

FIELD EVALUATION OF THE PYRETHROID NRDC-143, COMPARED WITH FENITROTHION,
ACEPHATE AND CHLORPYRIFOS-METHYL AS SIMULATED AERIAL SPRAY DEPOSIT
FOR CONTROL OF THE SPRUCE BUDWORM, CHORISTONEURA FUMIFERANA CLEM.

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RÉSUMÉ

Le pyrèthrinoïde de synthèse NRDC-143 ((±) cis-trans diméthyl-2,2 (dichloro-2,2 vinyl)-3,3 cyclopropane-carboxylate de phénoxy-3 benzyle) a été évalué sur le terrain et à petite échelle contre la tordeuse de bourgeons de l'épinette (Choristoneura fumiferana, Clem.) par épandage aérien simulé sur des épinettes blanches (Picea glauca, Moench, Voss). Des essais parallèles ont été effectués avec l'acéphate (O,S-diméthyl N-acétylthiophosphoramide); le fénitrothion (thiophosphate de O,O-diméthyle et de O-(méthyl-3 nitro-4 phényle) sous forme d'émulsion ou dans l'huile; et avec le chlorpyrifos-méthyl (thiophosphate de O,O-diméthyle et de O-(trichloro-3,5,6 pyridyle-2)).

Deux séries de tests ont été effectués, soit au début et au milieu du cycle évolutif de la tordeuse: la première à peu près au moment de l'émergence de son hibernacle, l'autre au moment où le nombre de larves des quatrième et cinquième stades était maximal.

Les premières applications de 100 grammes de NRDC-143 par hectare ont donné une réduction d'environ 80 % de la défoliation, comparativement à 50 % avec 225 grammes de fénitrothion dans l'huile. Parallèlement, l'acéphate (jusqu'à 462 g/ha) n'a pas été très efficace bien qu'une certaine protection ait été obtenue en dépit des fortes pluies tombées peu après l'application.

À la mi-saison, le NRDC-143 à raison de 100 g/ha a donné une réduction (65 %) des tordeuses du même ordre que la dose de 250 g/ha de fénitrothion dans l'huile. Ni la concentration de NRDC-143 (gamme étudiée: 0,8, 1,4, 2,8 et 5,6 %) ni la densité

des applications (de 13 à 69 gouttes par cm^2) n'a semblé influencer sur l'efficacité, le facteur régulateur étant la dose d'ingrédient actif.

Des essais préliminaires ont démontré que le chlorpyrifos-méthyl est au moins aussi efficace contre la tordeuse que le fénitrothion. L'infestation a diminué d'environ la moitié par rapport à 1975, soit à 14 tordeuses par branche de 45 cm ou 25 par 100 bourgeons.

ABSTRACT

The synthetic pyrethroid NRDC-143 (3-phenoxybenzyl (\pm)-cis-trans 2,2-dimethyl-3-(2,2-dichlorovinyl) cyclopropane carboxylate) was evaluated in small scale field tests for control of spruce budworm, *Choristoneura fumiferana*, Clem., by application as simulated aerial spray deposit on white spruce trees, *Picea glauca*, Moench, Voss. Companion tests were carried out using acephate (0,5-dimethyl acetophosphoroamidothioate); fenitrothion (0,0-dimethyl 0-(4-nitro-m-tolyl) phosphorothioate) in both emulsion and oil-based formulations; and with chlorpyrifos-methyl (0,0-dimethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate).

There were two series of tests, i.e., early and mid-season as related to budworm development. Early application was made at about the time of budworm emergence from their hibernaculae; the mid-season at time of peak occurrence of fourth and fifth instar larvae. Deposits of 100 g NRDC-143/ha in early application resulted in ca 80% reduction in defoliation, as compared with 225 g oil-based fenitrothion/ha giving 50% reduction. Early application of acephate in deposits of up to 462 g/ha was not very effective although there was some foliage protection despite heavy rains shortly after application.

In mid-season application, 100 g NRDC-143/ha gave budworm reduction of the same order (65%) as 250 g fenitrothion in oil solution. Concentration of NRDC-143 (0.8, 1.4 2.8 and 5.6% tested) or spray coverage in the range 13 to 69 drops/cm² did not appear to influence effectiveness, the controlling factor being dosage of active ingredient.

Preliminary testing of chlorpyrifos-methyl showed it to be at least as effective as fenitrothion for budworm control. Budworm infestation at the test site was ca one half that of 1975, viz., 14 per 45 cm branch length or 25 per 100 buds.

INTRODUCTION

Field evaluation of the efficacy of various insecticides and formulations as insecticidal treatments for aerial spray control of spruce budworm, *Choristoneura fumiferana*, Clem., was continued in 1976 in small scale experiments in which the materials were applied to individual small trees as a simulated aircraft spray deposit (Hopewell, 1975; Hopewell and Niqam, 1974; Niqam and Hopewell, 1973). In 1976, emphasis was on assessment of the synthetic pyrethroid, NRDC-143 (3-phenoxybenzyl (\pm)-cis-trans-2,2-dimethyl-3-(2,2-dichlorovinyl) cyclopropane carboxylate (previously referred to as FMC 33297). This material has given very promising results in laboratory and field tests. The experiments with NRDC-143 reported here were designed to (1) assess its stability and effectiveness under natural weathering conditions by early application, i.e., before or at about the time of budworm emergence from hibernaculae as compared with application at time of peak L_4 and L_5 instar larvae (2) compare two commercial formulations of it, and (3) to determine guidelines for an effective treatment at the most economical concentrations and application rates.

Companion tests were carried out using acephate (0,S-dimethyl acetophosphoroamidothioate) from Orthene^(R) 75S commercial formulation and with fenitrothion (0,0-dimethyl 0-(4-nitro-m-tolyl)phosphorothioate in both emulsion and oil-based formulations for comparison of effectiveness of the NRDC-143 application procedures. Criteria for comparison were reduction of budworm infestation levels and defoliation on treated as compared with those on untreated check trees.

A few trial applications of chlorpyrifos-methyl, 0,0-dimethyl 0-(3,5,6-trichloro-2-pyridyl)phosphorothioate (Reldan^(R) or DowCO-214) were included for preliminary evaluation against spruce budworm.

MATERIALS AND METHODS

1. Treatment Area and Tree Preparation

The work was carried out on a tree farm near Shawville, Quebec. The selected trees were white spruce, *Picea glauca* (Moench) Voss, 2.5 to 3 m in height, within a stand ranging in height from 2 to 8 m and carrying a natural infestation of spruce budworm, *Choristoneura fumiferana*, Clem. The selected trees were flagged and numbered consecutively. Four branches on each tree, one in each quadrant, at about 1.8 m above ground level were tagged 45 cm from the tip. The area around each tree was cleared, if necessary, by trimming foliage from adjacent trees to clear an area for the portable shelter placed around each tree during spray application.

2. Budworm Development and Infestation Level

Development and infestation levels were monitored by checking 10 standard 45 cm branches at 2-day intervals, if possible, from 20 May to 17 June. After most larvae had developed to at least third instar (L_3) they were separated from the foliage using the apparatus and technique described by DeBoo *et al* (1973) and Martineau and Benoit (1973), and total larvae per branch and development stage recorded. In addition, the number of buds on each branch was tallied to allow calculation of infestation levels in terms of number per bud as well as total number per 45 cm branch length.

3. Experimental Design

Four different insecticidal compounds were used, made up in 17 formulations, and applied in 32 individual test treatments. There were two series of tests, i.e., early and mid-season application. In the first series

application was made before budworm had emerged and become active in the needle mining stage; in the second series application was made when larvae were predominantly L_4 and L_5 .

Each treatment was replicated on three separate trees and effect of treatment evaluated by comparing the budworm population with that on three untreated check trees in the case of the early application tests. Treated and check trees were within an area of approximately 0.5 ha. The mid-season applications were applied to trees on an area of approximately 1.5 ha where 5 untreated trees were used as 'checks'.

4. Formulations

The test formulations were prepared from the following original concentrate preparations as received from commercial sources:

1. NRDC-143(A). Chipman Chemical Co., Stoney Creek, Ont., a concentrate containing 500 g AI/l for dilution with oil.
2. NRDC-143(B). FMC of Canada, Ltd., Burlington, Ont., a concentrate containing 800 g AI/l for dilution with oil.
3. Acephate (Orthene^(R) 75S). Chevron Chemical Co., (Canada), Oakville, Ont., a water soluble powder containing 75% active ingredient.
4. Fenitrothion (Sumithion^(R)) technical, 96% active ingredient, Sumitomo Chemical Co., Osaka, Japan.
5. Chlorpyrifos-methyl (Dowco 214 = Reldan^(R)). Dow Chemical Co., Sarnia, Ont., a concentrate containing 30 g / 100 ml (3 lbs./gal Imp.).

The above were used in 17 formulations as listed in Table I, and were applied as 32 treatments. For the series of early applications, i.e., from 6 to 13 May, only the Chipman sample of NRDC-143 was available; in the later series parallel tests were carried out with the FMC formulation of NRDC-143.

5. Spray Application and Deposit Sampling

Application of the simulated aerial spray was carried out by use of the apparatus and technique described by Hopewell, 1973. A portable shelter enclosing an area 2.1×2.1 m (7 x 7 feet) was placed around each tree before spray application. The required volume for the nominal dosage to be applied was measured into the syringe, e.g. 1.17 l/ha (16 fl. oz/acre) required 0.5 ml emitted over the enclosed 4.55 m^2 . The operator then raised the unit over the tree in the shelter and switched on the spinning disc and feed motor. The unit was moved systematically over the enclosure during emission (approximately 1 ml/minute) while elapsed emitting time was called out at intervals to aid in judgment of uniformity of emission over the total enclosed area.

A deposit sample was taken in each tree quadrant, (north, south, east, west) on sampling units consisting of a 9 cm diameter petri dish and a 10 x 10 cm Kromekote[®] card. These sampling units were placed on staked holders 1.8 m above ground level, approximately 0.5 m from the tree stem and close to the branch tagged for post-treatment biological assessment. The deposit samples were returned to the laboratory for colorimetric assessment of deposit and drop count.

6. Biological Assessment

The assessment of the larval population densities on the test trees was made about one month post treatment for early tests and two weeks post treatment for the later series. The 45 cm tagged branch from each quadrant was clipped off, the total number of buds counted and recorded, and the larvae separated from the foliage. The surviving budworm were counted and identified as to larval stage. The three replicates of each spray treatment gave 12 branch samples on which the average number of budworm survivors per branch and percentage of bud infestation was determined

and compared with survival on similar branches on the check trees.

7. Defoliation Assessment

The degree of foliage protection was assessed in late autumn as an additional index of treatment effect. The method followed was essentially that described by Fettes (1951) which quantifies defoliation into 10 classes. Five terminal current year shoots on each of 4 branches, one in each quadrant and adjacent to the branch sampled for surviving budworm, were examined visually *in situ*. Defoliation class of each shoot was judged by an experienced observer and tallied; the branch, tree and treatment group averages were derived from these data.

8. Tests and Treatment Detail

Data on the 32 experimental treatments carried out are given in Table II. Each experiment was numbered serially for convenience in keeping records and also, results of biological assessment were obtained and reported by tree number only. This avoided any possibility of bias in the results since the observers were not aware of the treatment received by any particular tree including checks.

RESULTS AND DISCUSSION

The results from the series of early trials with application 6 to 13 May are given in Table III. These data give deposits as measured on samples taken during application and the later biological assessment of tagged branches for numbers of budworm. Defoliation observations, taken later in the year are also included. There was considerable variation in deposits between trees in each test and between quadrants on the same tree. However, the results of the early tests (1 to 12), Table III, indicate that the early application of NRDC-143 resulted in significant reduction of budworm population density and defoliation. In most cases there was fairly good agreement between population reduction as calculated on the basis of larvae per branch and larvae per bud, but there are some discrepancies, as in tests 2, 9 and 12, which may be ascribed to low population densities and variations between trees, indicating insufficient replication. In general, percent control calculated on the basis of bud infestation agrees more closely with percent reduction in defoliation. It should be noted that defoliation assessment was derived independently from population reduction. Percent budworm reduction was calculated from both larvae per branch and bud infestation rate data which were derived from the same sample branches. Defoliation observations were made much later at the same locations on each tree as determined by the stubs of the excised sample branches. The percentage reduction in budworm population ranged from ca 50 to 75% for average deposits of 50 to 100 g/ha of active ingredient. Defoliation reduction was of the same order at these dosages.

Orthene at 100 to 450 g/ha was not as effective as NRDC-143 at an average 74 g/ha but did cause significant reduction of budworm population and defoliation. The oil solution of fenitrothion in the two early tests (10 and 11) also resulted in

budworm population reductions of 50 to 70% at deposits of 100 to 200 g/ha.

The fenitrothion emulsion (test 12) was apparently less effective than the oil solution.

The results of the experiments carried out when larvae were predominantly L_4 and L_5 with L_6 increasing to ca 30% near the end of application period (3 to 5 June) are given in Table IV. Considering the 14 tests (13 to 26) in which the active ingredient was NRDC-143, the average deposits of active ingredient for all samples in each have been plotted against average percent budworm reduction as calculated by both methods, and are shown in Fig. 1. A deposit of at least 100 g/ha was required to give budworm reductions in the order of 75%. Spray deposit coverage, i.e., number of drops/cm² (and thus drop size at comparable deposit levels) appeared of minor importance when percent larval reduction was compared with coverage at similar deposit levels, at least within the rather narrow average drop size range of these tests. There was no apparent difference between the activity of the two commercial formulations of NRDC-143.

The one experiment in which a 5% active ingredient formulation of acephate was used (No. 27) with an average deposit of 77 g/ha, gave ca 67% budworm reduction which surpassed fenitrothion emulsion (No. 28) at an average deposit of 230 g/ha resulting in a reduction of 52%, and had approximately the same effectiveness as fenitrothion oil solution at 247 g/ha (No. 29).

The three trials with chlorpyrifos-methyl (30, 31, 32) all gave good population reduction and foliage protection with average deposits of 219, 447 and 765 g/ha of active ingredient resulting in budworm reductions of 71, 57 and 79% respectively. This apparent lack of dosage response correlation may be the result of overdosage. Further testing will be needed to determine the minimal effective deposit.

Since the bulk of the data dealt with NRDC-143, a more intensive analysis of these data was possible by use of the individual sample branches

for each of which there was a measured deposit and the resulting post-treatment count of budworm infestation level. The data for these branches were organized in groups according to measured deposit of active ingredient and compared with the corresponding bud infestation levels. Included in this analysis are the data on the observed defoliation on branches in each tree quadrant and which are assumed to have received the same dosage as measured on the sampling unit for that quadrant. These results are summarized in Table V, and the resulting reductions in bud infestation and defoliation graphed in Figs. 2 and 3 respectively.

Results showed that NRDC-143 applied early in larval development, i.e., about time of emergence from their hibernaculae, can lower later budworm infestation levels and protect the trees from defoliation. With maximum infestation levels of approximately 25 per 100 buds in this location, a deposit of approximately 200 g NRDC-143/ha would be required for complete foliage protection by early application. In the mid-season applications considerable defoliation had already occurred but about 50% reduction in budworm infestation and defoliation could be expected by a deposit of approximately 100 g AI/ha (Figs. 2 and 3).

There was great variation in infestation levels between trees and even between branches of the same tree as is evident from the high standard deviations of the means of both bud infestation level and defoliation (Table V). For example, the mid-season application deposit level group 76 - 100 g/ha (Table V) which shows no reduction in defoliation, 6 of the 14 samples in this group of treated foliage had bud infestation levels higher than, or about equal to, that of the mean in the check trees. This anomalous point was eliminated from calculation of the line of best fit for the data on defoliation in mid-season application (Fig. 3).

The results of the monitoring of budworm development are shown in Fig. 4. Development proceeded much more regularly than in 1975, with each larval instar period confined to fairly distinct time intervals while in 1975 emergence and/or development was such that small numbers in each stadium occurred over much longer time periods. The infestation levels, i.e., number of larvae per 45 cm branch (Fig. 5) indicated an average population of approximately 14, which is about one half that found in 1975 on the same site. Percentage bud infestation, (Fig. 6) showed the maximum to have been ca 25 larvae per 100 buds.

The daily temperature records taken on site (Fig. 7), showed ideal conditions for budworm development with no frost after 5 May and for the most part, warm sunny days with gradually increasing daily mean temperatures. Rainfall records, (Fig. 8) showed early tests to have been exposed to approximately 90 mm of rain within the one-week period following application. This heavy precipitation so soon after treatment may account for the poor results from the acephate applications (Nos. 7, 8 and 9). Acephate is water-soluble and probably was washed from the foliage before it could be effective against the budworm. The single early application of acephate in 1975 gave very good results (Hopewell, 1975).

SUMMARY AND CONCLUSIONS

1. Application of 100 g/ha of NRDC-143 at about the time of larval emergence from hibernaculae resulted in an 80% reduction in defoliation, whereas 200 g/ha gave protection approaching 100%. However, it appears likely that deposits of 10 to 20 g/ha in early applications would significantly reduce budworm infestation and defoliation, although deposits in this low range were not tested.

2. A deposit of approximately 100 g AI/ha of NRDC-143 gave a budworm population reduction of the same order (65%) as 250 g AI/ha of fenitrothion applied in oil solution, with application when the larvae were predominantly L₄ and L₅.

3. Concentrations of NRDC-143 active ingredient (0.8, 1.4, 1.7, 2.8 and 5.6% concentrations tested) or spray coverage in the range 13 to 69 drops/cm², did not appear to influence effectiveness, the controlling factor being dosage of active ingredient.

4. There was no significant difference between the effectiveness of the two commercial formulations of NRDC-143 (Chipman 50% AI vs. FMC 80%) on the basis of equal amounts of active ingredient applied.

5. The oil-based formulation of fenitrothion was more effective than the emulsion in both early and mid-season applications. An early application of an average 108 g AI/ha of oil-based fenitrothion with calculated average drop diameter of 89 microns and coverage of 16 drops/cm² resulted in 60% reduction of larvae and defoliation. The mid-season application of 250 g/ha of 138 micron diameter drops at 10 drops/cm² resulted in 65% reduction of larvae and defoliation.

6. Early application of acephate (5 and 10% solutions prepared from Orthene^(R) 75S) in three tests at an average 96, 180 and 462 g AI/ha was not very effective although there was some foliage protection. Heavy rains within a week of treatment probably removed most of deposit from foliage. A mid-season application test using 5% solution applied at 77 g AI/ha gave 70% reduction in the budworm population.

7. Three trial applications of chlorpyrifos-methyl (Dowco 214, Reldan^(R)) showed it to be at least equivalent in effectiveness to fenitrothion oil formulation and superior to fenitrothion emulsion, both at average deposits in the order of 225 g AI/ha.

8. The budworm infestation level in the Shawville, Quebec, area was less than half that in 1975. Weather conditions for budworm development and tree growth during the test period were excellent, so that high percent budworm control would be more difficult to attain than in the previous year. Another difficulty encountered was great variation in budworm infestation levels between trees and between branches on the same tree. All tests were on white spruce with infestation levels of ca 14 budworm per 45 cm branch or 25 per 100 buds.

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Table I
Formulations Tested, Shawville - 1976

| No. | Formulation Code | Composition |
|---------|------------------|---|
| 1 | 143-IA | Chipman NRDC-143 diluted with oil diluent (Arotex 3470: Fuel Oil 2 1:3 by volume) to 3.4% AI (0.56 oz/16 fl. oz US)* |
| 2 | 143-IIA | Diluted to 5.6% AI (0.93 oz AI/16 fl. oz). |
| 3 | 143-IIIA | Diluted to 1.69% (0.6 oz AI/32 fl. oz). |
| 4 | 143-IVA | Diluted to 2.8% AI (0.5 oz AI/32 fl. oz). |
| 5 | 143-VA | Diluted to 0.8% AI (0.14 oz AI/64 fl. oz). |
| 6 | 143-VIA | Diluted to 1.4% AI (0.24 oz AI/64 fl. oz). |
| 7 to 12 | 143-VII to XIIB | FMC NRDC-143 diluted to same concentrations active ingredient as 1 to 6 above. |
| 13 | 0 - I | Acephate 10% - Orthene 75S diluted with 10% ethylene glycol in water. |
| 14 | 0 - II | Acephate 5% - Orthene 75S diluted with 10% ethylene glycol in water. |
| 15 | F - I | Fenitrothion 18% AI (3 oz AI/16 fl. oz) in a solvent containing Arotex: fuel oil #2: fuel oil #4 at volume ratios 12:53:35. |
| 16 | F - II | Fenitrothion 10% AI in emulsion with 1% Atlox ^R and 1% Arotex 3470. |
| 17 | D - I | Chlorpyrifos-methyl 10% AI in Arotex 3470: Fuel Oil 2 1:3. |

* Active Ingredient in ounces Avoir, Fluid volume in Fl. oz. U.S.

Table II
Formulations and Nominal Application Rates - Early Tests

| Test No. | Formulation* | Tree Nos. | Date | Nominal Application Rate |
|----------|--------------|-----------|------|------------------------------------|
| 1 | 143-IA | 1-2-3 | 6-5 | 1.13 l/ha (16 fl. oz/ac) |
| 2 | 143-IIA | 4-6-7 | 10-6 | " " |
| 3 | 143-IIIA | 8-9-10 | 11-6 | 2.26 l/ha (32 fl. oz/ac) |
| 4 | 143-IVA | 11-12-13 | 11-5 | " " |
| 5 | 143-VA | 16-17-18 | 11-5 | 3.4 l/ha (64 fl. oz/ac) |
| 6 | 143-VIA | 15-19-20 | 11-5 | " " |
| 7 | 0 - I | 21-22-23 | 12-5 | 2.9 l/ha (40 fl. oz/ac) |
| 8 | 0 - I | 24-26-27 | 12-5 | 1.4 l/ha (20 fl. oz/ac) |
| 9 | 0 - II | 28-29-30 | 13-5 | " " |
| 10 | F - I | 31-32-33 | 13-5 | 1.4 l/ha (16 fl. oz/ac) |
| 11 | F - I | 34-35-36 | 13-5 | " " |
| 12 | F - II | 37-38-39 | 13-5 | 2.9 l/ha (40 fl. oz/ac - emulsion) |

Mid-season Tests

| | | | | |
|----|----------|-----------|------|--------------------------|
| 13 | 143-IA | 40-41-42 | 27-5 | 1.14 l/ha (16 fl. oz/ac) |
| 14 | 143-IB | 43-44-45 | 27-5 | " " |
| 15 | 143-IIA | 47-48-49 | 27-5 | " " |
| 16 | 143-IIB | 50-51-52 | 28-5 | " " |
| 17 | 143-IIIA | 53-54-55 | 28-5 | " " |
| 18 | 143-IIB | 56-57-58 | 28-5 | " " |
| 19 | 143-IIIA | 60-61-62 | 29-5 | 2.27 l/ha (32 fl. oz/ac) |
| 20 | 143-IIB | 63-64-65 | 29-5 | " " |
| 21 | 143-IVA | 66-67-68 | 29-5 | " " |
| 22 | 143-IVB | 69-70-71 | 29-5 | " " |
| 23 | 143-VA | 72-73-74 | 2-6 | 4.52 l/ha (64 fl. oz/ac) |
| 24 | 143-VB | 75-76-77 | 2-6 | " " |
| 25 | 143-VIA | 78-80-81 | 2-6 | " " |
| 26 | 143-VIB | 82-83-84 | 2-6 | " " |
| 27 | 0 - II | 85-86-87 | 2-6 | 1.4 l/ha (19 fl. oz/ac) |
| 28 | F - II | 88-89-90 | 3-6 | 2.9 l/ha (40 fl. oz/ac) |
| 29 | F - I | 92-93-94 | 5-6 | 1.1 l/ha (16 fl. oz/ac) |
| 30 | D - I | 97-98-99 | 4-6 | 4.52 l/ha (64 fl. oz/ac) |
| 31 | D - I | 101-03-04 | 4-6 | 2.27 l/ha (32 fl. oz/ac) |
| 32 | D - I | 105-06-07 | 4-6 | 1.13 l/ha (16 fl. oz/ac) |

* Please refer to Table I for their composition.

Table III

Volume and Active Ingredient Deposit Applied to trees with Resulting Effect on Budworm
Population and Defoliation - Early Application -

| Test No. | Formulation | Tree No. | Deposit * | | | Calc. Drop. Diam. (μ) | Budworm Survivors * | | % Budworm Reduction | | % Defoliation Reduction |
|----------|-------------|----------|-------------|-----------|-----------------------|-----------------------|---------------------|--------------|---------------------|----------|-------------------------|
| | | | l./ha | gAI/ha | drops/cm ² | | per branch | per 100/buds | Branch Data | Bud Data | |
| 1 | 143-IA | 1 | 3.07 | 104 | 41 | | 1.00 | 1.18 | | | |
| | " | 2 | 3.15 | 107 | 42 | | 3.25 | 4.26 | | | |
| | " | 3 | 2.42 | 82 | 35 | | 2.75 | 5.23 | | | |
| | | | <u>2.88</u> | <u>98</u> | <u>39</u> | 112 | <u>2.33</u> | <u>3.56</u> | 59 | 77 | 70 |
| 2 | 143-IIA | 4 | 1.16 | 65 | 16 | | 7.75 | 10.58 | | | |
| | " | 6 | 0.78 | 44 | 16 | | 4.50 | 5.86 | | | |
| | " | 7 | 1.24 | 69 | 27 | | 4.75 | 5.14 | | | |
| | | | <u>1.06</u> | <u>59</u> | <u>20</u> | 100 | <u>5.67</u> | <u>7.19</u> | 1 | 53 | 55 |
| 3 | 143-IIIA | 8 | 2.50 | 42 | 24 | | 4.75 | 7.98 | | | |
| | " | 9 | 3.25 | 55 | 57 | | 3.25 | 3.37 | | | |
| | " | 10 | 3.98 | 67 | 25 | | 3.25 | 6.19 | | | |
| | | | <u>3.24</u> | <u>55</u> | <u>35</u> | 121 | <u>3.75</u> | <u>5.85</u> | 35 | 62 | 58 |
| 4 | 143-IVA | 11 | 2.22 | 62 | 22 | | 2.75 | 4.12 | | | |
| | " | 12 | 1.58 | 44 | 12 | | 4.50 | 6.04 | | | |
| | " | 13 | 5.20 | 146 | 46 | | 0.50 | 0.90 | | | |
| | | | <u>3.30</u> | <u>92</u> | <u>27</u> | 133 | <u>2.58</u> | <u>3.69</u> | 55 | 76 | 76 |
| 5 | 143-VA | 16 | 6.25 | 50 | 61 | | 3.00 | 6.59 | | | |
| | " | 17 | 6.95 | 56 | 64 | | 4.25 | 5.43 | | | |
| | " | 18 | 5.65 | 45 | 97 | | 5.50 | 5.61 | | | |
| | | | <u>6.28</u> | <u>50</u> | <u>74</u> | 117 | <u>4.25</u> | <u>5.88</u> | 26 | 62 | 66 |

Table III (Continued)

| Test No. | Formulation | Tree No. | Deposit * | | | Calc. Drop. Diam. (μ) | Budworm Survivors * | | % Budworm Reduction | | % Defoliation Reduction |
|----------|-------------|----------|-------------|------------|-----------------------|-----------------------------|---------------------|--------------|---------------------|----------|-------------------------|
| | | | l/ha | gAI/ha | drops/cm ² | | per branch | per 100/buds | Branch Data | Bud Data | |
| 6 | 143-VIA | 15 | 7.42 | 104 | 82 | | 2.25 | 4.17 | | | |
| | " | 19 | 7.02 | 98 | 84 | | 5.00 | 13.70 | | | |
| | " | 20 | 5.10 | 71 | 62 | | 3.00 | 4.32 | | | |
| | | | <u>6.51</u> | <u>91</u> | <u>76</u> | 118 | <u>3.42</u> | <u>7.40</u> | 40 | 52 | 81 |
| 7 | 0 - I | 21 | 3.72 | 372 | 18 | | 5.75 | 11.22 | | | |
| | " | 22 | 7.24 | 724 | 18 | | 3.25 | 5.35 | | | |
| | " | 23 | 2.90 | 290 | 18 | | 3.75 | 7.32 | | | |
| | | | <u>4.62</u> | <u>462</u> | <u>18</u> | 170 | <u>4.25</u> | <u>7.96</u> | 26 | 48 | 38 |
| 8 | 0 - I | 24 | 2.79 | 279 | 5 | | 4.25 | 7.05 | | | |
| | " | 26 | 2.14 | 214 | 10 | | 7.25 | 13.30 | | | |
| | " | 27 | 0.49 | 49 | 7 | | 6.25 | 7.40 | | | |
| | | | <u>1.81</u> | <u>181</u> | <u>7.3</u> | 168 | <u>5.92</u> | <u>9.25</u> | 0 | 40 | 52 |
| 9 | 0 - II | 28 | 2.51 | 125 | 10 | | 4.50 | 10.00 | | | |
| | " | 29 | 1.50 | 75 | 4 | | 7.50 | 15.96 | | | |
| | " | 30 | 1.76 | 88 | 5 | | 7.25 | 15.18 | | | |
| | | | <u>1.92</u> | <u>96</u> | <u>6.3</u> | 180 | <u>6.42</u> | <u>13.71</u> | 0 | 11 | 30 |
| 10 | F - I | 31 | 1.30 | 234 | 2 | | 5.75 | 10.32 | | | |
| | " | 32 | 1.36 | 245 | 22 | | 0.50 | 0.90 | | | |
| | " | 33 | 1.24 | 223 | 12 | | 3.50 | 6.80 | | | |
| | | | <u>1.30</u> | <u>234</u> | <u>12</u> | 127 | <u>3.25</u> | <u>6.00</u> | 43 | 61 | 48 |

Table III (Continued)

| Test No. | Formulation | Tree No. | Deposit * | | | Calc. Drop. Diam. (μ) | Budworm Survivors * | | % Budworm Reduction | | % Defoliation Reduction |
|----------|-------------|----------|-----------|--------|-----------------------|-----------------------------|---------------------|--------------|---------------------|----------|-------------------------|
| | | | l/ha | gAl/ha | drops/cm ² | | per branch | per 100/buds | Branch Data | Bud Data | |
| 11 | F - I | 34 | 0.76 | 137 | 27 | | 4.00 | 5.71 | | | |
| | " | 35 | 0.65 | 117 | 9 | | 2.50 | 4.12 | | | |
| | " | 36 | 0.39 | 70 | 12 | | 2.25 | 2.08 | | | |
| | | | 0.60 | 108 | 16 | 89 | 2.92 | 3.97 | 50 | 74 | 57 |
| 12 | F - II | 37 | 1.02 | 102 | -- | | 9.00 | 15.52 | | | |
| | " | 38 | 0.57 | 57 | -- | | 4.25 | 8.06 | | | |
| | " | 39 | 0.69 | 69 | -- | | 3.75 | 6.38 | | | |
| | | | 0.76 | 76 | | -- | 5.67 | 9.99 | 1 | 35 | 31 |
| | Checks | 5 | | | | | 3.50 | 4.90 | | | 14** |
| | " | 14 | | | | | 7.00 | 25.00 | | | 35** |
| | " | 25 | | | | | 6.75 | 16.36 | | | 54** |
| | | | | | | | 5.75 | 15.42 | | | 34.3 |
| | | | | | | | ± 1.95 | ± 10.0 | | | ± 20.0 |

* Average of 12 samples - 4 from each tree.

** Average percent defoliation.

Table IV

Volume and Active Ingredient Deposit Applied to Trees with Resulting Effect on Budworm
Population and Defoliation - Midseason Application to L₄ and L₅ -

| Test No. | Formulation | Tree No. | Deposit* | | | Diam. (μ) | Budworm Survivors * | | % Budworm Reduction | | % Defoliation Reduction |
|-------------|-------------|-------------|-------------|------------|-----------------------|-----------|---------------------|--------------|---------------------|-------------|----------------------------|
| | | | ℓ/ha | gAI/ha | drops/cm ² | | per branch | per 100/buds | Branch Data | Bud Data | |
| 13 | 143-IA | 40 | 1.35 | 46 | 17 | | 1.00 | 2.88 | | | |
| | " | 41 | 2.24 | 76 | 20 | | 3.00 | 5.71 | | | |
| | " | 42 | 1.05 | 36 | 13 | | 9.50 | 26.57 | | | |
| | | | <u>1.55</u> | <u>53</u> | <u>17</u> | 120 | <u>4.50</u> | <u>11.72</u> | 48 | 22 | 22 |
| 14 | 143-IB | 43 | 1.98 | 67 | 28 | | 9.25 | 26.24 | | | |
| | " | 44 | 1.35 | 46 | 23 | | 9.00 | 26.28 | | | |
| | " | 45 | 1.25 | 41 | 11 | | 7.75 | 20.53 | | | |
| | | | <u>1.53</u> | <u>52</u> | <u>21</u> | 112 | <u>8.67</u> | <u>24.35</u> | 0 | 0 | 0 |
| 15 | 143-IIA | 47 | 1.05 | 59 | 15 | | 8.00 | 15.61 | | | |
| | " | 48 | 0.72 | 40 | 16 | | 4.50 | 10.65 | | | |
| | " | 49 | 1.82 | 102 | 12 | | 6.50 | 15.66 | | | |
| | | | <u>1.20</u> | <u>67</u> | <u>14</u> | 118 | <u>6.33</u> | <u>13.97</u> | 27 | 6 | 0 |
| 16 | 143-IIB | 51 | 3.08 | 172 | 28 | | 1.25 | 2.30 | | | |
| | " | 52 | 1.48 | 83 | 18 | | 1.25 | 1.81 | | | |
| | | | <u>2.28</u> | <u>128</u> | <u>23</u> | 124 | <u>1.25</u> | <u>2.05</u> | 85 | 86 | 48 |
| 17 | 143-IIIA | 53 | 1.72 | 29 | 16 | | 3.75 | 4.31 | | | |
| | " | 54 | 1.35 | 23 | 9 | | 6.25 | 13.59 | | | |
| | " | 55 | 1.38 | 23 | 15 | | 5.25 | 11.00 | | | |
| | | | <u>1.48</u> | <u>25</u> | <u>13</u> | 130 | <u>5.08</u> | <u>9.63</u> | 42 | 35 | 35 |

Table IV (Continued)

| Trees No. | Formulation | Tree No. | Deposit | | | Diam. (μ) | Budworm Survivors * | | % Budworm Reduction | | % Defoliation Reduction |
|--------------|-------------|-------------|-------------|-----------|-----------------------|-----------------|---------------------|--------------|---------------------|-------------|----------------------------|
| | | | l/ha | gAl/ha | drops/cm ² | | per branch | per 100 Buds | Branch Data | Bud Data | |
| 18 | 143-IIIB | 56 | 2.08 | 35 | 20 | | 8.50 | 12.69 | | | |
| | " | 57 | 1.42 | 24 | 12 | | 16.00 | 22.07 | | | |
| | " | 58 | 0.65 | 11 | 7 | | 9.50 | 10.61 | | | |
| | | | <u>1.38</u> | <u>23</u> | <u>13</u> | 127 | <u>11.33</u> | <u>15.12</u> | 0 | 0 | 0 |
| 19 | 143-IIIA | 60 | 3.25 | 55 | 23 | | 9.00 | 10.17 | | | |
| | " | 61 | 3.50 | 59 | 29 | | 5.75 | 5.40 | | | |
| | " | 62 | 2.42 | 41 | 24 | | 2.75 | 3.91 | | | |
| | | | <u>3.06</u> | <u>52</u> | <u>25</u> | 133 | <u>5.83</u> | <u>6.49</u> | 33 | 56 | 64 |
| 20 | 143-IIIB | 63 | 3.32 | 56 | 38 | | 4.50 | 6.67 | | | |
| | " | 64 | 4.38 | 74 | 27 | | 3.00 | 11.65 | | | |
| | " | 65 | 2.58 | 44 | 26 | | 6.25 | 8.14 | | | |
| | | | <u>3.42</u> | <u>58</u> | <u>30</u> | 130 | <u>4.58</u> | <u>8.82</u> | 47 | 41 | 40 |
| 21 | 143-IVA | 66 | 3.30 | 92 | 34 | | 3.25 | 5.02 | | | |
| | " | 67 | 4.25 | 119 | 37 | | 5.50 | 12.02 | | | |
| | " | 68 | 2.55 | 71 | 29 | | 3.00 | 4.93 | | | |
| | | | <u>3.37</u> | <u>94</u> | <u>33</u> | 125 | <u>3.92</u> | <u>7.32</u> | 55 | 51 | 54 |
| 22 | 143-IVB | 69 | 2.85 | 80 | 38 | | 1.50 | 2.33 | | | |
| | " | 70 | 2.55 | 71 | 23 | | 3.50 | 5.78 | | | |
| | | 71 | 1.90 | 53 | 27 | | 3.25 | 5.75 | | | |
| | | | <u>2.43</u> | <u>68</u> | <u>29</u> | 117 | <u>2.75</u> | <u>4.62</u> | 68 | 69 | 75 |
| 23 | 143-VA | 72 | 5.38 | 43 | 64 | | 1.75 | 4.07 | | | |
| | " | 73 | 4.78 | 38 | 57 | | 5.00 | 9.48 | | | |
| | | 74 | 2.70 | 22 | 25 | | 6.75 | 12.92 | | | |
| | | | <u>4.29</u> | <u>34</u> | <u>49</u> | 119 | <u>4.17</u> | <u>8.82</u> | 52 | 41 | 42 |

Table IV (Continued)

| Test No. | Formulation | Tree No. | Deposit | | | Diam. (μ) | Budworm Survivors * | | % Budworm Reduction | | % Defoliation Reduction |
|----------|-------------|----------|-------------|------------|-----------------------|-----------|---------------------|--------------|---------------------|----------|-------------------------|
| | | | l/ha | gAI/ha | drops/cm ² | | per branch | per 100/buds | Branch Data | Bud Data | |
| 24 | 143-VB | 75 | 3.72 | 30 | 49 | | 13.25 | 21.03 | | | |
| | " | 76 | 2.38 | 19 | 24 | | 3.50 | 4.83 | | | |
| | " | 77 | 1.93 | 15 | 30 | | 3.00 | 7.64 | | | |
| | | | <u>2.68</u> | <u>21</u> | <u>34</u> | 115 | <u>6.58</u> | <u>11.17</u> | 24 | 25 | 50 |
| 25 | 143-VIA | 78 | 1.92 | 27 | 27 | | 5.00 | 7.75 | | | |
| | " | 80 | 1.50 | 21 | 28 | | 2.25 | 3.49 | | | |
| | " | 81 | 3.30 | 46 | 42 | | 5.25 | 7.00 | | | |
| | | | <u>2.24</u> | <u>31</u> | <u>32</u> | 110 | <u>4.17</u> | <u>6.08</u> | 52 | 59 | 42 |
| 26 | 143-VIB | 82 | 7.52 | 105 | 64 | | 1.00 | 1.77 | | | |
| | " | 83 | 7.68 | 108 | 77 | | 2.75 | 4.21 | | | |
| | " | 84 | 5.95 | 83 | 65 | | 1.75 | 3.27 | | | |
| | | | <u>7.05</u> | <u>99</u> | <u>69</u> | 125 | <u>1.83</u> | <u>3.08</u> | 79 | 79 | 77 |
| 27 | 0 - II | 85 | 1.58 | 79 | 15 | | 4.75 | 6.09 | | | |
| | " | 86 | 2.12 | 106 | 20 | | 0.50 | 1.16 | | | |
| | " | 87 | 0.91 | 46 | 14 | | 3.50 | 6.42 | | | |
| | | | <u>1.54</u> | <u>77</u> | <u>16</u> | 122 | <u>2.92</u> | <u>4.56</u> | 66 | 69 | 45 |
| 28 | F - II | 88 | 2.54 | 254 | 41 | | 2.75 | 4.62 | | | |
| | " | 89 | 2.96 | 296 | 53 | | 4.50 | 7.63 | | | |
| | " | 90 | 1.40 | 140 | 17 | | 5.00 | 9.35 | | | |
| | | | <u>2.30</u> | <u>230</u> | <u>37</u> | 106 | <u>4.08</u> | <u>7.20</u> | 53 | 52 | 26 |

Table IV (Continued)

| Test No. | Formulation | Tree No. | Deposit* | | | Diam. (μ) | Budworm Survivors* | | % Budworm Reduction | | % Defoliation Reduction |
|-------------|-------------|----------|-------------|------------|-----------------------|-----------------|--------------------|--------------|---------------------|----------|-------------------------|
| | | | l/ha | gAI/ha | drops/cm ² | | per branch | per 100/buds | Branch Data | Bud Data | |
| 29 | F - I | 92 | 1.38 | 248 | 13 | 138 | 1.25 | 3.03 | 73 | 57 | 67 |
| | " | 93 | 1.27 | 229 | 8 | | 2.25 | 3.98 | | | |
| | " | 94 | 1.46 | 263 | 9 | | 3.50 | 12.28 | | | |
| | | | <u>1.37</u> | <u>247</u> | <u>10</u> | | <u>2.33</u> | <u>6.43</u> | | | |
| 30 | D - I | 97 | 6.60 | 660 | 58 | 133 | 0.25 | 0.36 | 79 | 79 | 85 |
| | " | 98 | 10.50 | 1050 | 73 | | 0.25 | 0.40 | | | |
| | " | 99 | 5.85 | 585 | 56 | | 5.00 | 8.55 | | | |
| | | | <u>7.65</u> | <u>765</u> | <u>62</u> | | <u>1.83</u> | <u>3.10</u> | | | |
| 31 | D - I | 101 | 3.00 | 300 | 37 | 126 | 1.00 | 2.14 | 61 | 52 | 74 |
| | " | 102 | 5.42 | 542 | 34 | | 2.25 | 4.33 | | | |
| | " | 103 | 5.00 | 500 | 57 | | 7.00 | 15.22 | | | |
| | | | <u>4.47</u> | <u>447</u> | <u>43</u> | | <u>3.42</u> | <u>7.23</u> | | | |
| 32 | D - I | 105 | 2.25 | 225 | 34 | 117 | 0.50 | 1.52 | 72 | 71 | 80 |
| | " | 106 | 3.02 | 302 | 28 | | 2.75 | 4.12 | | | |
| | " | 107 | 1.30 | 130 | 17 | | 4.00 | 7.27 | | | |
| | | | <u>2.19</u> | <u>219</u> | <u>26</u> | | <u>2.42</u> | <u>4.30</u> | | | |
| Checks | | 62 | | | | | 6.00 | 13.95 | | | 61.5** |
| (Untreated) | | 79 | | | | | 14.50 | 14.76 | | | 44.5 |
| | | 91 | | | | | 8.50 | 15.38 | | | 16.25 |
| | | 95 | | | | | 9.75 | 15.98 | | | 45.0 |
| | | 100 | | | | | 4.75 | 14.73 | | | 21.25 |
| | | | | | | | <u>8.70</u> | <u>14.95</u> | | | <u>37.7</u> |
| | | | | | | | ± 3.8 | ± 0.76 | | | ± 18.7 |

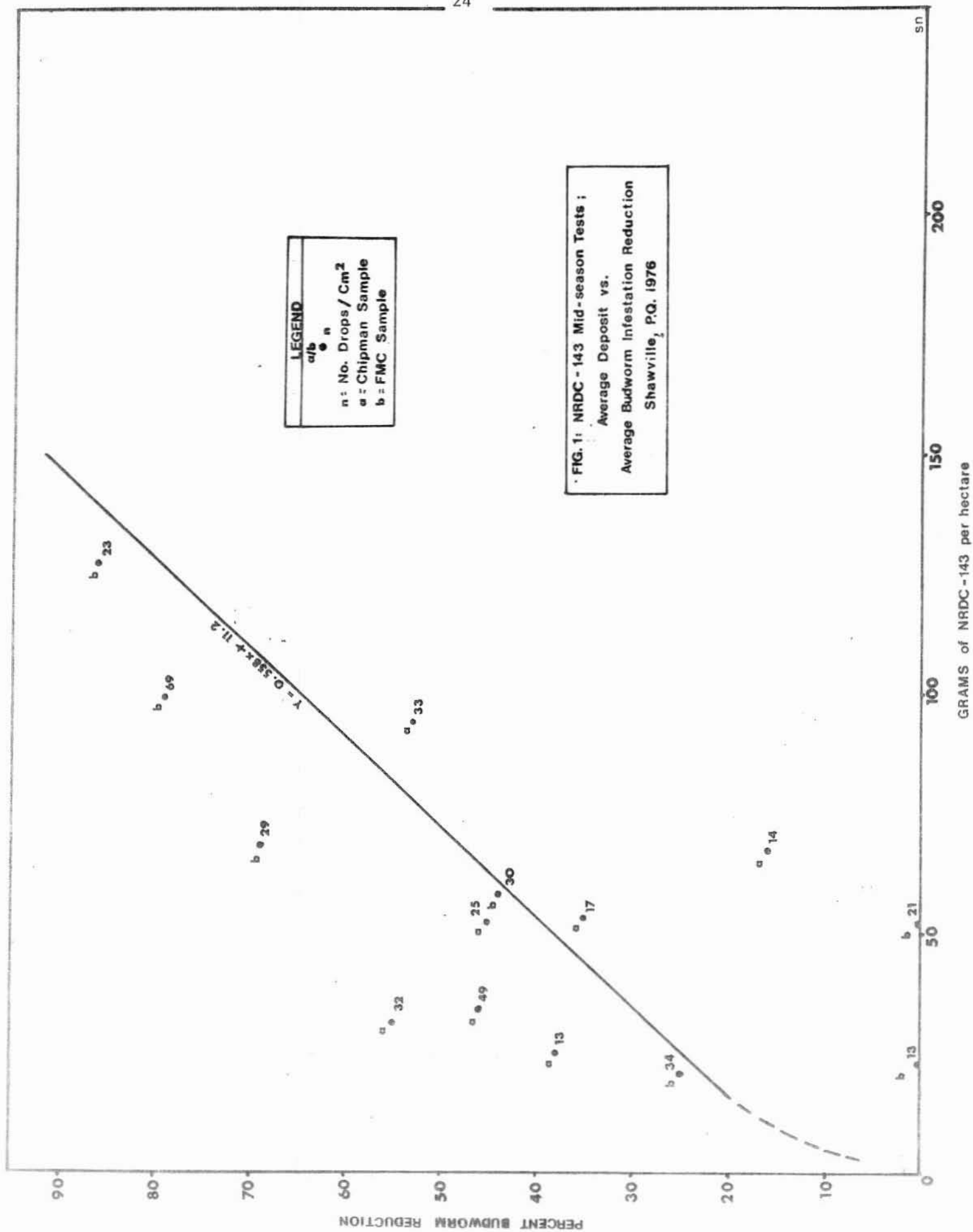
* Average of 12 samples - 4 from each tree

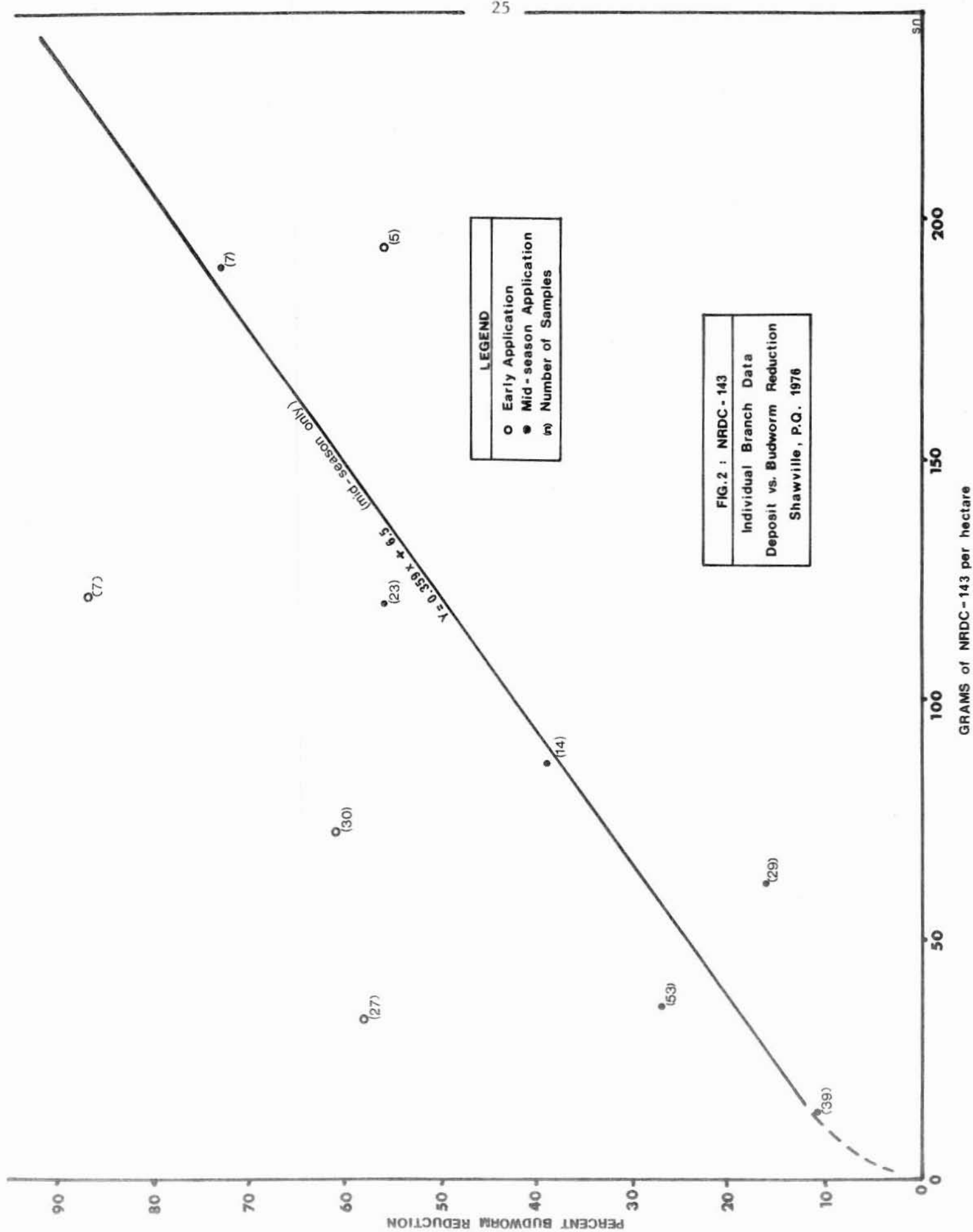
** Percent defoliation.

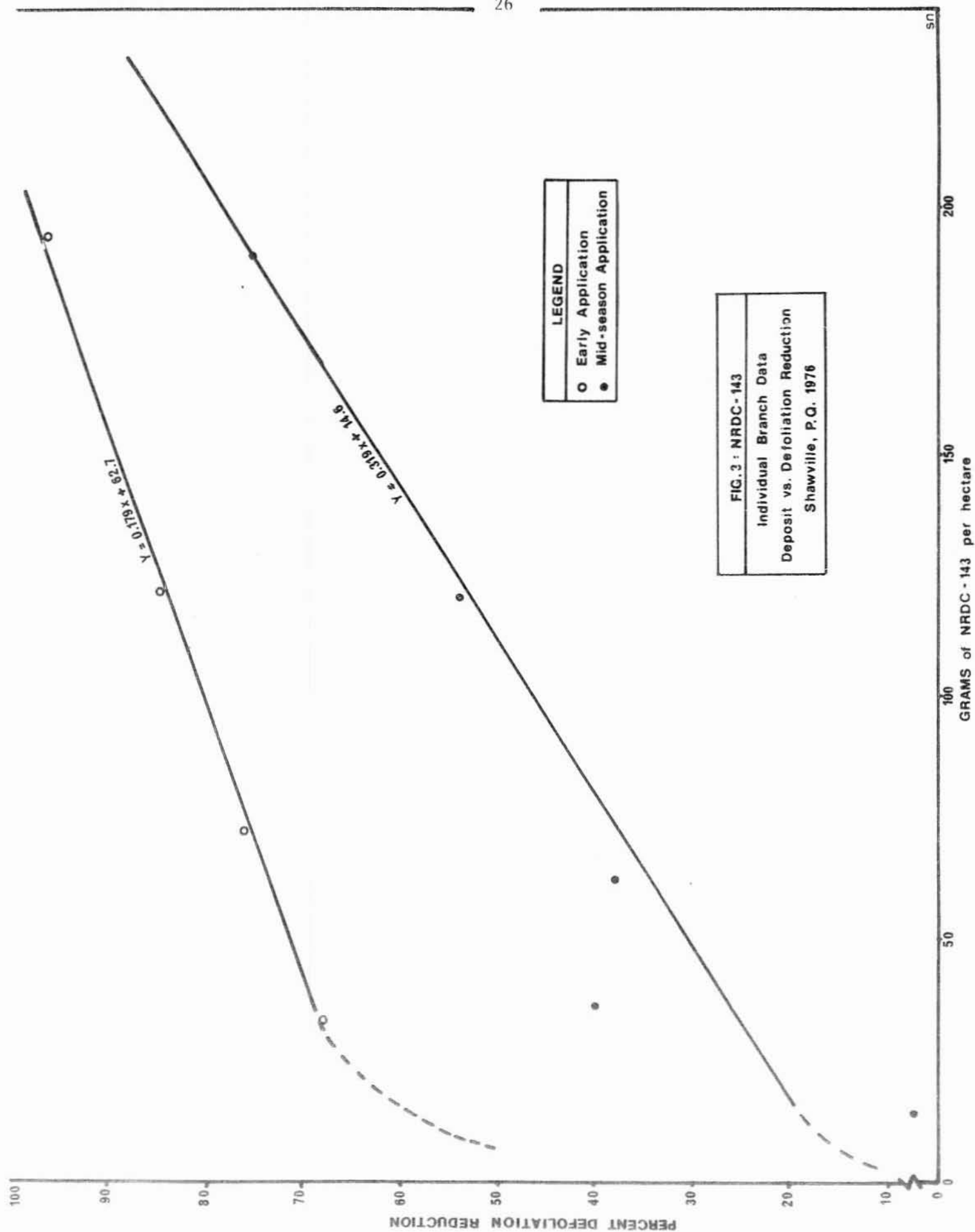
Table V

Summary of all NRDC-143 Spray Deposit Data on the Sample Branches and Resulting
Bud Infestation Levels and Defoliation by Spruce Budworm

| No. of Branch Samples | Range of Deposit (g AI/ha) | Deposit (g AI/ha) Mean and S.D. | Larvae per 100 buds Mean and S.D. | Percent larval reduction vs. checks | Defoliation (%) | |
|-------------------------------|----------------------------------|---------------------------------------|---|---|------------------|-----------------------------|
| | | | | | Mean and S.D. | Reduction from checks |
| <u>Early Application</u> | | | | | | |
| 27 | < 50 | 33 ± 12 | 6.5 ± 3.8 | 58 | 11 ± 16 | 68 |
| 30 | 51 - 100 | 72 ± 15 | 6.1 ± 6.3 | 61 | 8 ± 15 | 76 |
| 7 | 101 - 150 | 121 ± 15 | 2.0 ± 2.6 | 87 | 5 ± 9 | 85 |
| 5 | > 150 | 194 ± 47 | 6.9 ± 6.0 | 56 | 1 ± 1.4 | 97 |
| 12 | Untreated checks | ----- | 15.6 ± 9.6 | 0 | 34 ± 22 | 0 |
| <u>Mid-season Application</u> | | | | | | |
| 39 | > 25 | 14 ± 6 | 13.3 ± 14.4 | 11 | 36 ± 24 | 6 |
| 53 | 26 - 50 | 36 ± 7 | 10.9 ± 9.4 | 27 | 23 ± 22 | 40 |
| 29 | 51 - 75 | 62 ± 5 | 12.5 ± 11.5 | 16 | 23 ± 24 | 38 |
| 14 | 76 - 100 | 87 ± 6 | 9.1 ± 8.8 | 39 | 38 ± 32 | 0 |
| 23 | 101 - 150 | 120 ± 11 | 6.5 ± 5.4 | 56 | 19 ± 18 | 49 |
| 7 | > 150 | 190 ± 52 | 4.0 ± 4.0 | 73 | 9 ± 9 | 75 |
| 20 | Untreated checks | ----- | 14.9 ± 7.0 | -- | 38 ± 24 | -- |







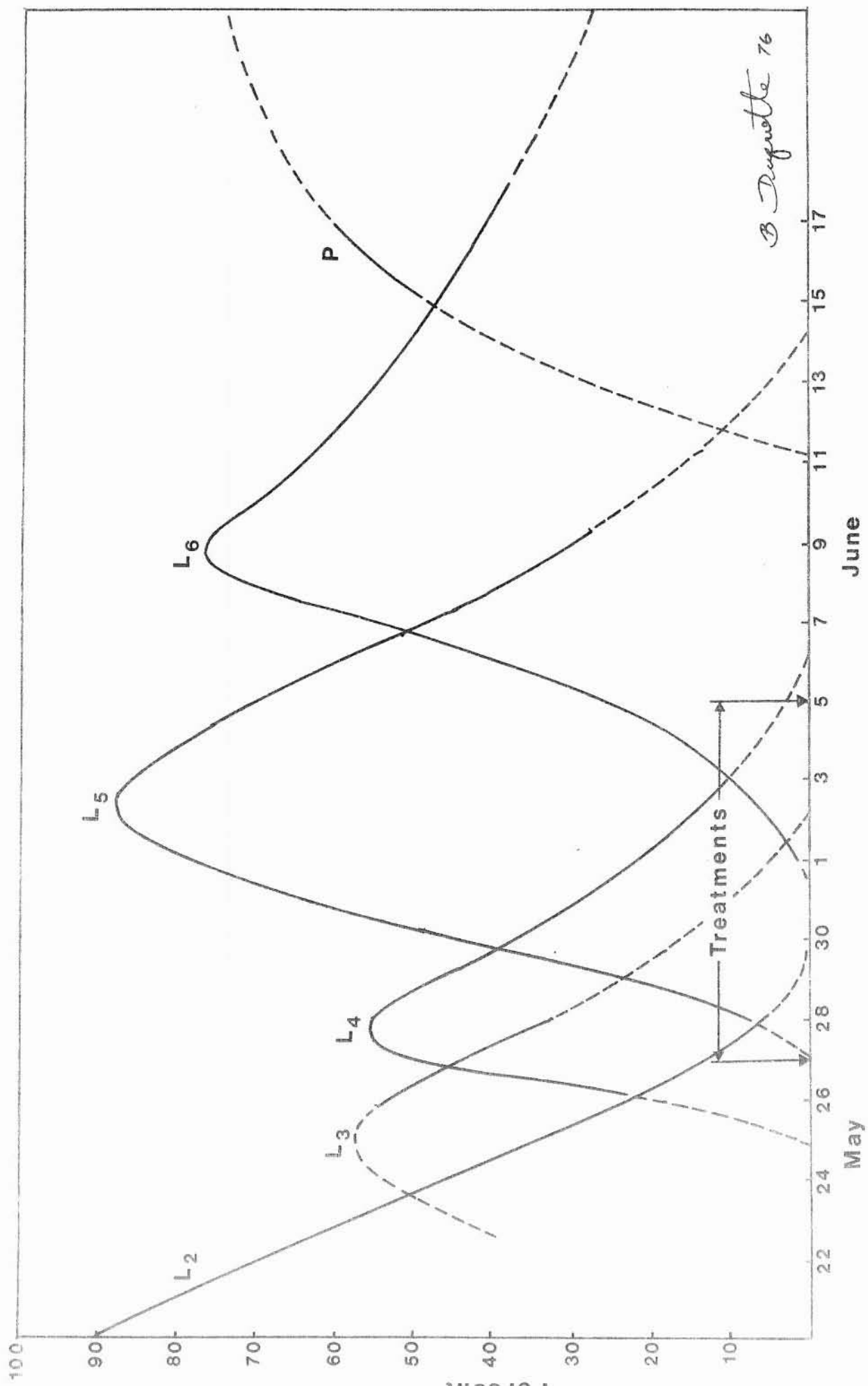


Fig. 4. Larval Population Development at Shawville, P.Q., 1976

BUDWORM INFESTATION
SHAWVILLE P.Q.
1976

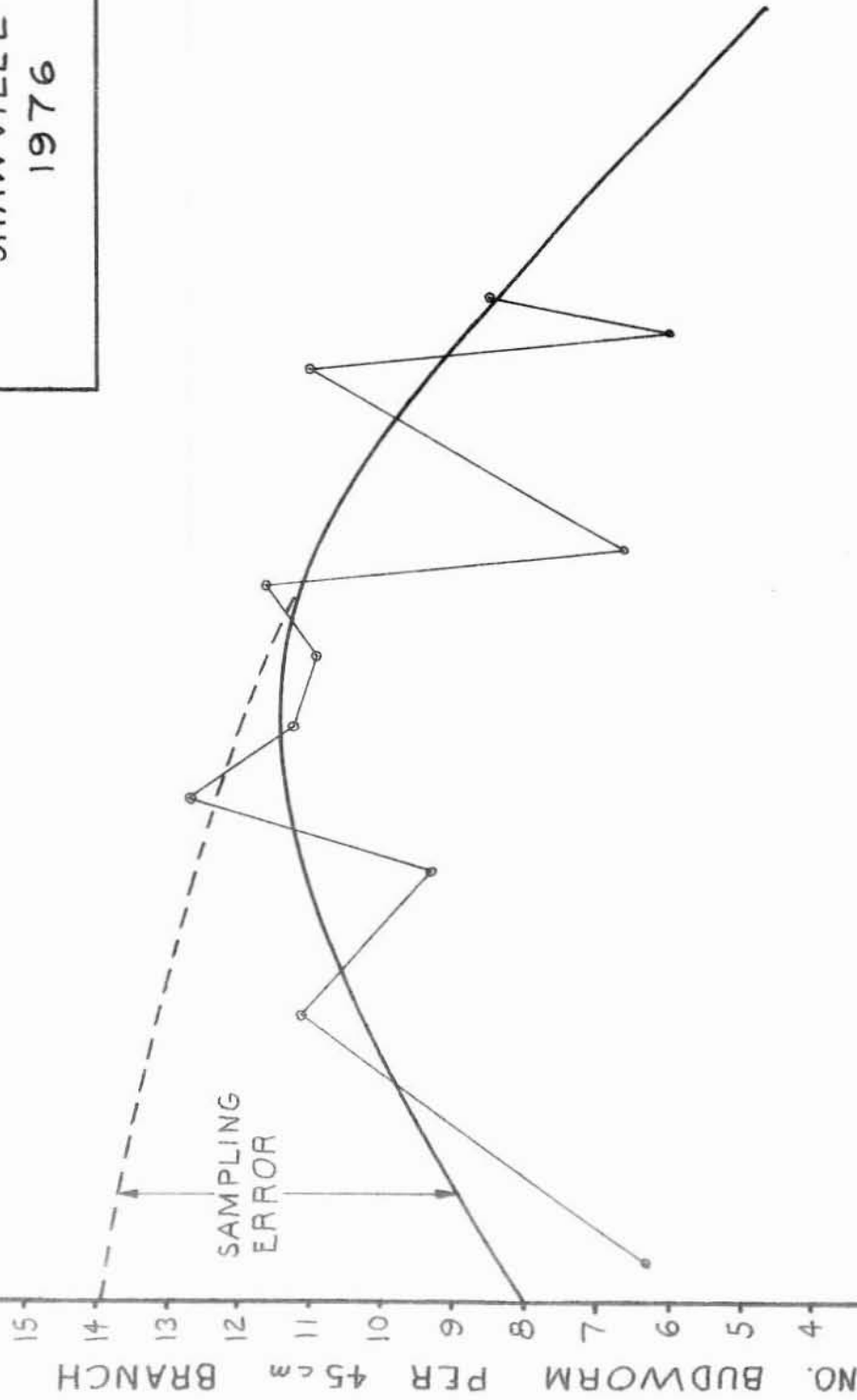


Fig. 5. Average number budworm per 45 cm branch.

B. DUQUETTE

22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 22 23 25
MAY JUNE
DATE

BUDWORM INFESTATION
SHAWVILLE P.Q.
1976

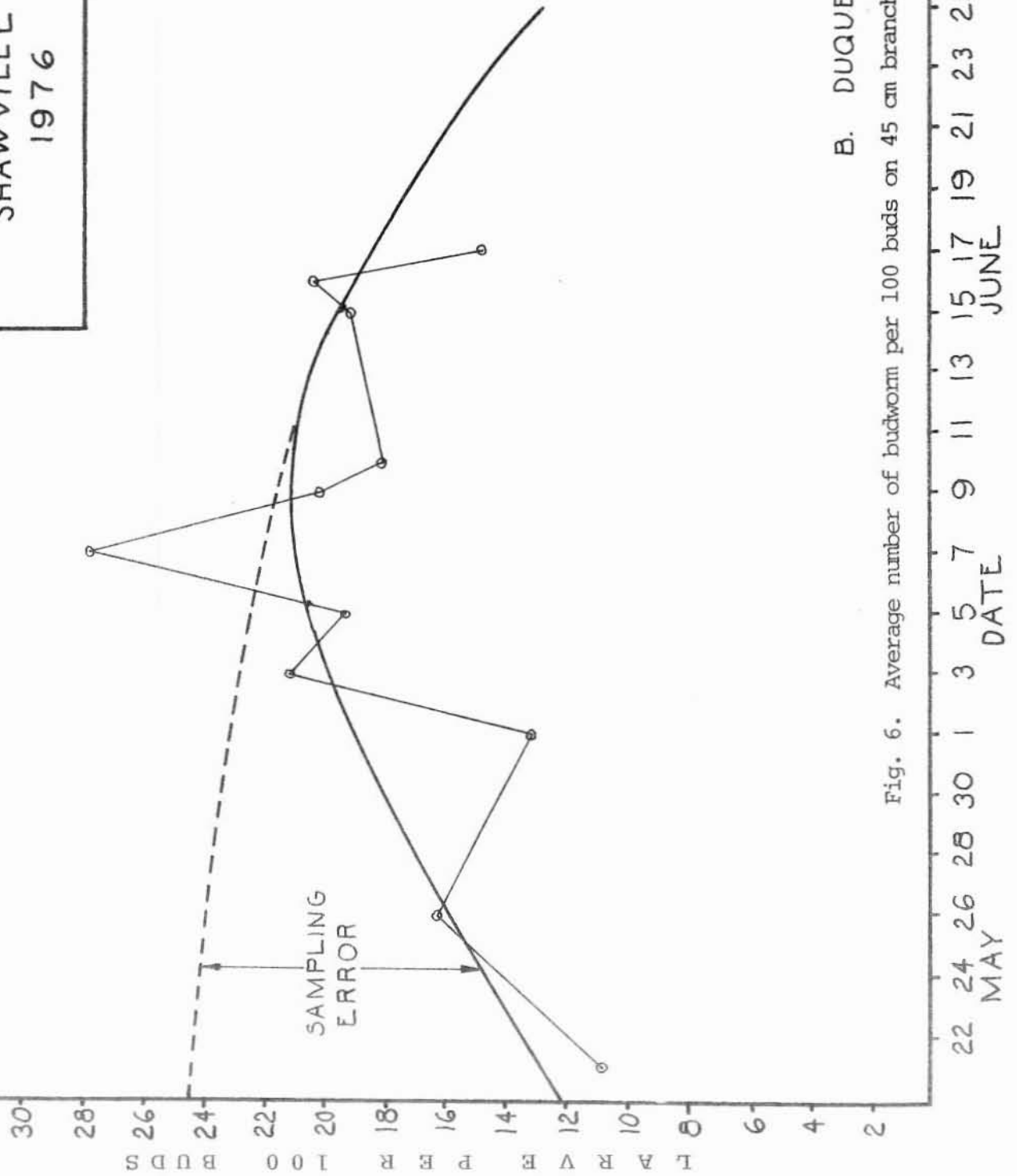
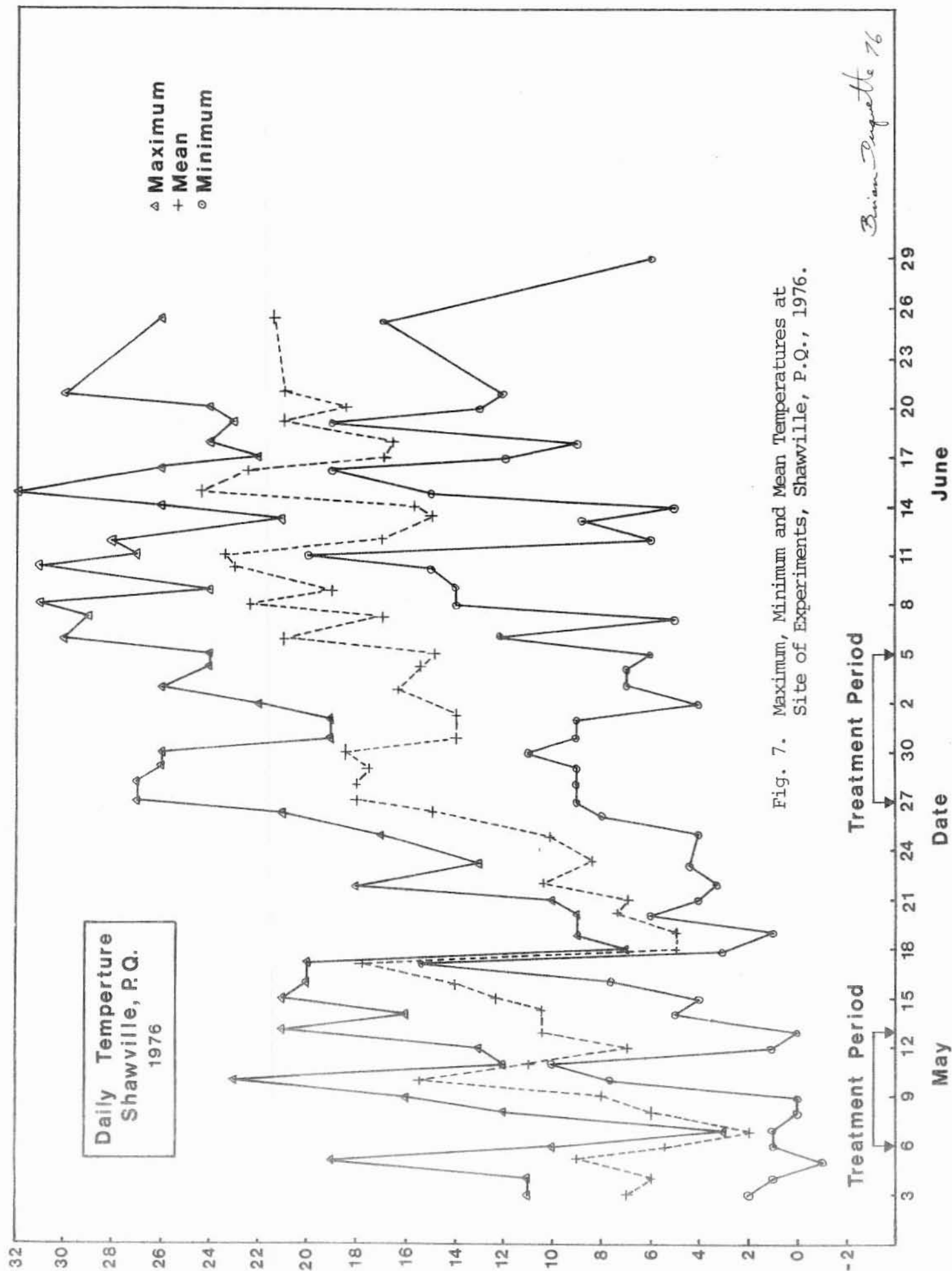


Fig. 6. Average number of budworm per 100 buds on 45 cm branches.

B. DUQUETTE



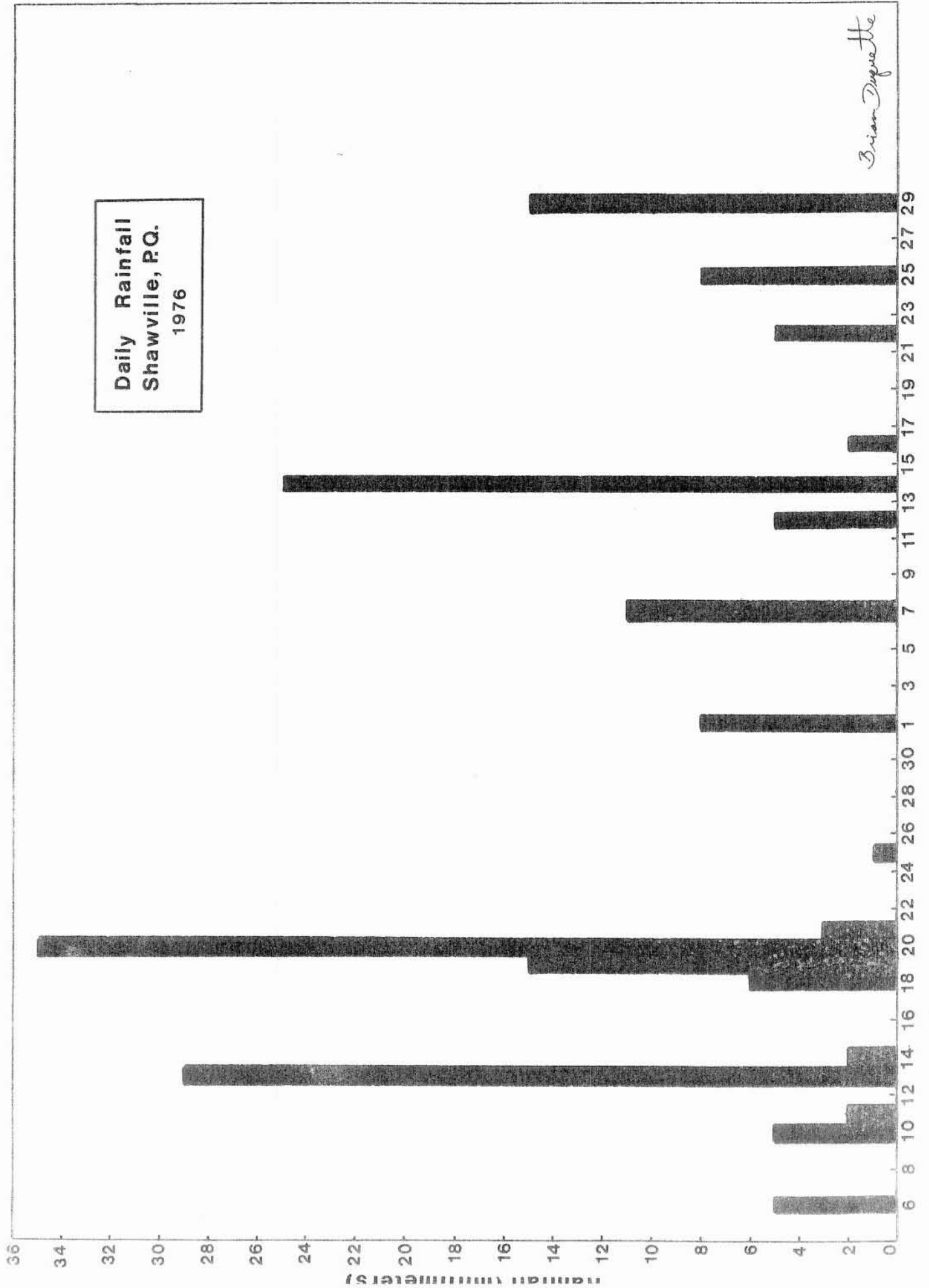


Fig. 8. Rainfall on Site, Shawville, 1976