	2.115	0.056	2.102	98.42

Table 9. Quality control data for initial deposit on sugar maple foliage.

CHEM ID	QC NO.	FORTIF. DATE	ANALYSIS DATE	FILE NO.	EXP.TTL ug	RPT.TTL ug	% REC	RATE ug/g	MEAN % REC	STD
VISION	1	JAN1790	JAN2390	700	21360	18480	86.51	4239.6		
VISION	2	JAN1790	JAN2390	701	21360	17740	83.05	4136.4		
VISION	3	JAN1790	JAN2390	703	21360	18090	84.69	4102.6	84.75	1.41
VISION	4	JAN1790	JAN2490	728	14952	12470	83.40	2964.8		
VISION	5	JAN3090	FEB0290	708	14952	12080	80.79	2944.5		
VISION	6	JAN1790	JAN2390	710	14952	12800	85.60	2971.0	83.26	1.96
VISION	7	JAN2490	FEB1990	855	10680	8590	80.43	2287.4		
VISION	8	JAN2490	FEB1990	857	10680	7630	71.44	2319.1		
VISION	9	JAN2490	FEB1990	858	10680	7790	72.94	2318.9	74.93	3.93
VISION	10	JAN2490	JAN3090	754	7120	5648	79.31	1645.6		
VISION	11	JAN2490	JAN3090	755	7120	5945	83.49	1635.2		
VISION	12	JAN2490	JAN3090	757	7120	4948	69.49	1637.8	77.43	5.86
VISION	13	JAN3090	FEB0290	803	2136	1556	72.84	412.66		
VISION	14	JAN3090	FEB0290	800	2136	1481	69.35	414.39		
VISION	15	JAN3090	FEB0290	802	2136	1577	73.82	419.99	72.00	1.92
								MEAN	**78.40**	**4.85**
T-DOWN	1	FEB1990	FEB2290	875	19800	16640	84.04	4025.1		
T-DOWN	2	FEB1990	FEB2290	876	19800	16070	81.16	4005.2		
T-DOWN	3	FEB1990	FEB2290	878	19800	16290	82.27	4048.0	82.49	1.18
T-DOWN	4	FEB2290	FEB2790	888	9900	7338	74.12	2366.4		
T-DOWN	5	FEB2290	FEB2790	890	9900	8170	82.52	2374.7		
T-DOWN	6	FEB2290	FEB2790	891	9900	7980	80.60	2324.2	79.08	3.59
T-DOWN	7	MAR1990	MAR2690	47	1980	1613	81.47	372.69		
T-DOWN	8	MAR1990	MAR2690	49	1980	1430	72.22	382.68		
T-DOWN	9	MAR1990	MAR2690	50	1980	1418	71.63	371.20	75.11	4.50
								MEAN	**78.80**	**3.01**
14420	1	MAR0590	MAR0990	956	16320	13492	82.67	3692.4		
14420	2	MAR0590	MAR0990	957	16320	14851	90.99	3576.2		
14420	3	MAR0590	MAR0990	959	16320	11647	71.36	3706.7	81.67	8.04
14420	4	MAR0890	MAR1390	988	8840	6677	75.53	2059.1		
14420	5	MAR0890	MAR1390	989	8840	6932	78.41	2038.3		
14420	6	MAR0890	MAR1390	991	8840	7133	80.69	2006.4	78.21	2.11
14420	7	MAR1490	MAR2690	30	2040	1753	85.91	328.59		
14420	8	MAR1490	MAR2690	31	2040	1682	82.47	331.34		
14420	9	MAR1490	MAR2690	0.3	2040	1714	83.99	331.34	84.12	1.40
								MEAN	**81.30**	**2.42**
							OVERALL	**MEAN**	**79.37**	**3.26**

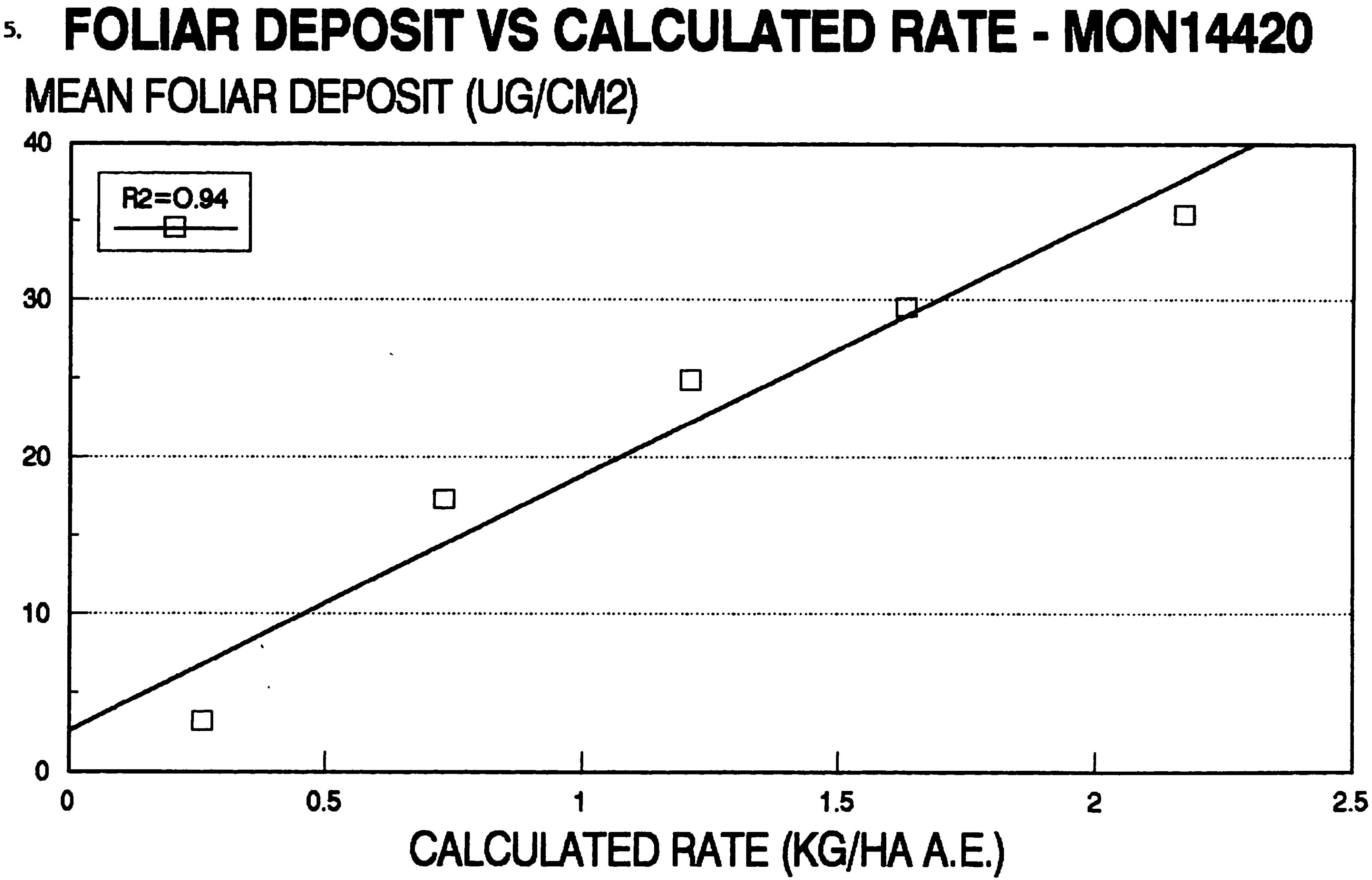
Note : RELEASE has yet to be processed.

Table 10. Glyphosate residue analysis of sugar maple samples.

CHEM	RATE kg/ha	REP	SAMPLE ID.	PLOT NO.	DATE SAMP.	DATE ANAL.	FILE NO.	RESIDUE ug/g	L-AREA MEAN	DEP. ug/cm²	DEP AVG	ug/cm² STD
VISION	2.134	L	IDF-V5-11	11	40989	230190	705	416.84	67	31.93		
VISION	2.134	M	IDF-V5-4	4	50989	240190	718	397.06	74	27.50		
VISION	2.134	H	IDF-V5-80	80	60989	20290	796	365.04	71	26.10	28.51	2.49
VISION	1.663	L	IDF-V4-44	44	40989	90390	947	367.72	74	25.24		
VISION	1.663	M	IDF-V4-5	5	50989	230190	711	490.66	77	32.52	* reanalyzed	
VISION	1.663	H	IDF-V4-63	63	60989	230190	713	311.25	83	19.51	25.76	5.32
VISION	1.192	L	IDF-V3-34	34	40989	190290	851	291.87	74	20.44		
VISION	1.192	L	IDF-V3-34	34	40989	130390	982	313.47	74	21.96		
VISION	1.192	M	IDF-V3-42	42	50989	190290	852	113.21	55	10.60		
VISION	1.192	H	IDF-V3-51	51	60989	190290	854	252.19	71	18.30	17.82	4.37
VISION	0.721	L	IDF-V2-8	8	40989	300190	773	98.52	73	6.97		
VISION	0.721	M	IDF-V2-17	17	50989	310190	775	101.55	53	9.79		
VISION	0.721	H	IDF-V2-53	53	60989	310190	780	102.46	69	7.74	8.17	1.19
VISION	0.250	L	IDF-V1-61	61	40989	20290	791	70.37	66	5.44		
VISION	0.250	M	IDF-V1-88	88	50989	20290	793	26.22	47	2.84		
VISION	0.250	H	ID-V1-108	108	60989	20290	794	39.89	74	2.76	3.68	2.22
T-DOWN	1.980	L	IDF-T5-39	39	40989	220290	871	609.04	71	44.19	*reanalyzed	
T-DOWN	1.980	M	IDF-T5-98	98	50989	220290	874	328.50	75	22.30		
T-DOWN	1.980	H	IDF-T5-58	58	60989	220290	873	264.42	68	19.92	28.81	18.04
T-DOWN	1.543	L	IDF-T4-7	7	40989	220290	879	206.01	73	14.42		
T-DOWN	1.543	M	IDF-T4-13	13	50989	220290	868	219.63	79	14.09		
T-DOWN	1.543	H	IDF-T4-59	59	60989	220290	870	236.11	76	15.64	14.72	6.72
T-DOWN	1.107	L	IDF-T3-43	43	40989	270290	884	178.10	60	15.22		
T-DOWN	1.107	M	ID-T3-100	100	50989	270290	887	185.34	91	10.39		
T-DOWN	1.107	H	IDF-T3-81	81	60989	270290	885	168.73	77	11.35	12.32	6.35
T-DOWN	0.671	L	IDF-T2-33	33	40989	190390	43	139.72	77	9.19		
T-DOWN	0.671	M	ID-T2-103	103	50989	190390	46	140.63	79	9.03		
T-DOWN	0.671	H	IDF-T2-67	67	60989	190390	44	68.63	85	4.11	7.45	2.36
T-DOWN	0.235	L	IDF-T1-40	40	40989	190390	37	68.92	74	4.75		
T-DOWN	0.235	M	IDF-T1-48	48	50989	190390	38	40.86	93	2.23		
T-DOWN	0.235	H	ID-T1-112	112	60989	190390	40	58.54	84	3.52	3.50	1.03
14420	2.134	L	IDF-N5-49	49	40989	90390	954	611.73	74	41.61		
14420	2.134	M	IDF-N5-32	32	50989	90390	953	449.46	72	31.36		
14420	2.134	H	IDF-N5-23	23	60989	90390	951	412.95	64	33.51	35.49	17.70
14420	1.663	L	IDF-N4-60	60	40989	90390	950	309.11	56	28.04		
14420	1.663	M	IDF-N4-24	24	50989	90390	948	341.42	64	27.62		
14420	1.663	H	IDF-N4-50	50	60989	230190	714	449.43	70	33.05	29.57	13.12
14420	1.192	L	ID-N3-101	101	40989	130390	986	340.91	56	31.25		
14420	1.192	M	IDF-N3-57	57	50989	130390	983	381.35	74	26.06		
14420	1.192	H	IDF-N3-70	70	60989	130390	985	288.88	83	17.66	24.99	13.68
14420	0.721	L	IDF-N2-52	52	40989	260390	25	219.48	78	14.21		
14420	0.721	M	ID-N2-106	106	50989	260390	27	231.71	64	18.55		
14420	0.721	H	IDF-N2-68	68	60989	260390	28	245.50	65	19.19	17.31	2.21
14420	0.250	L	IDF-N1-10	10	40989	260390	41	22.36	79	1.44		
14420	0.250	M	ID-N1-113	113	50989	260390	22	72.48	69	5.34		
14420	0.250	H	IDF-N1-79	79	60989	260390	24	37.20	68	2.80	3.20	1.61
CONTROL	0.000	L	IDF-CON-1	1	40989	90590	264	0.48	76	0.03		

Note : RELEASE has yet to be processed.

FIG. 5.



MEAN FOLIAR DEPOSIT ON SUGAR MAPLE FOLIAGE
CALC RATE BASED ON TANK MIX VOL APPLIED & CONC.
MEANS OF N=3, 8 SUBSAMPLES PER REP

FIG. 6.

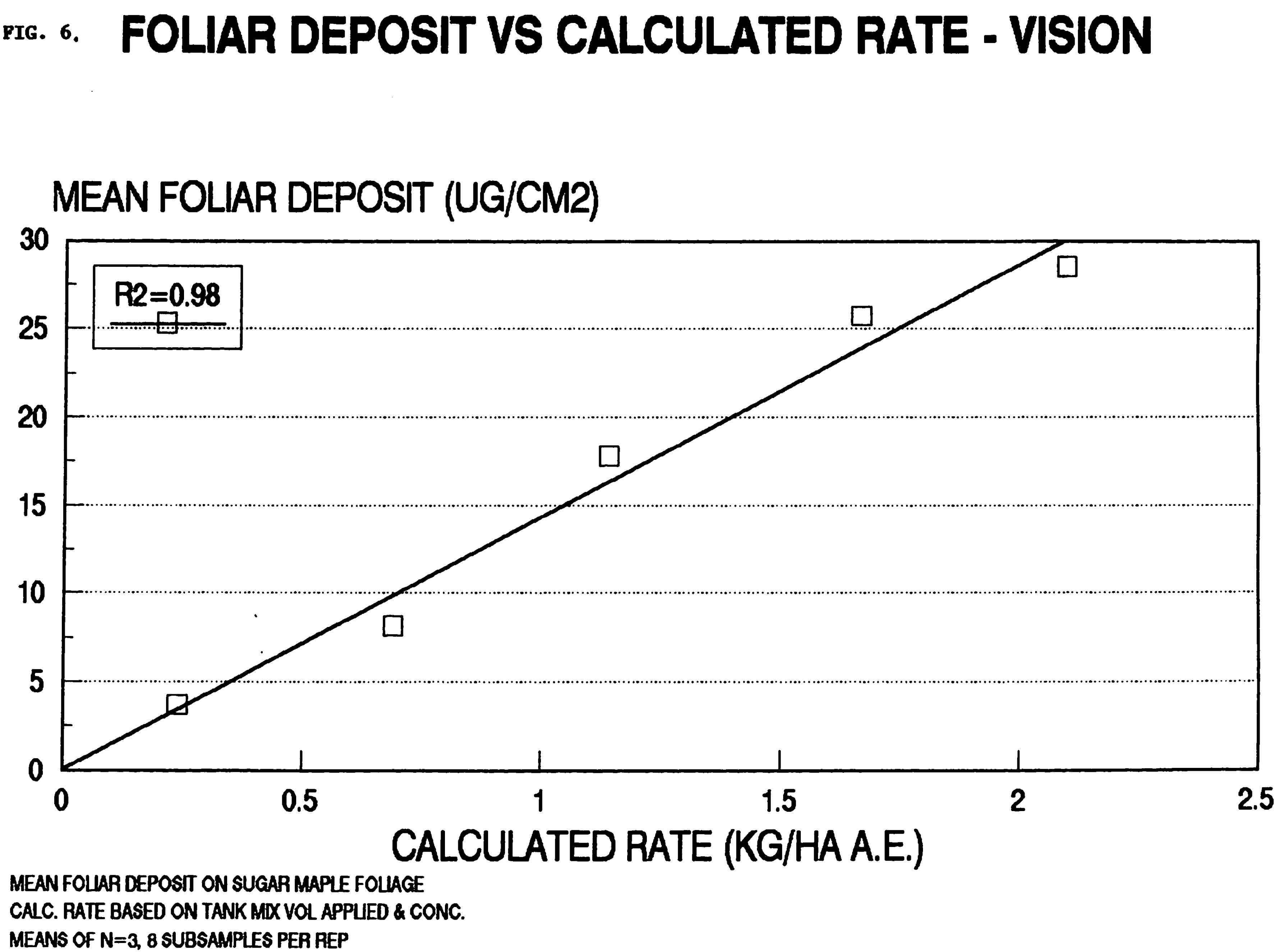
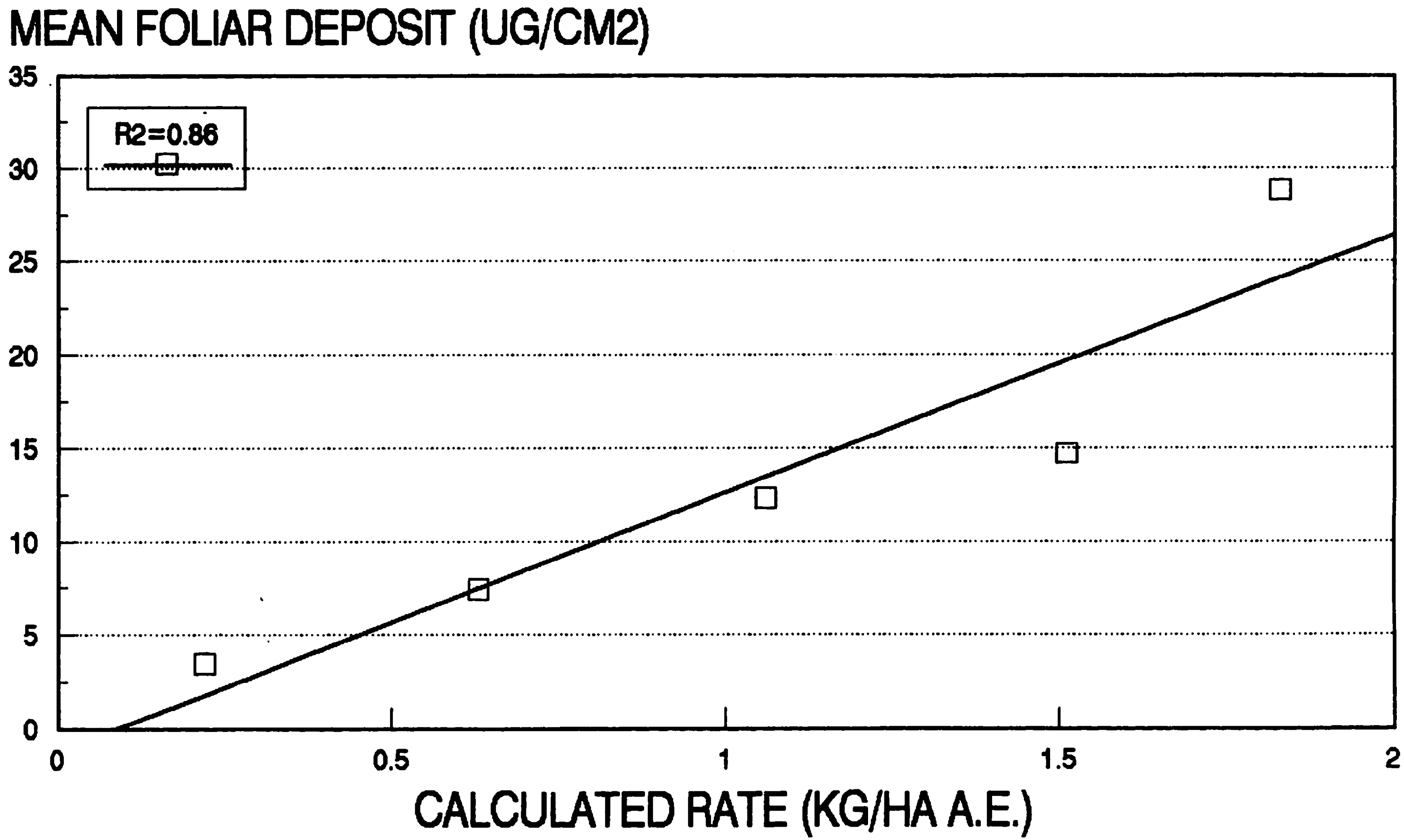

FOLIAR DEPOSIT VS CALCULATED RATE - VISION
MEAN FOLIAR DEPOSIT (UG/CM2)
R2=0.98
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
CALCULATED RATE (KG/HA A.E.)
MEAN FOLIAR DEPOSIT ON SUGAR MAPLE FOLIAGE
CALC. RATE BASED ON TANK MIX VOL APPLIED & CONC.
MEANS OF N=3, 8 SUBSAMPLES PER REP

FIG. 7. **FOLIAR DEPOSIT VS CALCULATED RATE - TOUCHDOWN**



MEAN FOLIAR DEPOSIT ON SUGAR MAPLE FOLIAGE
CALC. RATE BASED ON TANK MIX VOL APPLIED & CONC.
MEANS OF N=3, 8 SUBSAMPLES PER REP

two surfaces for potential adsorption and were taken from various heights as well as various locations within the brush canopy these data cannot be reliably recalculated to yield rate estimates in kg a.e./ha.

Residue analysis of artificial deposit collector samples have been completed. The extreme variability in results reflects the inadequacy of a single subsample for deposit assessment and the problems associated with the use of artificial estimation of on-target deposit. Dose-response relationships for all products will be based on actual active ingredient deposited on sugar maple foliage.

c) **Meteorology:**

Measurements were made during each spray session and the ensuing period until 25/10/89. Wind speed measurements were needed to ensure that spray drift did not cause herbicide to be deposited in adjacent plots, and a wind speed limit of 5 km/h was observed for spray applications. During the 4/9/89 application, the wind speed averaged 4.6 km/h (SD 0.9) and the wind direction averaged 320 degrees (SD 24) between 6.35 and 8.35 am. For the spray application on 5/9/89, the wind speed averaged 4.3 km/h (SD 1.7) and the wind direction averaged 83 degrees (SD 37) between 6.30 and 8.35 am. Between 6.30 and 8.30 am on 6/9/89 the measured wind speed averaged 3 km/h (SD 2.7) and the wind direction averaged 57 degrees (SD 31). During the spray applications, and for the period immediately thereafter, the data logger was non-functional, consequently no measurements of air or soil temperature, relative humidity or rainfall are available during this period. Nevertheless this information is available from 11/9/89 until 25/10/89 for use in relation to the herbicide persistence measurements. Meteorological measurements logged during the period 11/9/89 - 25/10/89 will be analyzed for use in relation to herbicide dissipation measurements.

d) **Environmental Fate and Persistence**

As noted previously, residue analysis for fate and persistence determinations has been initiated and is currently ongoing. Target completion date for all residue sample analyses is December, 1991.

BUDGET STATUS

Table 11 outlines the current and projected financial status of this trial. These figures do not include the important logistical support provided by J.D. Irving Limited and Forestry Canada - Maritimes Region. Current expenditures are slightly below budget figures ($5000), however this will be offset by chemical analysis which is being spread over a two-year period.

Table 11. Current and projected financial status of Brush Trial.

Cooperator	pre 1989	1989	1990	1991	1992 +
Monsanto	0	15085	9544	2715	0
DowElanco	0	8665	5274	1810	0
Chipman	0	5250	5250	5250	0
J.D. Irving	5000	0	0	0	0
FPMI*	22000	30000	22000	18000	10000
total spent:	27500	54000			
carry over :		5000			

* includes salaries of permanent staff, overhead, lab expenses, etc.

REFERENCES

HUSCH, B., MILLER, C.I., and BEERS, T.W. 1972. Forest mensuration. John Wiley & Sons, New York, N.Y.

MANVILLE, J.F. 1983. Herbicides and research: context and perspective. Expert Comm. Weeds, West. Sect. Meet. Nov. 29-Dec. 1, 1983, Vancouver, B.C.

MOORE, G.C. 1985. New Brunswick herbicide manual. Dept. of Nat. Res.

N.B., 80 pp.

REYNOLDS, P.E. 1988. Prognosis for future forestry herbicide use in Canada. CPPA Woodlands Section Paper. Canadian Forest Industries Magazine 108(2):35-42.

STEPHENSON, G.R., and K.R. SOLOMON. 1987. Determination of the leachability, persistence and lateral movement of triclopyr (GARLON) in selected Canadian forestry soils. Final report for the Canadian Forestry Service Program of Research by Universities in Forestry (PRUF), 39pp.

THOMPSON, D.G., COWELL, J.E., DANIELS, R.J., STAZNIK, B., and MacDONALD, L.M. 1989. Liquid chromatographic method for quantitation of glyphosate and metabolite residues in organic and mineral soils, stream sediments, and hardwood foliage. J. Assoc. Off. Anal. Chem. 72(2):355-360.

Table 6. Proportion of sites sprayed per year ± estimated standard error.

Source	Spray policy	Spray frequency
Stedinger model	DSP	.176 ± .009
	SSP	.107 ± .006
	DSP2[1]	.222 ± .014
Jones model	DSP	.041 ± .006
	SSP	.027 ± .003
Survey data		.226 ± .046

[1]DSP with spray mortality reduced from 90% to 80% (Stedinger, 1977).

Table 7. Frequencies of block conditions recorded in the field.

DEF(t)	EGG(t) 1	2	3	4	5	6
1	.02	.04	.02	.01	.01	.00
	(.02,.03)	(.03,.05)	(.02,.03)	(.01,.01)	(.01,.01)	(.00,.00)
2	.01	.04	.03	.01	.01	.00
	(.01,.01)	(.03,.05)	(.02,.04)	(.01,.01)	(.01,.01)	(.00,.00)
3	.01	.04	.03	.02	.02	.00
	(.01,.01)	(.03,.05)	(.02,.04)	(.02,.03)	(.02,.03)	(.00,.00)
4	.01	.05	.06	.04	.04	.01
	(.01,.01)	(.04,.06)	(.05,.07)	(.03,.05)	(.03,.05)	(.01,.01)
5	.00	.03	.03	.03	.03	.01
	(.00,.00)	(.02,.04)	(.02,.04)	(.02,.04)	(.02,.04)	(.01,.01)
6	.00	.06	.11	.07	.10	.03
	(.00,.00)	(.05,.07)	(.09,.13)	(.06,.08)	(.09,.12)	(.02,.04)

KEY: m(n) where m = mean frequency, n = sample size, and U and L are the upper and lower 95% confidence limits, respectively.
(L,U)

Table 8. Frequencies of block conditions - Stedinger model with the DSP.

DEF(t)	EGG(t) 1	2	3	4	5	6
1	.03(-.01)	.25(-.21)	.05(-.03)	.00(.01)	.00(.01)	.00(0)
	(.02,.04)	(.24,.26)*	(.04,.06)*	(.00,.01)	(.00,.00)*	(.00,.00)
2	.00(.01)	.10(-.06)	.09(-.06)	.01(0)	.00(.01)	.00(0)
	(.00,.00)*	(.09,.11)*	(.08,.10)*	(.00,.01)	(.00,.00)*	(.00,.00)
3	.00(.01)	.04(0)	.10(-.07)	.04(-.02)	.00(.02)	.00(0)
	(.00,.00)*	(.04,.05)	(.09,.11)*	(.03,.05)	(.00,.01)*	(.00,.00)
4	.00(.01)	.01(.04)	.03(.03)	.06(-.02)	.04(0)	.00(.01)
	(.00,.00)	(.00,01)*	(.02,.04)*	(.05,.07)	(.03,.04)	(.00,.00)*
5	.00(0)	.00(.03)	.00(.03)	.00(.02)	.02(.01)	.00(.01)
	(.00,.00)	(.00,.00)	(.00,.00)*	(.00,.01)*	(.01,02)	(.00,.00)*
6	.00(0)	.00(.06)	.00(.11)	.02(.05)	.11(-.01)	.00(.03)
	(.00,.00)	(.00,.00)*	(.00,.00)*	(.02,.03)	(.10,.12)	(.00,.01)

KEY: m(e) where m = mean frequency, e = survey mean - m, and U and L are the upper and lower

(L,U) 95% confidence limits, respectively.

* indicates no overlap with the corresponding confidence interval for the field data (Table 7).

Table 9. Frequencies of block conditions - Stedinger model with the SSP.

	EGG(t)					
DEF(t)	1	2	3	4	5	6
1	.22(-.19)	.36(-.32)	.06(-.04)	.00(.01)	.00(.01)	.00(0)
	(.21,.23)*	(.35,.37)*	(.06,.07)*	(.00,.01)	(.00,.00)*	(.00,.00)
2	.00(.01)	.06(-.02)	.05(-.02)	.00(.01)	.00(.01)	.00(0)
	(.00,.00)*	(.05,.07)	(.04,.06)	(.00,.01)	(.00,.00)*	(.00,.00)
3	.00(.01)	.02(.02)	.04(-.01)	.02(0)	.00(.02)	.00(0)
	(.00,.00)*	(.01,.05)	(.03,.05)	(.01,.03)	(.00,.01)*	(.00,.00)
4	.00(.01)	.01(.04)	.02(.04)	.02(.02)	.01(.03)	.00(.01)
	(.00,.00)*	(.00,.01)*	(.01,.02)*	(.02,.03)	(.01,.02)*	(.00,.00)
5	.00(0)	.00(.03)	.00(.03)	.00(.03)	.01(.02)	.00(.01)
	(.00,.00)	(.00,.00)*	(.00,.00)*	(.00,.00)*	(.00,.01)*	(.00,.00)*
6	.00(.0)	.00(.06)	.02(.09)	.04(.03)	.05(.05)	.00(.03)
	(.00,.00)	(.00,.00)*	(.01,.03)*	(.03,.04)*	(.04,.06)*	(.00,.00)*

KEY: m(e) where m = mean frequency, e = survey mean - m, and U and L are the upper and lower

(L,U) 95% confidence limits, respectively.

* indicates no overlap with the corresponding confidence interval for the field data (Table 7).

Table 10. Frequencies of block conditions - Jones model with the DSP.

	EGG(t)					
DEF(t)	1	2	3	4	5	6
1	.45(-.43)	.23(-.19)	.00(.02)	.00(.01)	.00(.01)	.00(0)
	(.43,.47)*	(.21,.24)*	(.00,.01)*	(.00,.00)*	(.00,.00)*	(.00,.00)
2	.00(.01)	.04(0)	.05(-.02)	.00(.01)	.00(.01)	.00(0)
	(.00,.00)*	(.03,.05)	(.04,.06)	(.00,.01)	(.00,.00)*	(.00,.00)
3	.00(.01)	.03(.01)	.04(-.01)	.03(-.01)	.01(-.01)	.00(0)
	(.00,.00)*	(.03,.04)	(.04,.05)	(.03,.04)	(.00,.01)*	(.00,.00)
4	.00(.01)	.00(.05)	.01(.05)	.03(-.01)	.06(-.02)	.00(-.01)
	(.00,.00)*	(.00,.00)*	(.00,.01)	(.02,.03)	(.05,.07)	(.00,.01)
5	.00(0)	.00(03)	.00(.03)	.00(.03)	.01(.02)	.00(.01)
	(.00,.00)	(.00,.00)*	(.00,.00)*	(.00,.00)*	(.01,.01)*	(.00,.01)
6	.00(0)	.00(.06)	.00(.11)	.00(.07)	.00(.10)	.00(.03)
	(.00,.00)	(.00,.00)*	(.00,.00)*	(.00,.00)*	(.00,.00)*	(.00,.00)*

KEY: m(e) (L,U) where m = mean frequency, e = survey mean - m, and U and L are the upper and lower 95% confidence limits, respectively.

* indicates no overlap with the corresponding confidence interval for the field data (Table 7).

Table 11. Frequencies of block conditions - Jones model with the SSP.

	EGG(t)					
DEF(t)	1	2	3	4	5	6
1	.71(-.69)	.18(-.14)	.00(.02)	.00(.01)	.00(.01)	.00(0)
	(.69,.73)*	(.17,.19)*	(.00,.01)*	(.00,.00)*	(.00,.00)*	(.00,.00)
2	.00(.01)	.02(.02)	.02(.01)	.00(.01)	.00(.01)	.00(0)
	(.00,.00)*	(.02,.03)	(.01,.02)	(.00,.00)*	(.00,.00)*	(.00,.00)
3	.00(.01)	.01(.03)	.01(.02)	.01(.01)	.00(.02)	.00(0)
	(.00,.00)*	(.00,.01)*	(.01,.02)	(.00,.01)*	(.00,.01)*	(.00,.00)
4	.00(.01)	.00(.04)	.00(.06)	.01(.02)	.01(.03)	.00(.01)
	(.00,.00)*	(.00,.00)*	(.00,.01)*	(.00,.01)*	(.01,.02)*	(.00,.00)*
5	.00(0)	.00(.03)	.00(.03)	.00(.03)	.00(.03)	.00(.01)
	(.00,.00)	(.00,.00)*	(.00,.00)*	(.00,.00)*	(.00,.01)*	(.00,.00)*
6	.00(0)	.00(.06)	.00(.11)	.00(.07)	.00(.10)	.00(.03)
	(.00,.00)	(.00,.00)*	(.00,.00)*	(.00,.01)*	(.00,.01)*	(.00,.00)*

KEY: m(e) where m = mean frequency, e = survey mean - m, and U and L are the upper and lower

(L,U) 95% confidence limits, respectively.

* indicates no overlap with the corresponding confidence interval for the field data (Table 7).

FIGURES

Figure 1. Spruce budworm life cycle in Maine (see text).

Figure 2. Jones' (1979) representation of the budworm-forest system in his model. The outer circle represents the budworm life cycle, the inner circle the forest cycle. Ovals show budworm life stages; arrows indicate causal relationships among ecological processes and the budworm.

Figure 3. Recruitment ratios for the Jones (a) and the Stedinger (b) models plotted against budworm density (in new healthy egg masses/m^2 of foliated branch surface). The forest environment from the budworm's perspective is indicated as either very good (VG), good (G), poor (P), or very poor (VP). The budworm population is in equilibrium along the horizontal line, EGG(t+1)/EGG(t) = 1.0. The densities L*, U, and H* represent the budworm population equlibria corresponding to curve G. L* and H* are the low and high stable equilibrium densities, respectively; U indicates the unstable equilibrium density (see text). (After Stedinger, 1984).

Figure 4. Relationships between the mean egg mass density EGG(t), and the average of the percent current defoliation class, DEF(t), in unsprayed sites. Vertical bars encompass the larger EGG(t) intervals of two SE about the mean. The survey data (boxes) are plotted along with output from Jones' (triangles) and Stedingers' (circles) models when run under the deterministic (a) and stochastic (b) spray policies. Sample sizes exceed 35 sites.

Figure 5. Relationships between the mean percent defoliation of new foliage in year t+1, DEF(t+1), and the egg-mass-density class in the previous year, EGG(t), for areas unsprayed in both years t and t+1. Vertical bars indicate the larger DEF(t+1) intervals of two SE about the mean. The influence of the deterministic (a) and stochastic (b) spray policies on output from Jones' (triangles) and Stedingers' (circles) models is shown along with the survey data (boxes). Sample sizes exceed 135 model sites and 40 survey blocks unless denoted in parentheses.

Figure 6. Relationships between the mean egg mass densities in successive years, EGG(t) and EGG(t+1), for unsprayed areas. Vertical bars show the larger EGG(t+1) intervals of two SE about the mean. The effects of the deterministic (a) and stochastic (b) spray policies are indicated for Jones' (triangles) and Stedingers' (circles) models. Sample sizes exceed 40 forest blocks for the survey data (boxes) and 125 model sites unless denoted in parentheses.

Figure 7. Relationships between the mean percent current defoliation in successive years, DEF(t) and DEF(t+1), for unsprayed areas. Vertical bars indicate the larger DEF(t+1) intervals of two SE about the mean. The influence of the deterministic (a) and stochastic (b) spray policies on Jones' (triangles) and Stedingers' (circles) models is shown. Sample sizes exceed 125 blocks for the survey data (boxes) and 25 model sites unless denoted in parentheses.

Figure 8. Relationship between the egg mass density at individual sampling sites within a forest block and the block mean. Only sprayed (S) and unsprayed (U) blocks with four or more sampling sites were considered. Sample sizes exceed 30 sites.

Figure 9. Relationships between the mean percent current defoliation, DEF(t+1), and the egg-mass-density class' average in the previous year, EGG(t), for areas unsprayed in year t and sprayed in year t+1. Vertical bars show the larger DEF(t+1) intervals of two SE about the mean. The influence of the deterministic (a) and stochastic (b) spray policies on output from Jones' (triangles) and Stedingers' (cricles) models is shown along with the survey data (boxes). Sample sizes exceed 15 model sites and 25 survey blocks unless denoted in parentheses.

Figure 10. Relationships between the mean egg mass densities in successive years, EGG(t) and EGG(t+1), for areas unsprayed in year t and sprayed in year t+1. Vertical bars show the larger EGG(t+1) intervals of two SE about the mean. The effects of the deterministic (a) and stochastic (b) spray policies are indicated for Jones' (triangles) and Stedingers' (circles) models. Sample sizes exceed 25 forest blocks for the survey data (boxes) and 15 model sites unless denoted in parentheses.

Figure 11. Relationships between the mean percent current defoliation in successive years, DEF(t) and DEF(t+1), for areas unsprayed in year t and sprayed in year t+1. Vertical bars encompass the larger DEF(t+1) intervals of two SE about the mean. The influence of the deterministic (a) and stochastic (b) spray policies on Jones' (triangles) and Stedingers' (circles) models is shown. Sample sizes exceed 10 blocks for the survey data (boxes) and 10 model sites unless denoted in parentheses.

Fig. 1

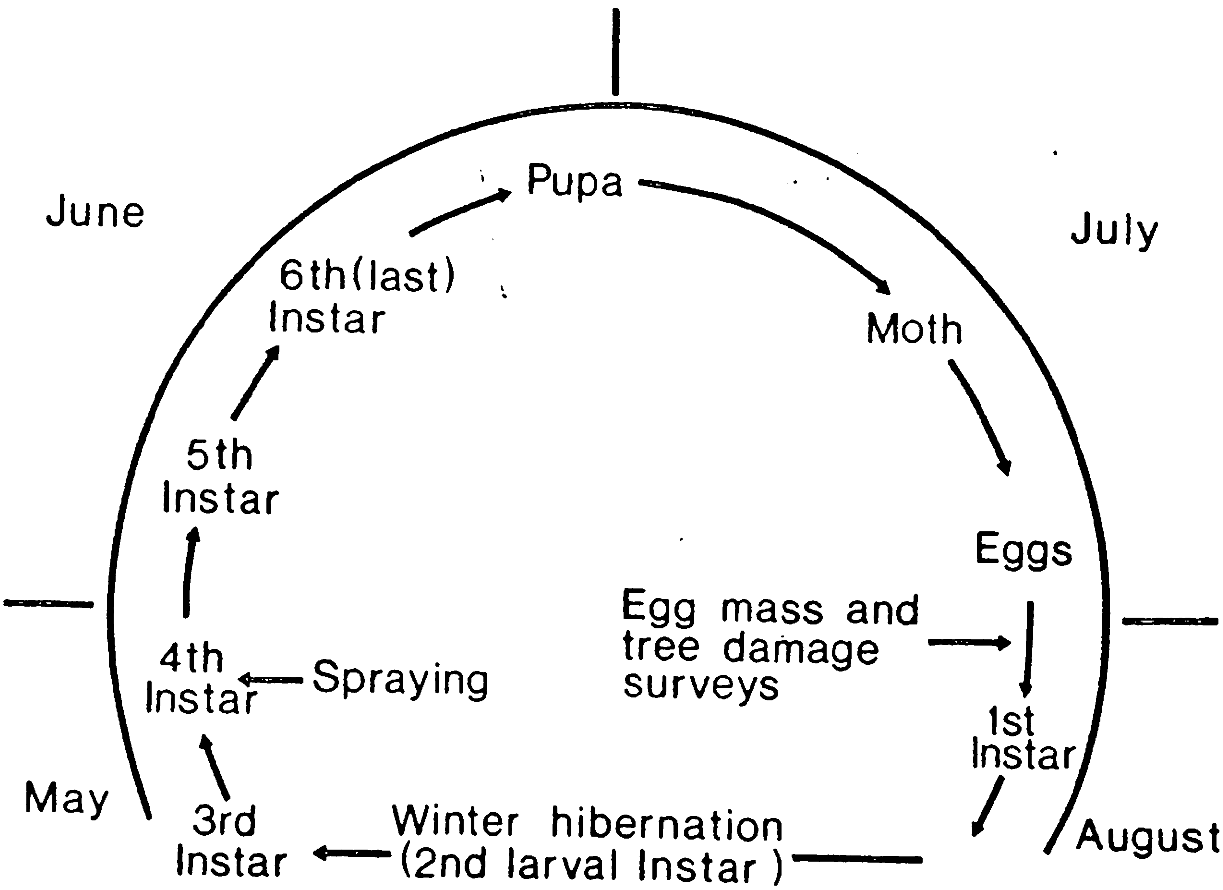
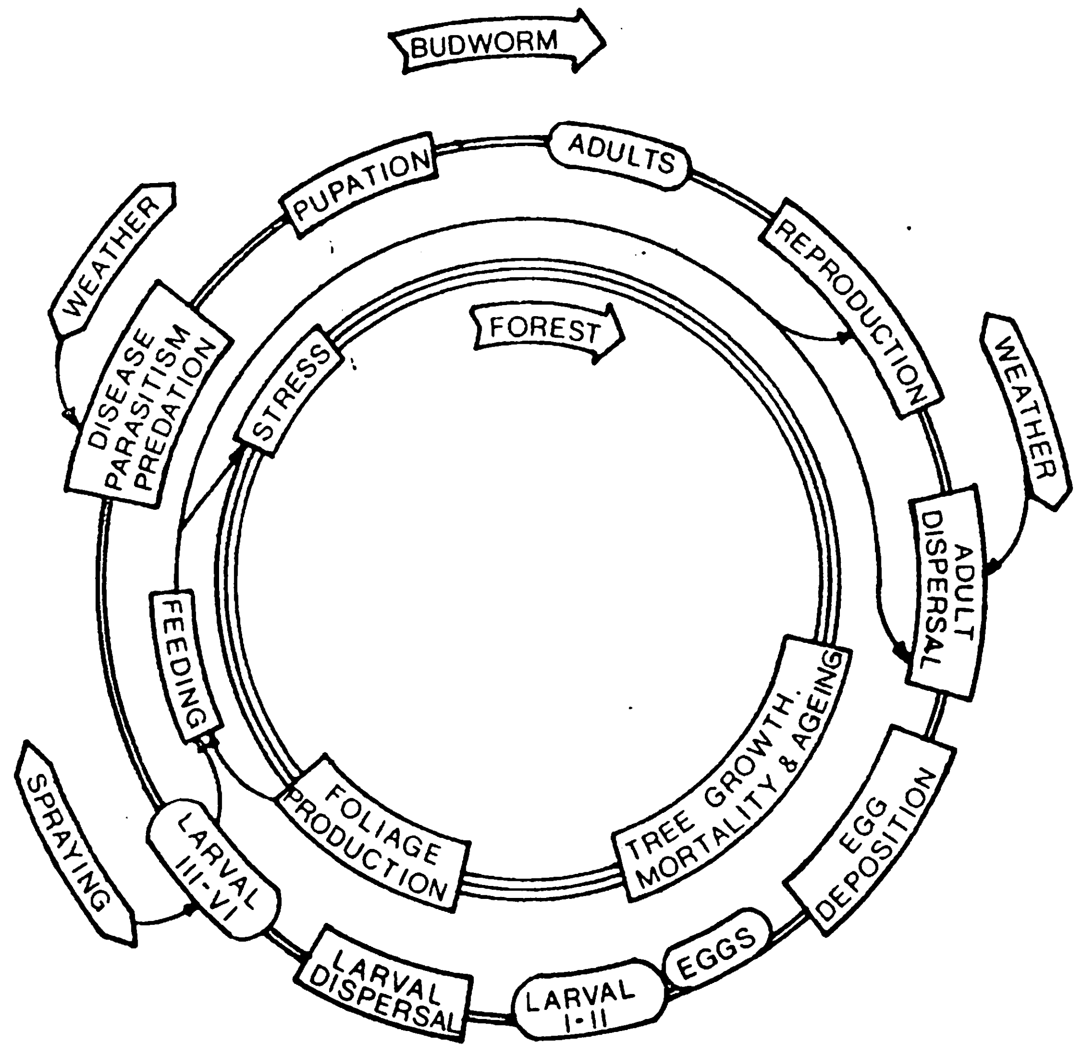
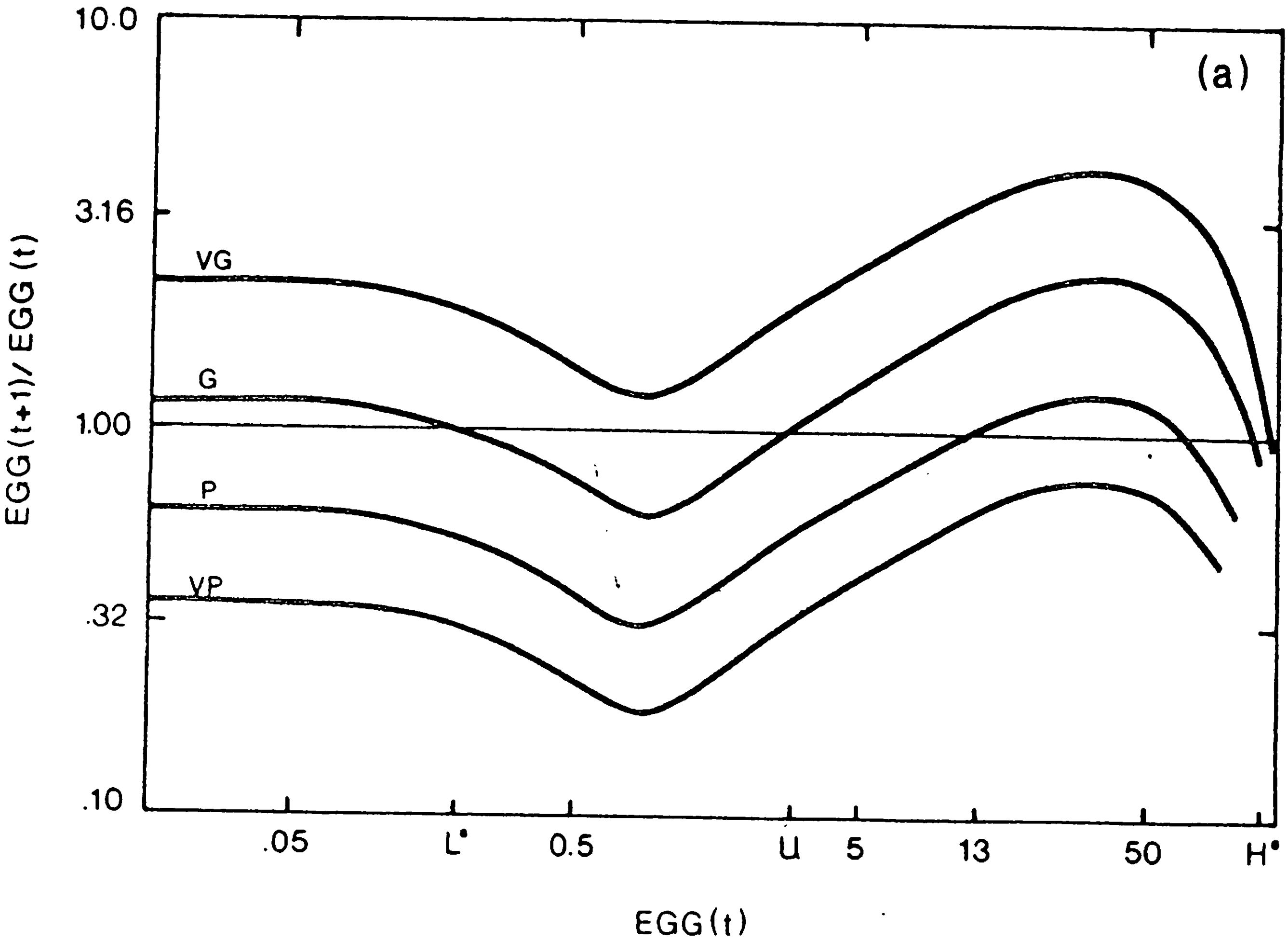

June
July
Pupa
6th(last) Instar
Moth
5th Instar
Eggs
Egg mass and tree damage surveys
4th Instar
Spraying
1st Instar
May
3rd Instar
Winter hibernation (2nd larval Instar)
August

Fig. 2

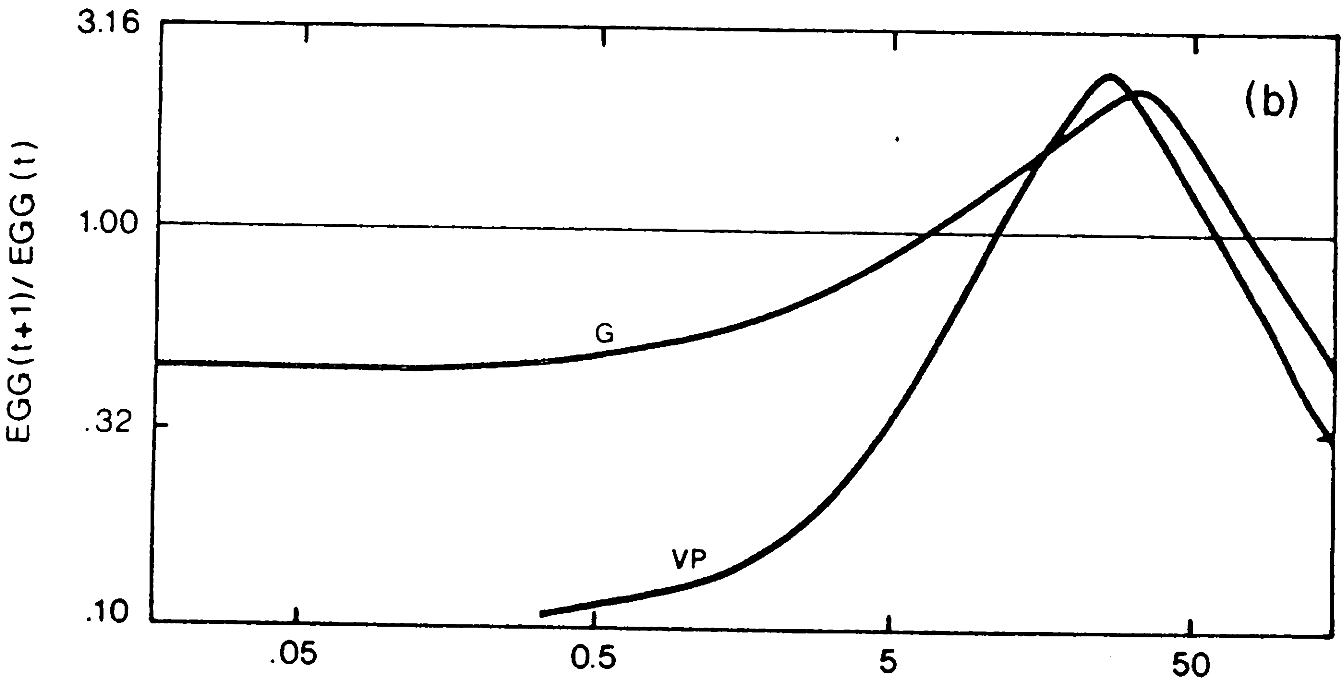


BUDWORM
ADULTS
REPRODUCTION
WEATHER
ADULT DISPERSAL
EGG DEPOSITION
EGGS
LARVAL I-II
LARVAL DISPERSAL
LARVAL III-VI
SPRAYING
FEEDING
DISEASE PARASITISM PREDATION
WEATHER
PUPATION
FOREST
STRESS
FOLIAGE PRODUCTION
TREE GROWTH, MORTALITY & AGEING

Fig. 3



10.0
3.16
1.00
.32
.10
(a)
VG
G
P
VP
EGG(t+1)/ EGG(t)
.05
L*
0.5
U
5
13
50
H*
EGG(t)



3.16
1.00
.32
.10
(b)
G
VP
EGG(t+1)/ EGG(t)
.05
0.5
5
50

Fig. 4

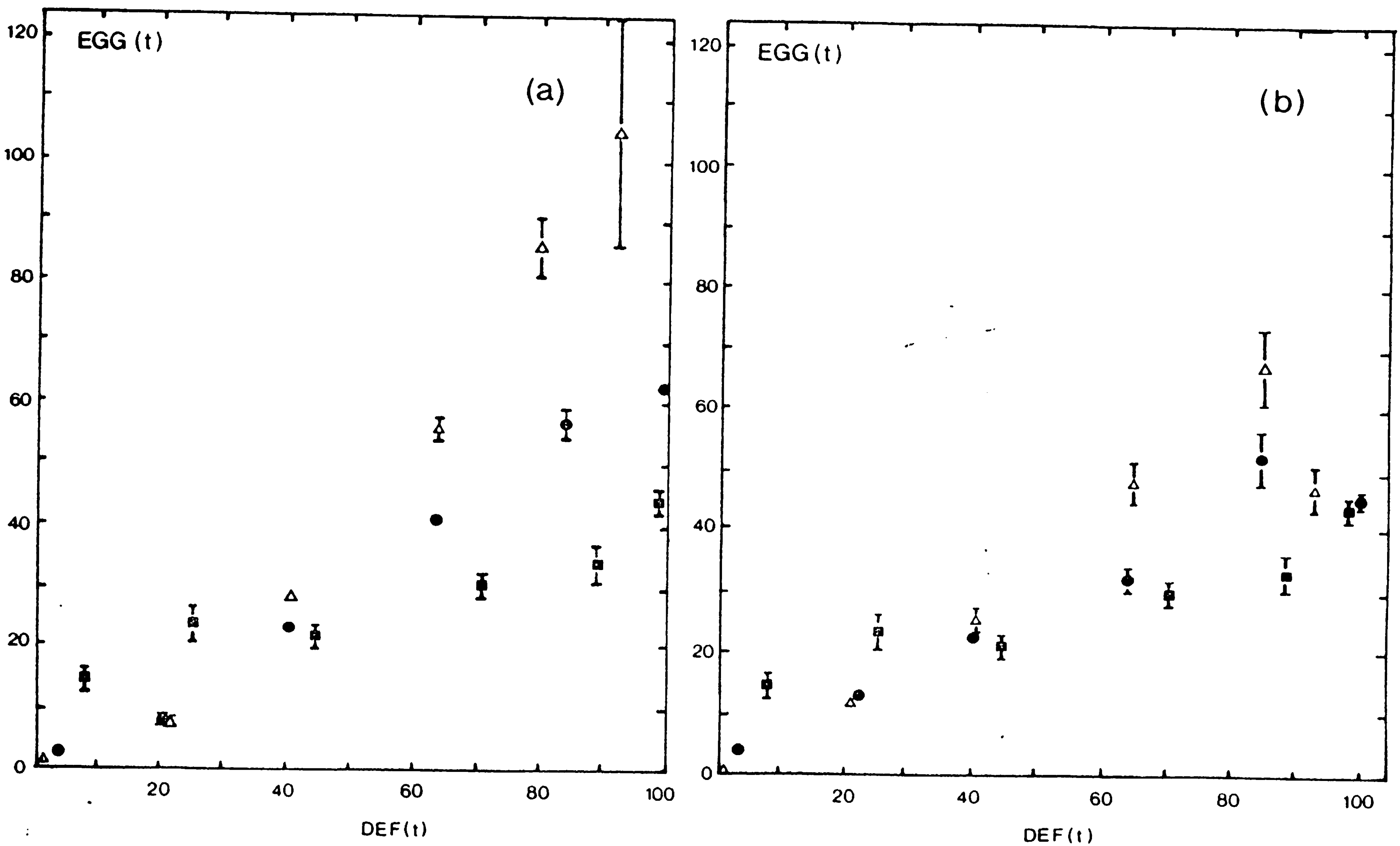


Fig. 5

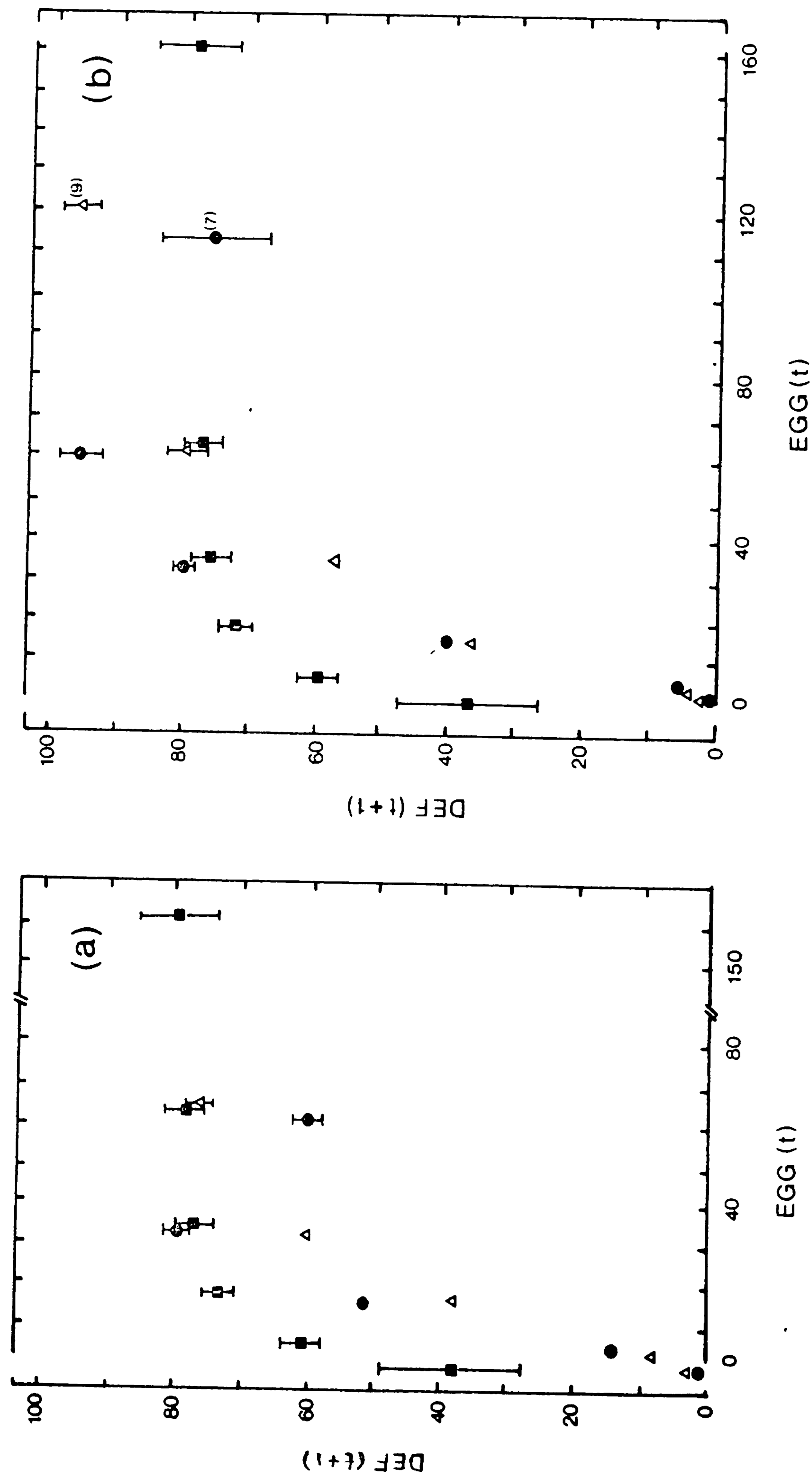
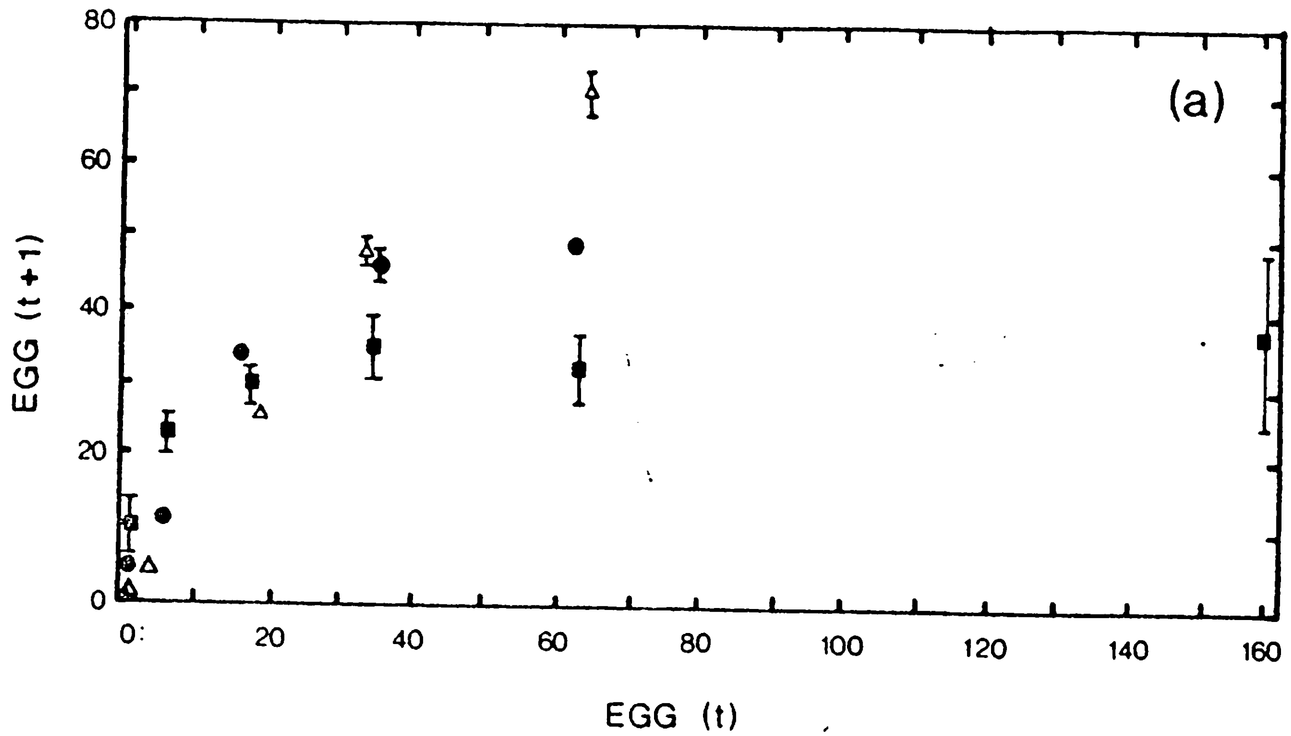
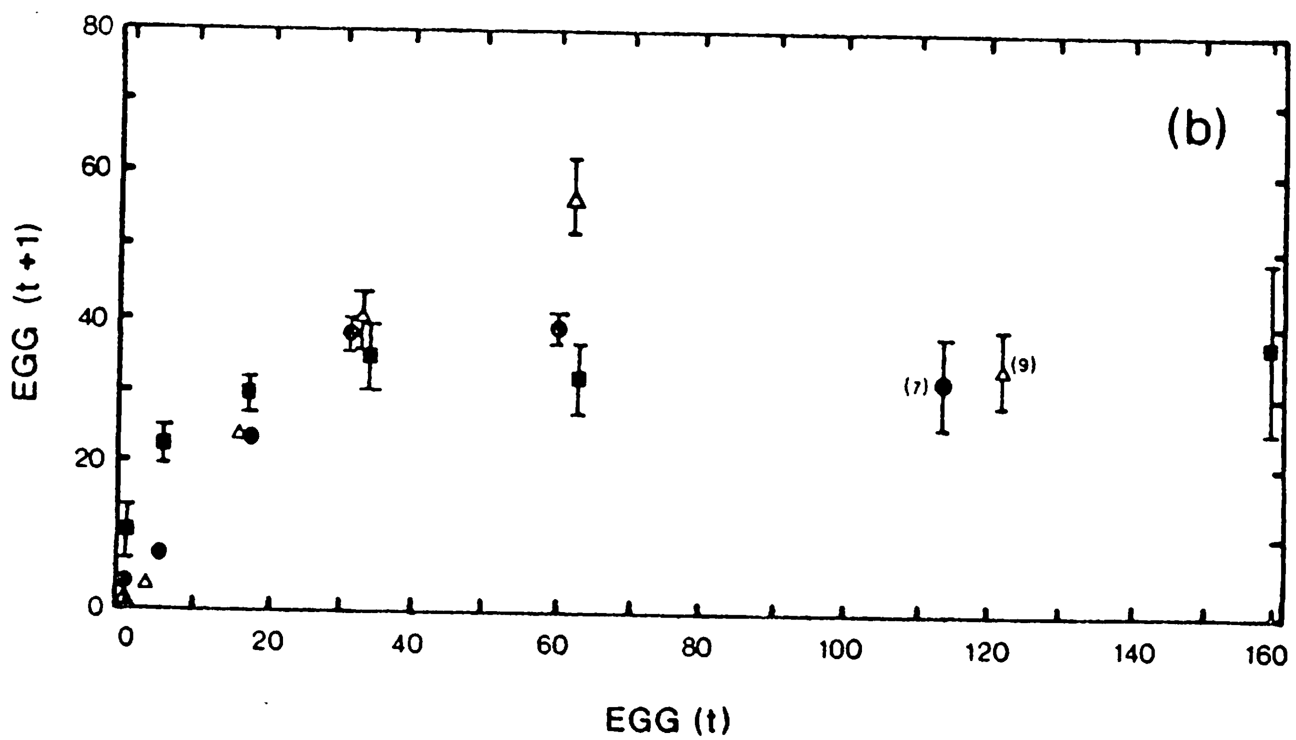


Fig 6



(a)
EGG (t+1)
EGG (t)
0
20
40
60
80
100
120
140
160



(b)
(7)
(9)
EGG (t+1)
EGG (t)
0
20
40
60
80
100
120
140
160

Fig. 7

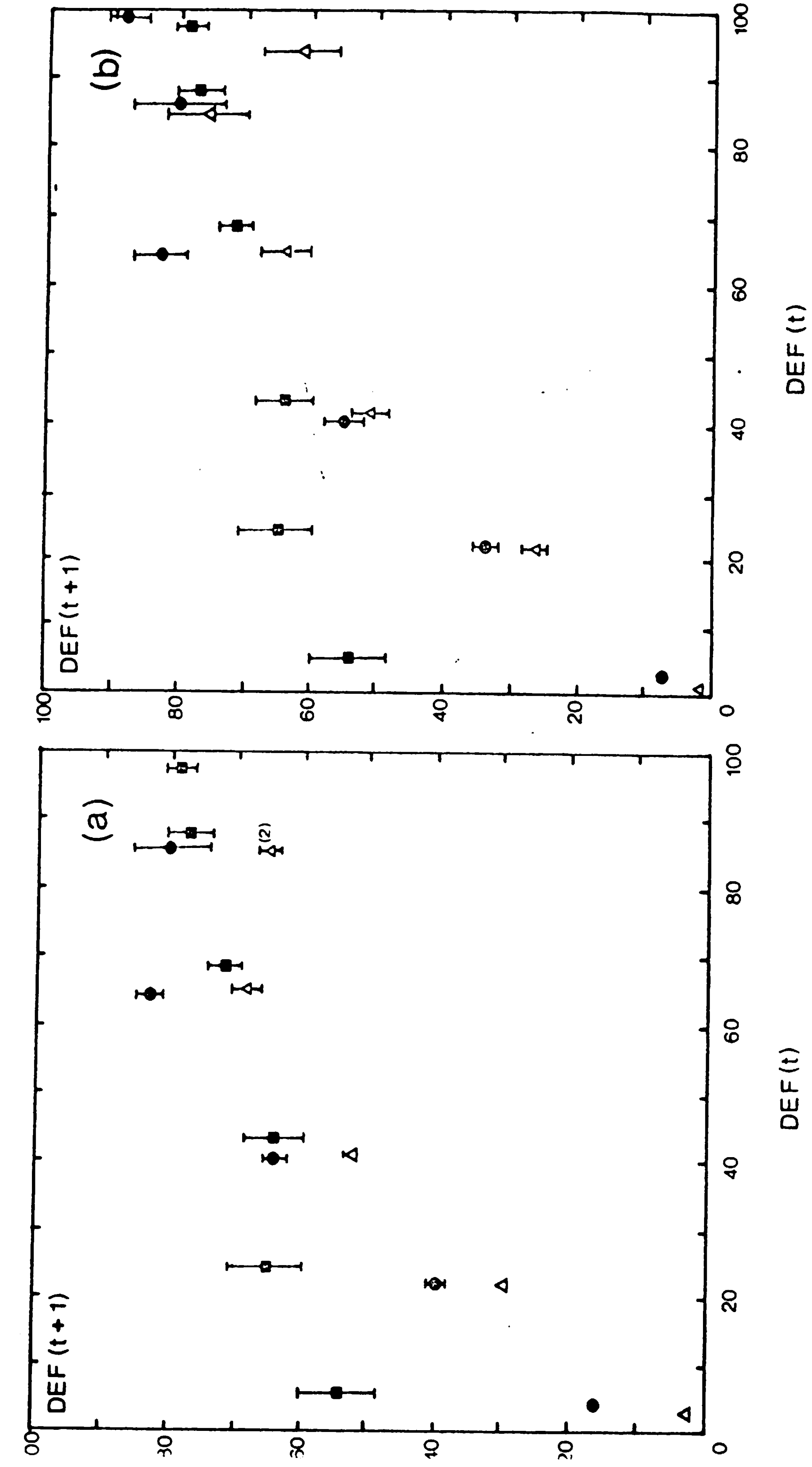


Fig. 8

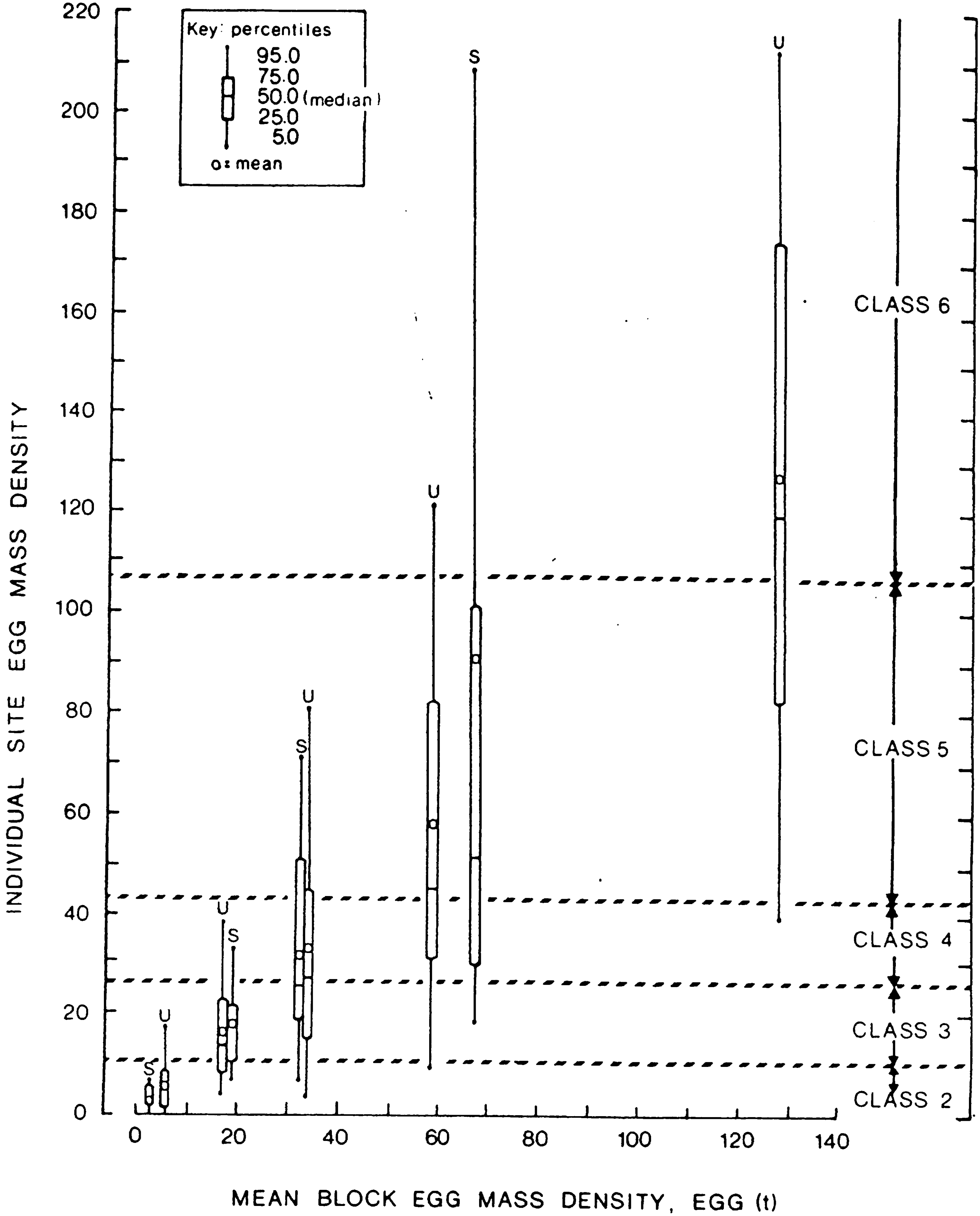

Key: percentiles
95.0
75.0
50.0 (median)
25.0
5.0
o: mean
INDIVIDUAL SITE EGG MASS DENSITY
MEAN BLOCK EGG MASS DENSITY, EGG (t)
CLASS 6
CLASS 5
CLASS 4
CLASS 3
CLASS 2
S
U
0
20
40
60
80
100
120
140
160
180
200
220

Fig. 9

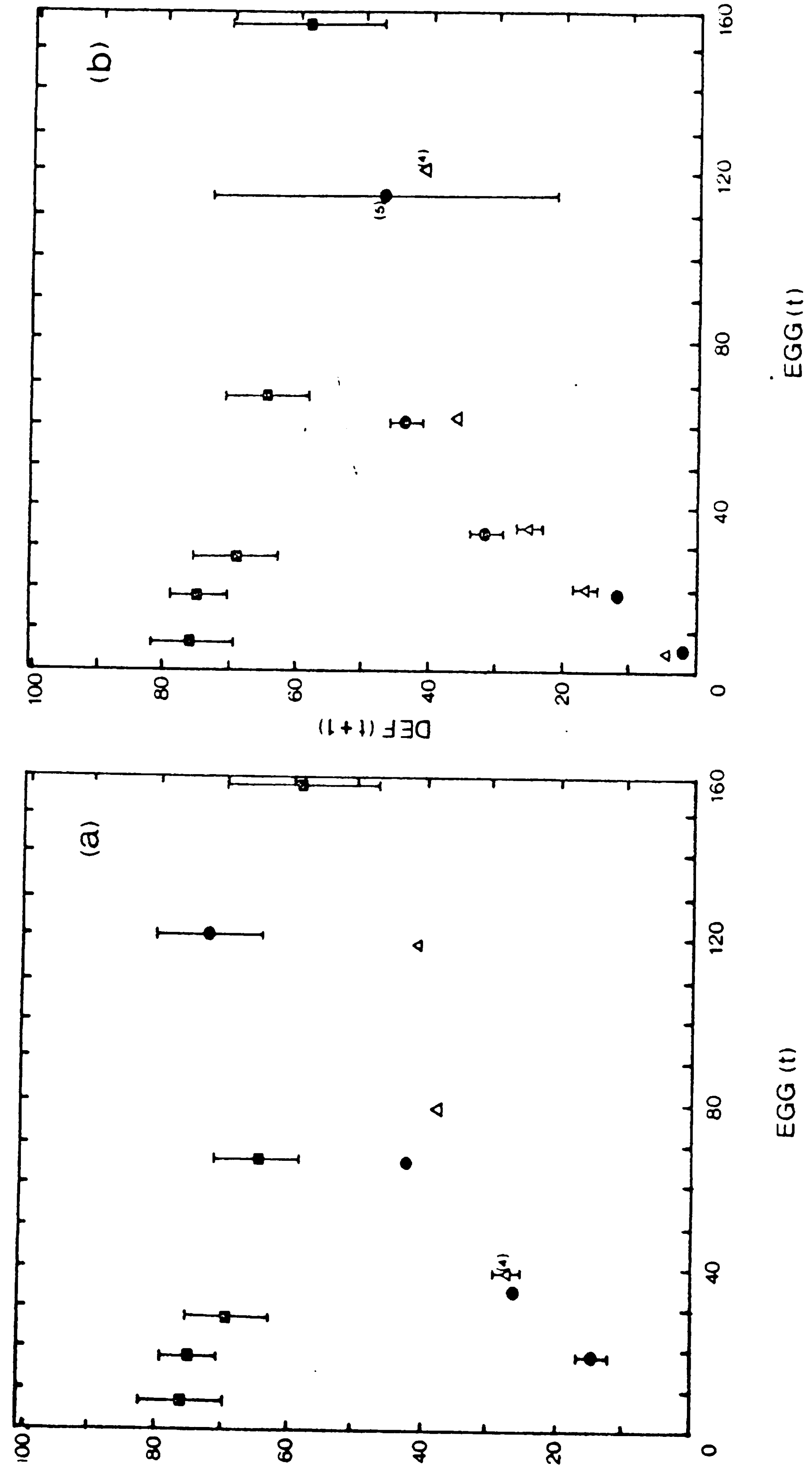


Fig 10

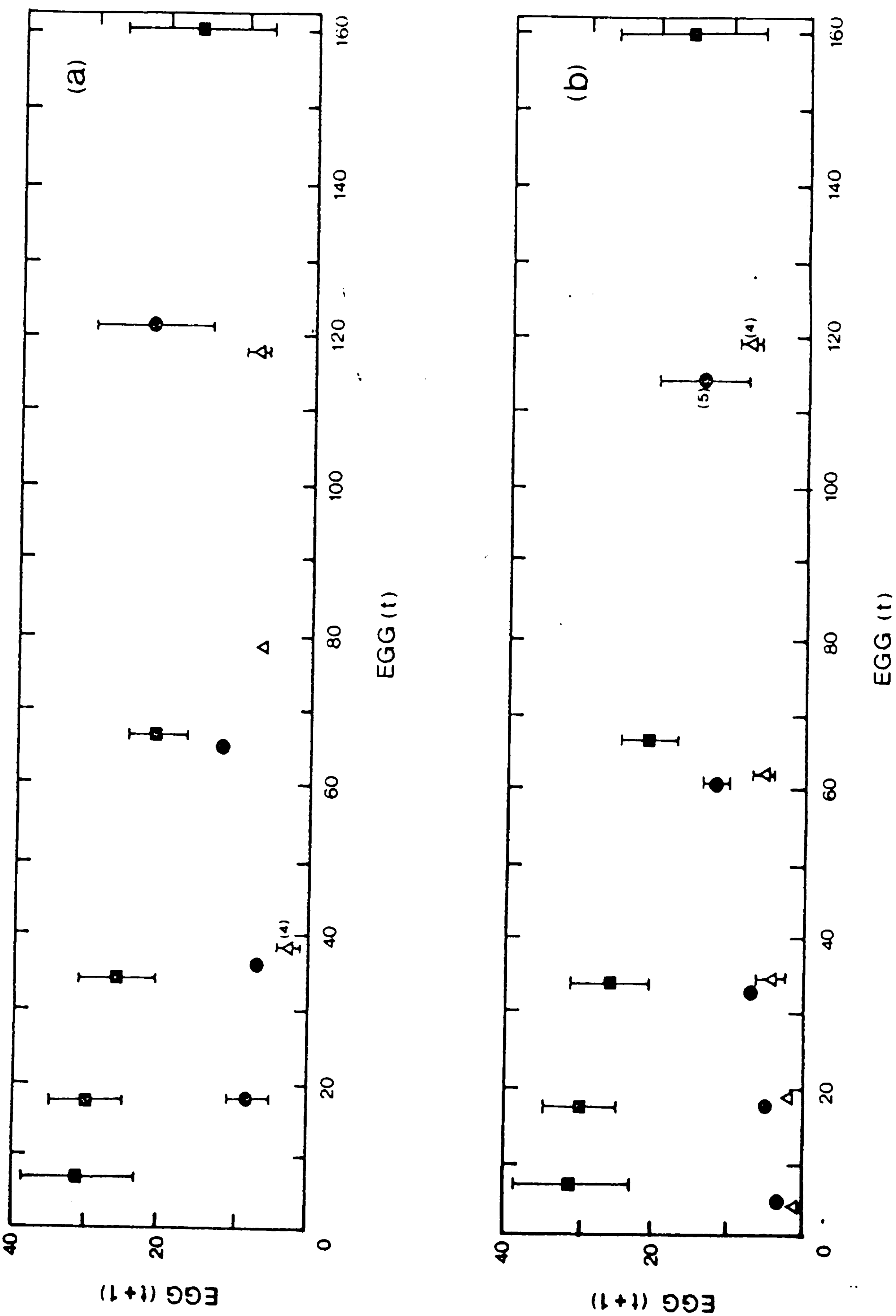


Fig. 11