SURVEY OF THE EFFICACY OF ROOT REMOVAL OPERATIONS SURVEY II

by

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FOREWORD

This report is one of a series of internal reports distributed by Forest Protection Branch, B.C. Ministry of Forests, to record accomplishments and interim or provisional results for the information of staff, colleagues, and others.

In the Canada-British Columbia Forest Resources Development Agreement (FRDA) 1985 to 1990, over 100 pest control projects were directly funded by the province and administered by protection staff. To facilitate application of the results, and development of improved forest health management strategies, the contractors reports have been edited and distributed as internal reports. Accordingly, any opinions and recommendations expressed are those of the contractor, and not necessarily those of the ministry or the FRDA management committee.

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The guidelines for internal reports outlined in the Protection Manual were adhered to as closely as possible. All manuscripts were altered to comply with a common format, but entire reports were not rewritten to conform to a standardized outline.

Most Executive Summaries were the work of Graham Hawkins of MoF Inventory Branch (formerly with Pacific Coast Forest Biology). All word processing was accomplished by Catriona Kaufman of Top Kat Services. Will Gordon of R. White Woods inc. prepared all maps and figures.

R. White, editor
R. White Woods inc.

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EXECUTIVE SUMMARY

Two separate surveys were conducted on the coast (January - March 1986: PM-PB-66) and in the interior and on the coast (November 1986 - January 1987: PM-PB-67) to determine the effectiveness of stump excavations for removing infected material. Both surveys employed the same methods. Suitable stumped areas, treated from less than one year to 15 years before the survey, were selected for sampling, and 11 were surveyed. The amount of residual material and its infective potential were determined and analyzed with respect to site factors such as soil type and moisture, depth, percent coarse fraction and terrain. Strips and plots were established at regular intervals for uniform sampling at eight sites, while non-random sampling was employed at three sites due to access restrictions and the desire to intensively sample infection centres.

A small backhoe was employed to excavate roots and soil at each plot. Excavations were performed down to the C-horizon. Dimensions, species and notes on any infection were recorded for all excavated root pieces, and suspected infected roots were incubated for confirmation. Site and soil factors were determined and also recorded per plot. Data on residual root material were analyzed by the percent of roots infected, the volume of infected roots per total volume of soil and the volume of all roots per total volume of soil. Site and soil factors were correlated with these analyses.

Results from both surveys indicated that statistically meaningful relationships could not be made between either total or infected root volume and the method of root removal or site age. Trends indicated that root-raking operations are not significant in reducing the amount of infected material. More root material was left on sites with high soil cohesion (silt and clay types), but relatively little of this material was infected due to the poor survival of pathogens under the wet conditions generally existing in these soil types. More infected material occurred in soils with greater porosity (sand types), but more material was also removed from these soil types.

In general, stumping operations were certainly effective in removing much of the infected material from heavily infected sites. Data from this project indicated that there was no significant difference in removal efficacy between excavator and bulldozer equipment. However, another study conducted for Forestry Canada in 1987 clearly showed that a large excavator is capable of removing more material than either a bulldozer or small excavator. Relatively few and smaller pieces of infected root material remain after treatment with a large hydraulic excavator/bucket and thumb.

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1 INTRODUCTION

Phellinus weirii (Murr.) Gilbertson and *Armillaria ostoyae* (Romagn.) Herinke cause destructive root diseases of coastal and interior coniferous tree species in British Columbia. The pathogens spread by root contact and survive in root material for many years, thereby posing a potential threat to the susceptible species of the next rotation. Indeed, *P. weirii* causes the most destructive disease of second-growth Douglas-fir stands in the Pacific Northwest (Bloomberg & Reynolds 1982). Because the incidence of infected stumps or roots is a major factor governing losses in the subsequent stands (Wallis 1976), stumping the infection centres prior to planting has been recognized as a method to prevent such losses.

This study, similar to one previously conducted by Hawkins and Kunzli in 1986, investigated the efficacy of root removal operations. Site factors, including soil type, moisture, depth, percent coarse fraction and slope were noted since the probability of root contact and spread of infection are dependent on these (Reynolds & Bloomberg 1982). The volume of both infected and non-infected root material remaining in the soil was measured in order to assess the potential threat of infection by *P. weirii* and *A. ostoyae.*

2 MATERIALS AND METHODS

One interior site and two coastal sites were sampled. The sampled portion of the Golden site (Figure 1) had been stumped, piled and burned. At the Squamish site (Figure 2) only the stumps of trees identified as infected prior to and during the harvesting operation had been removed. Because some stumps remain within the infection centres, these centres were not well defined. The stumps had been neither piled nor burned, although a burn was intended to be conducted in the fall of 1986. The infection centres of the Powell River site (Figure 3) were well defined and a 10m margin had been included in the stumped centres. The entire site had been burned.

Procedures for uniform sampling were utilized within the stumped area of the Golden site. Only the infection centres were surveyed at the Squamish and Powell River sites, so sampling was therefore biased. A grid system consisting of a baseline, strips and plots was used. Strips were traversed at constant headings and at regular intervals, where possible, from an initially established baseline. Sample plots were established at uniform distances along each strip, where feasible. Excavation down to the C-horizon was performed at each marked plot.

Five strips were traversed at the Golden site. Although the entire block was infected with *A. ostoyae*, only the stumped portion was sampled at 25m intervals and positioned in such a way as to cover most of the area. Because an experiment is being conducted within this stumped area and could not be disturbed, this portion of the block was not sampled. Thirty plots were sampled at this site.

At the Squamish site, twenty strips were traversed at 10m intervals within the poorly defined boundaries of the infection centres. Plots were positioned 10m apart unless a steep slope or the presence of slash dictated that they be offset. Initially, 58 plots were to be sampled, but three were omitted because bedrock was visible a few centimetres below the surface. Therefore, 55 plots were examined. In addition, the bearing and distance to any unremoved Douglas-fir or western hemlock stump was recorded.

Ten strips were traversed at 25m intervals within two of the infection centres of the Powell River site. Plots were also 25m apart unless they were offset as a result of slash or the road. A total of 46 plots were examined.

When examining plots, a procedure similar to that of the previous project (Hawkins & Kunzli 1986) was used. A depth to the bottom of the B-horizon was considered to have been attained once bedrock, solid clay or a depth of 1.3m was reached. The plots were examined systematically and measured for depth, bottom length and width, and top length and width to the nearest 10cm to obtain the length and width to the nearest 10cm in order to determine soil volume. A soil field analysis was then performed and the percent coarse fraction and soil fine fraction texture recorded. Soil pH (determined with litmus paper accurate to 1.0 pH units), soil moisture, depth and colour, were also

recorded. The porosity of the soil and the presence or absence or seepage were noted. Depth to bedrock was estimated and parent material, rock type and soil base status were assessed. In addition, the aspect and percent slope were determined at each plot centre. The data were collected on plot cards and later key-punched.

Root debris in the excavated soil or protruding into the sample pit was then measured. Root material of susceptible species (Douglas-fir [*Pseudotsuga menziesii*] and western hemlock [*Tsuga heterophylla*] in *P. weirii* infection centres and subalpine fir [*Abies lasiocarpa*], Engelmann spruce [*Picea engelmannii*] and western hemlock in the *A. ostoyae* infection centres) was distinguished from that of other species in order to derive a volume for root material based on a potential source of inoculum. Any susceptible root material measuring one centimetre or greater in diameter and at least five centimetres in length was recorded. An accurate estimate of the root volume remaining in the soil was thus obtained.

Since evidence of *A. ostoyae* or *P. weirii* was sought in the field, any suspected material was taken for incubation. Sample roots were measured and tagged for incubation. These samples were split, wrapped in wet newspaper and left at room temperature (at least 20°C) for seven days in order for the mycelia of any *P. weirii* or *A. ostoyae* present to develop. The samples were then examined with a dissecting microscope. The presence of viable *P. weirii* mycelia could be determined readily since brown setaceous hyphae were easily discernable among the white mycelial mats. Viable *A. ostoyae* mycelia were identified as pink to brown mycelial tufts. Any samples which tested positive for *P. weirii* were noted for either the ectotrophic or endotrophic form, where possible, since the two trophic types may pose a different potential threat (Bloomberg & Reynolds 1982).

3 RESULTS

There was considerable variation between the sites in the amount of root material recovered. The highest incidence of either root pathogen *Phellinus weirii* or *Armillaria ostoyae*, in terms of the percentage of plots containing the inoculum, occurred at the Golden site. Although eleven plots (36.6%) contained root material with viable *A. ostoyae*, this provides only 0.017m^3 of infected root material per cubic metre of soil and 3.73% of the total root volume (Table 1). In addition, the amount of infected root material recovered from the plots containing viable pathogen varied considerably between plots (Figure 4). The infected root volume ranged from 6.76% of the total root volume of the plot (Plot 6), which accounted for 0.0002m^3 of root material to 51.46% of the total root volume of the plot (Plot 1), which accounted for 0.001m^3 of root material.

The next highest incidence of a pathogen, *P. weirii* in this case, occurred at the Squamish site. Here, 18 plots (32.7%) contained viable pathogen for a total volume of 0.151m^3 of infected root material per cubic metre of soil and 32.78% of the total root volume (Table 1). This site demonstrated more interplot variation with respect to infected root volume than the Golden site (Figure 5). It ranged from 0.87% of the total root volume of the plot (Strip 3, Plot 1), which accounted for 0.0001m^3 of root material to 96.17% of the total root volume of the plot (Strip 11, Plot 4), which accounted for 0.047m^3 of root material.

At the Powell River site a large volume of infected roots, 0.045m^3 of infected root material per cubic metre of soil was found, comprising 26.87% of the total root volume (Table 1). However, only 22% of the plots at this site contained viable inoculum. The infected root volume ranged from 0.35% of the total root volume of the plot (Strip 9, Plot 1), which accounted for 0.00003m^3 of root material, to 97.07% of the total root volume of the plot (Strip 5, Plot 5), which accounted for 0.021m^3 of root material (Figure 6).

Although the greatest volume of root material (0.222m^3) was recovered from the Powell River site, the largest volume of soil (132.255m^3) was also excavated from this site. Only 0.167m^3 total root volume per total soil volume was recovered here as compared with 0.468m^3 and 0.462m^3 from the Golden and Squamish sites, respectively. Generally, a greater total volume of root material was found in those sites with soil of high cohesion (personal observation). Silt, silty clay and silty clay loam soil types were prominent at the Golden site and had a high percentage root volume per total soil volume but a low volume of infected material. Sandy loam and loamy sand soil types were prominent at the Squamish site and maintained a high percentage root volume per total soil volume and high infected root volume per total soil volume and high infected root volume per total soil volume. The Powell River site consisted mainly of sand which maintained a low percentage of total root volume per total soil volume and a low incidence of infection. The soil at this site has a high coarse fraction.

4 DISCUSSION

The volume of uninfected and infected root material remaining at a site after the stumping operation is dependent on a number of factors. The number of stems per hectare, the size of infection centres, the soil type, moisture, nutrient regime and slope affect the residual root volume. Moreover, the survey method itself may influence the data obtained.

The growth of the two pathogens, *Phellinus weirii* and *Armillaria ostoyae*, suggests that there would be less residual infected root material in stumped *A. ostoyae* infection centres than in *P. weirii* infection centres. Once entry of the root is gained, *P. weirii* parasitizes and kills cells of the phloem and xylem as well as penetrating and destroying the older, thick-walled xylem elements (Nelson 1962). In the case of *A. ostoyae*, once entry of the root is gained, the toxins secreted by the pathogen kill the cambium and the fungus spreads through the dead substrate (Foster & Baranyay 1973), and eventually attacks the wood as well. Thus, *A. ostoyae* mycelia grow mainly in the cambium, so there would be a lower probability that the root would break during the root removal operation than with *P. weirii* mycelia, which grow in the sapwood and heartwood (Johnson, personal communication). One explanation for the low percentage of infected root volume at the Golden site (3.73%) as compared to the other sites could be this difference in growth habit between the two pathogens.

There is no clear relationship between residual root volume and soil type because of the few sites examined. However, higher total residual root volumes were recovered from the more cohesive soils (silty clay, silty clay loam, silt and silty loam at the Golden site, and sandy loam, sandy clay loam, loam and loamy sand at the Squamish site). The incidence of infected root material remaining nevertheless appears to be much lower in the silty type soils. This may be a result of the aforementioned growth habit of *A. ostoyae*. Conversely, this low incidence of infected root material may be due to a combination of poor aeration, extreme moisture, and the presence of organisms antagonistic to the pathogen. Thus, the difficulty of removing roots from these soil types may not imply an increase in the incidence of root disease after root removal operations (Hawkins & Kunzli 1986). In sandy soils, there seems to be a higher incidence of infected root volume. *P. weirii* thrives in soil moisture regimes from fresh to moist (Bloomberg & Beale 1985). Perhaps the pathogen requires adequate aeration under moist conditions.

No relationship between the quantity of infected root material and nutrient regime, pH or coarse fraction could be determined. Neither could any relationships be made between the previous stand volume of the various sites. Unfortunately, very little data on the number of stems per hectare in the infection centres were obtainable.

Little comparison can be made regarding the effect of stump removal method on the total infected root volume because all three sites were treated similarly using Cat 235

excavators. Although one would expect fewer roots to be left behind by excavator-type equipment than crawler-type equipment, when the method used on these sites is compared to those of the previous report (Hawkins & Kunzli 1986), both types of equipment left behind significant volumes of both infected and non-infected roots. A difference of only two years exists between the stumping operations of the three sites, so again, little comparison can be made.

At all the sites the remaining roots may pose little potential threat of infection to the next crop because the infected roots were mainly of small dimensions; therefore, they are less likely to be contacted by live roots. Some large diameter infected roots were recovered from the Squamish and Powell River sites. However, results from a previous report (PM-PB-66) suggest that root segments less than six centimetres in diameter and 26cm long still contained inoculum after 14 years. The potential threat of infection also depends on the mycelial form of *P. weirii* — ectotrophic or endotrophic — colonizing the root segments. Although the ectotrophic form poses more of a threat (Bloomberg & Reynolds 1982), few roots showed evidence of this mycelial growth (28 root segments at the Powell River site and 11 at the Squamish site). Some additional threat is posed by the remaining stumps at the Squamish site. Wallis and Bloomberg (1981) found that in 45-60 year old stands about 50% of the total number of diseased trees were recorded using above ground indicators. An additional 25-35% of the diseased trees were accounted for when mycelium on the root collar before the stand was felled and/or stain-decay on the stump surface after the trees were cut were identified. Therefore, some stumps remaining within the infection centres may be infected.

In stands infected with *P. weirii* and older stands infected with *A. ostoyae*, the disease is spread by root contact. Rhizomorphs spread *A. ostoyae* in interior trees less than 10 years old (Morrison 1981). Reynolds and Bloomberg (1982) found an increase in the probability of root contact with an increase in soil gravel content and slope. Because stoniness is also reported to promote more lateral branching (Haais 1921; Faulkner & Malcolm 1972), the probability of root contact increases. Therefore, the Powell River site may pose a significant potential threat to infection because of high gravel and cobble content of the soils and the high infected root volume remaining. The sites show little variation in slope.

Although only three sites were sampled, there seemed to be little difference in the effectiveness of the survey techniques in terms of the spacing of the uniform grid over an entirely stumped area or only within the infection centres. Both infected and non-infected root material was recovered from surveys using 10 x 10m and 25 x 25m spacing. Therefore, the strip and plot spacing could be modified by the survey crew to fit a given area under constraints imposed by slash or terrain. A low volume of infected root material may have been recovered as a result of the less biased survey method (uniform grid, location of infection centres unknown) at the Golden site. There may have been a high total root volume at the Squamish site because some stumps

within the infection centres were not excavated. In addition, the 10 x 10m spacing used at this site may created more variation in the data. Only the Powell River site maintained well-defined infection centre boundaries but some sampling was conducted within the 10m margin, so again some inaccuracy of the data may result.

The incubation technique employed in this survey is fast, simple, and generally reliable. However, some root specimens which exhibited evidence of the pathogen did not show positive after incubation. For *P. weirii*, an abundance of white mycelia could be observed, but the definitive brown setaceous hyphae were totally absent. In the case of *A. ostoyae*, an abundance of white mycelia could be observed, but the characteristic pink to brown mycelial tufts were undiscernible. The application of accurate and fairly simple spore viability tests (Yu *et al.* 1984) would eliminate these queries of viability.

The various types of excavating equipment performed well. Excavation in all soil types was rapid and a very high coarse fraction did not impede efficiency. Further, slash removal proved to be a simple task. The tractor-mounted backhoe (Golden) and the Caterpillar 225 (Powell River) were very mobile on the steeper slopes.

5 RECOMMENDATIONS

The following recommendations are made:

1. More survey work should be conducted on sites infected with *Armillaria ostoyae*. Only one such site was examined, and thus little comparison could be made between this site and those infected with *Phellinus weirii*.

2. Extensive control surveys should be performed in order to truly quantify the data.

3. All stumps of susceptible species should be removed from the infection centre.

4. Viability tests on the hyphae and spores of *P. weirii* and *A. ostoyae* using the method of Yu *et al.* (1984) should be investigated.

5. Accurate information on stems per hectare and species composition within the infection centre should be obtained.

6 CONCLUSION

Although only three sites were examined, the more cohesive soil types retained more root material, but the level of infected root material appeared to be lower in these. Sandy soils retained relatively high levels of infected roots. The levels of root infection may be related to the differences in growth habit between the two pathogens, *P. weirii* and *Armillaria ostoyae*, soil porosity, or the absence of species antagonistic to the pathogens. There may, however, be little potential threat posed by the infected roots remaining in the soil because of their small dimensions and the small number of roots with ectotrophic mycelium.

Both excavator- and crawler-type equipment seem to be equally effective in root removal. The survey method, using a uniform grid, was effective but often difficult to implement because of slash, terrain or infection centre size.

Unfortunately, the data are not very conclusive because so few sites were examined. Further investigation into the efficacy of root removal operations, especially in *A. ostoyae* infection centres, is required.

7 REFERENCES

Bloomberg, W.J. and J.D. Beale. 1985. Relationship of ecosystem to *Phellinus weirii* root rot on southern Vancouver Island. Unpublished.

Bloomberg, W.J. and G. Reynolds. 1982. Factors affecting transfer and spread of *Phellinus weirii* mycelium in roots of second-growth Douglas-fir. Can. J. For. Res. 12:424-427.

Faulkner, M.E. and D.C. Malcolm. 1972. Soil factors affecting root morphology and stability of Scots pine on upland heaths. Forestry 45:23-36.

Foster, A.J. and J.A. Baranyay. 1973. *Armillaria* root rot. Forest Insect and Disease Pest Leaflet 35.

Haais, F.W. 1921. Relation between soil type and root form of western yellow pine seedlings. Ecology 2:292-303.

Hawkins, G. and N. Kunzli. 1986. Survey of the efficacy of root removal operations. B.C. Ministry of Forests. Internal report. PM-PB-66.

Morrison, D.J. 1981. *Armillaria* root disease: A guide to disease, diagnosis, development and management in British Columbia. Can. For. Serv. PFRC BC-X-203. 15pp.

Nelson, E.E. 1962. *Poria weirii* root rot of Douglas-fir: Survival of the pathogen and infection of the host. Oregon State University Ph.D. Thesis. 71pp.

Reynolds, K.M. and Bloomberg, W.J. 1982. Estimating probability of intertree root contact in second-growth Douglas-fir. Can. J. For. Res. 12:493-498.

Wallis, G.W. 1976. *Phellinus* (Poria) *weirii* root rot: Detection and management proposals in Douglas-fir stands. Environment Canada For. Tech. Rep. 12. 16pp.

Wallis, G.W. 1976. Growth characteristics of *Phellinus* (Poria) *weirii* in soil and on root and other surfaces. Can. J. For. Res. 6:229-232.

Wallis, G.W. and W.J. Bloomberg. 1981. Estimating the total extent of *Phellinus weirii* root rot centres using above- and below-ground disease indicators. Can. J. For. Res. 11:827-830.

Yu, S.Q., E.J. Trione and T.M. Ching. 1984. Biochemical determination of the viability of fungal spores and hyphae. Mycologia 76:608-613.

TABLE 1 SUMMARY OF DATA FOR SITES VISITED

	Golden	Squamish	Powell River
Treatment method and date stumped	D, W, B 1984	D 1986	D, B 1986
Machine used	Excavator	Cat 225 Excavator	Excavator
Sampling method description	• uniform	• biased • only infected area sampled	• biased • only infected area sampled
Sample spacing - Strips and Plots (m)	25 x 25	10 x 10	25 x 25
Number of Plots	30	55	46
Total soil volume excavated (m^3)	29.63	38.25	132.25
Total root volume (m^3)	0.1389	0.1767	0.2215
Non-infected root volume remaining (m^3)	0.1335	0.1187	0.1620
Infected root volume remaining (m^3)	0.0052	0.0579	0.0595
% total root volume per total soil volume	0.47	0.46	0.17
% infected root volume per total soil volume	0.02	0.15	0.05
% infected root volume per total root volume	3.73	32.78	26.87
Number of plots containing pathogens	11	18	10

FIGURE 1 **GOLDEN SITE**

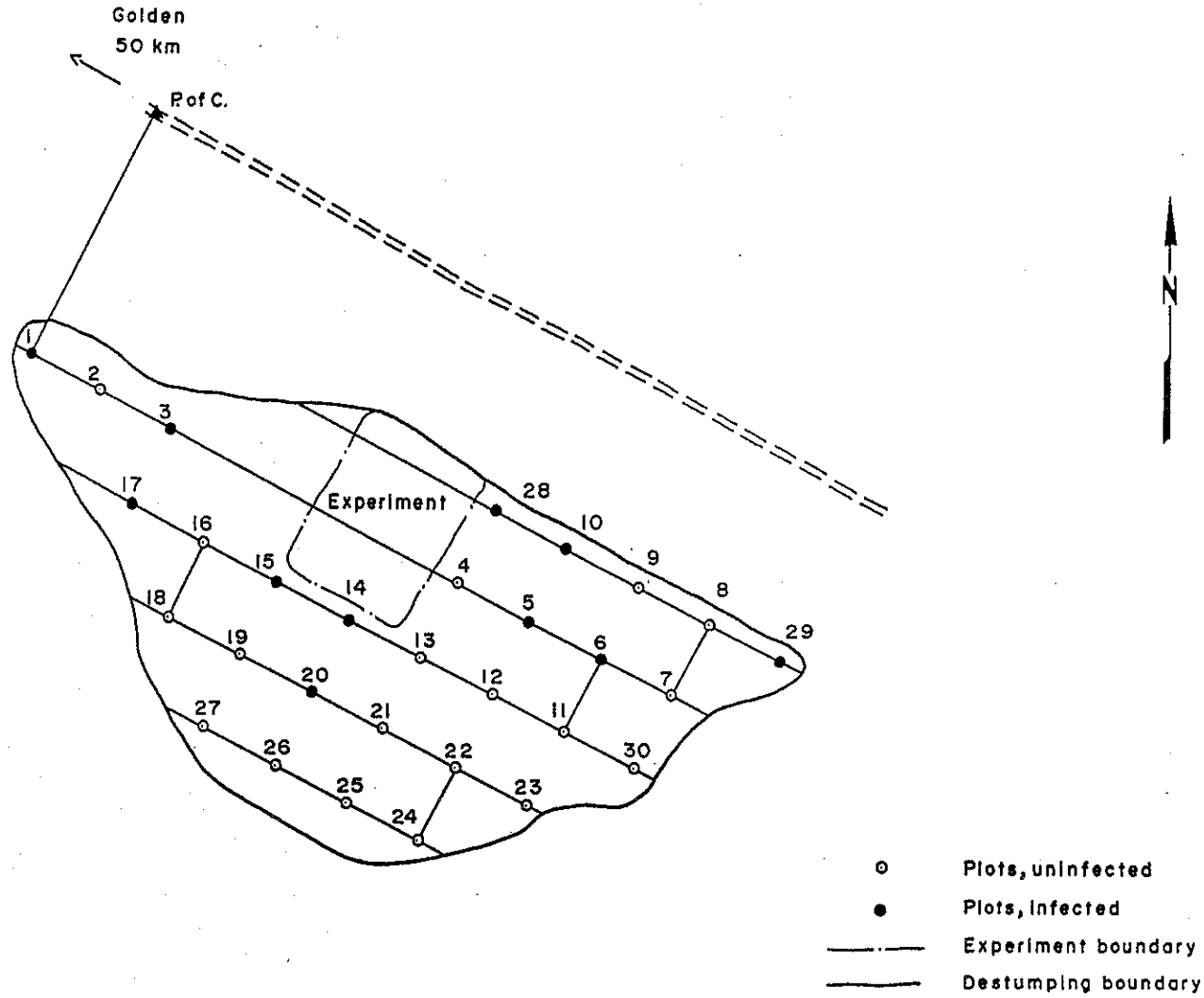

FIGURE 2 SQUAMISH SITE

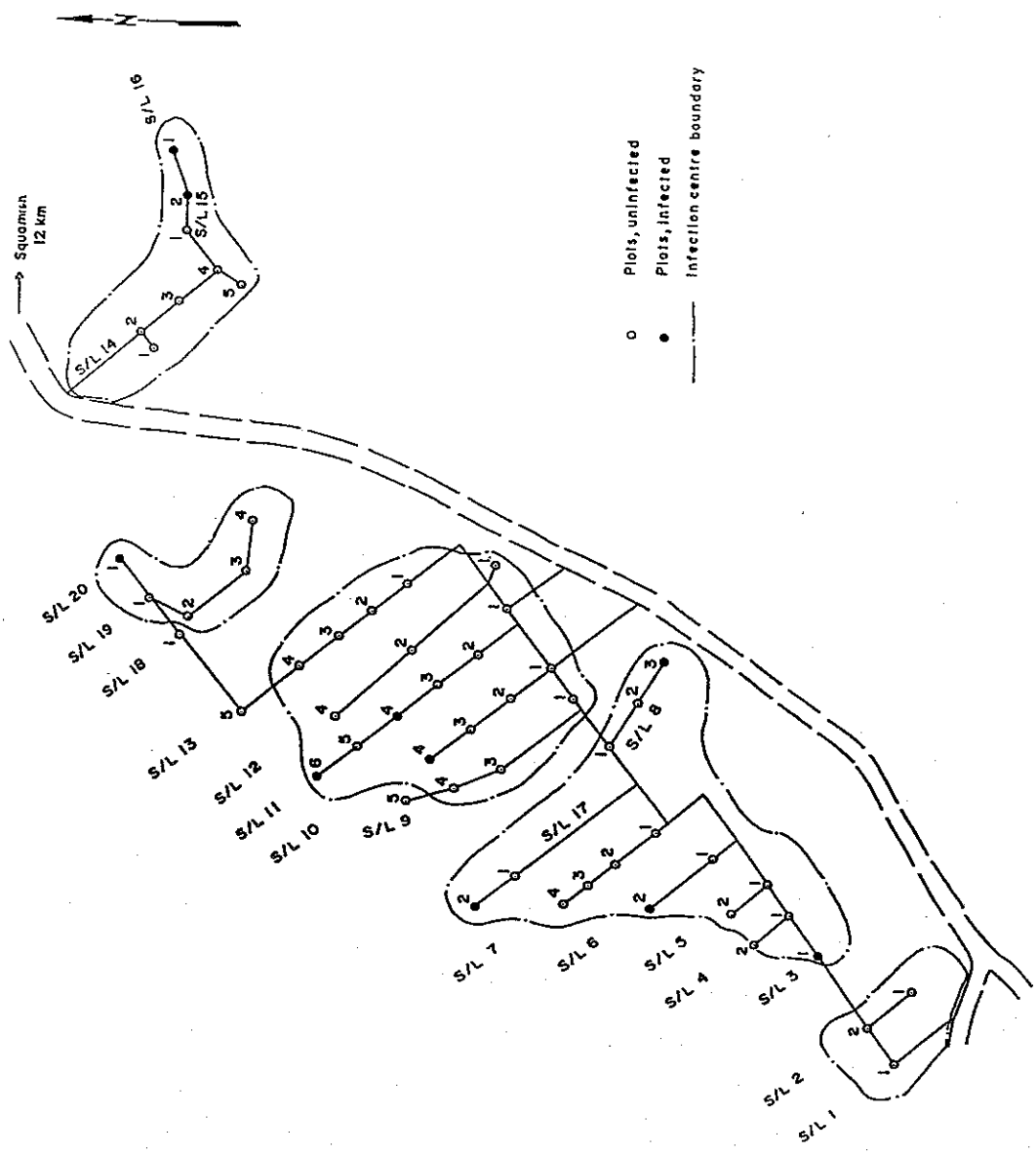

FIGURE 3 **POWELL RIVER SITE**

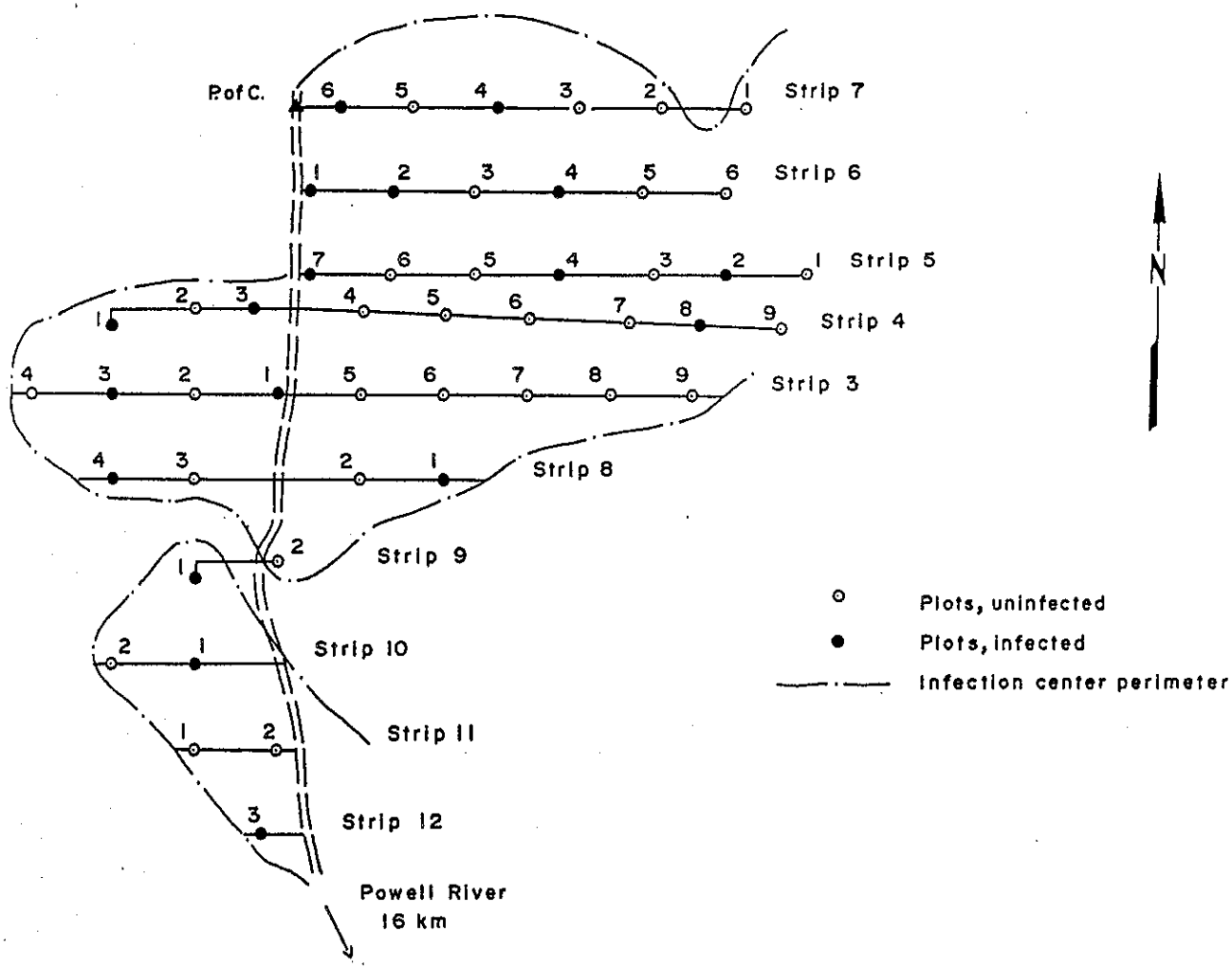

FIGURE 4 TOTAL AND INFECTED ROOT VOLUME PLOTS CONTAINING INOCULUM GOLDEN

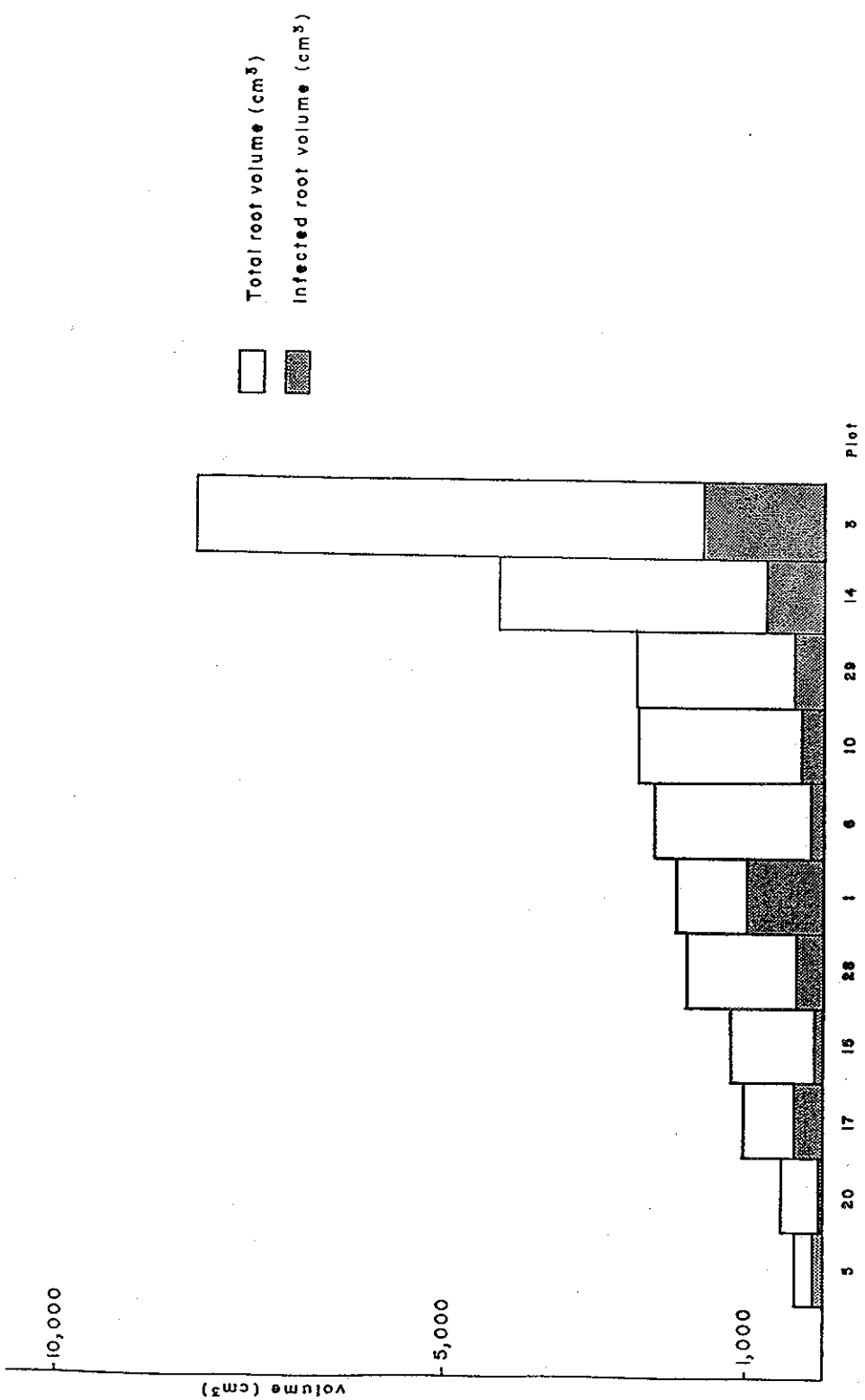

FIGURE 5 **TOTAL AND INFECTED ROOT VOLUME PLOTS CONTAINING INOCULUM, SQUAMISH**

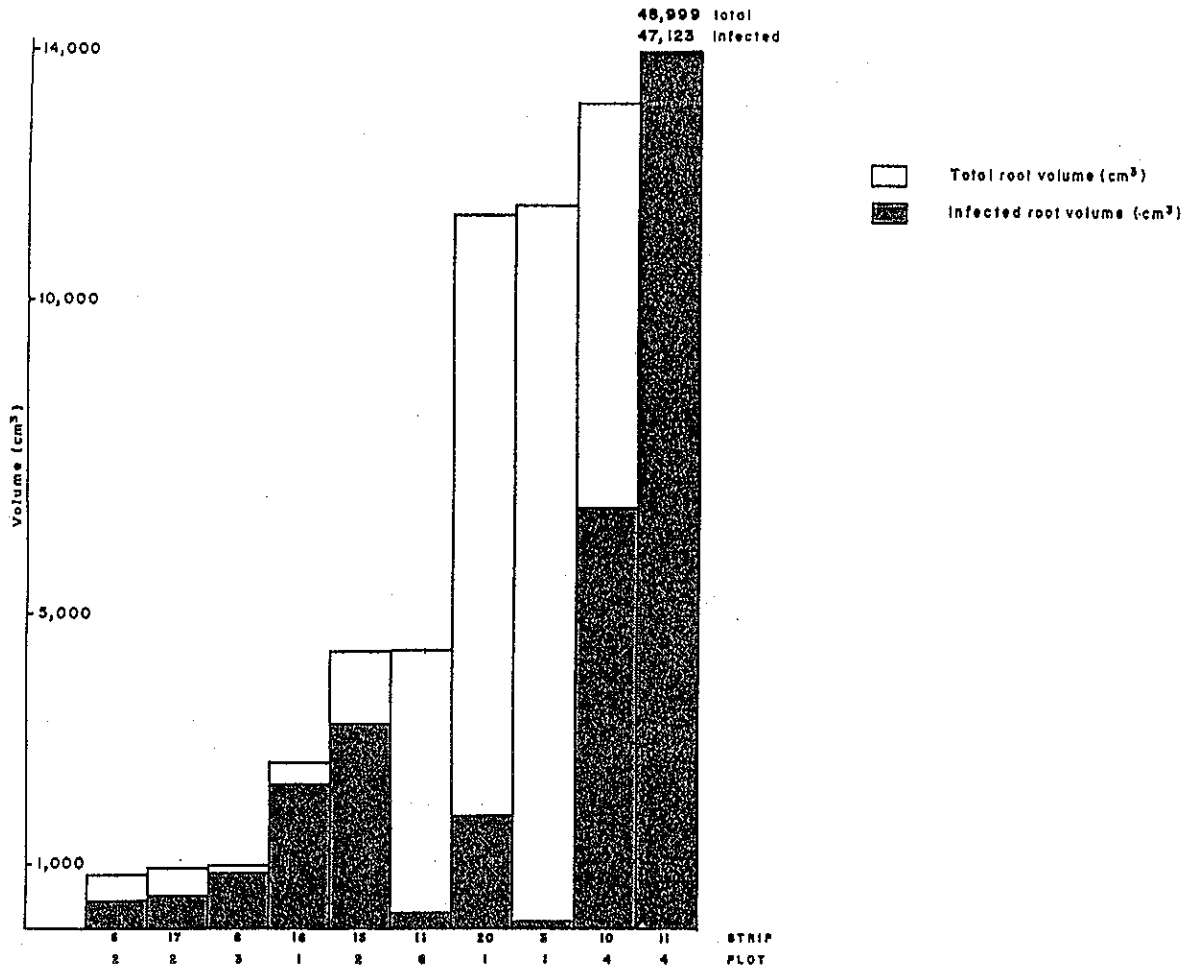
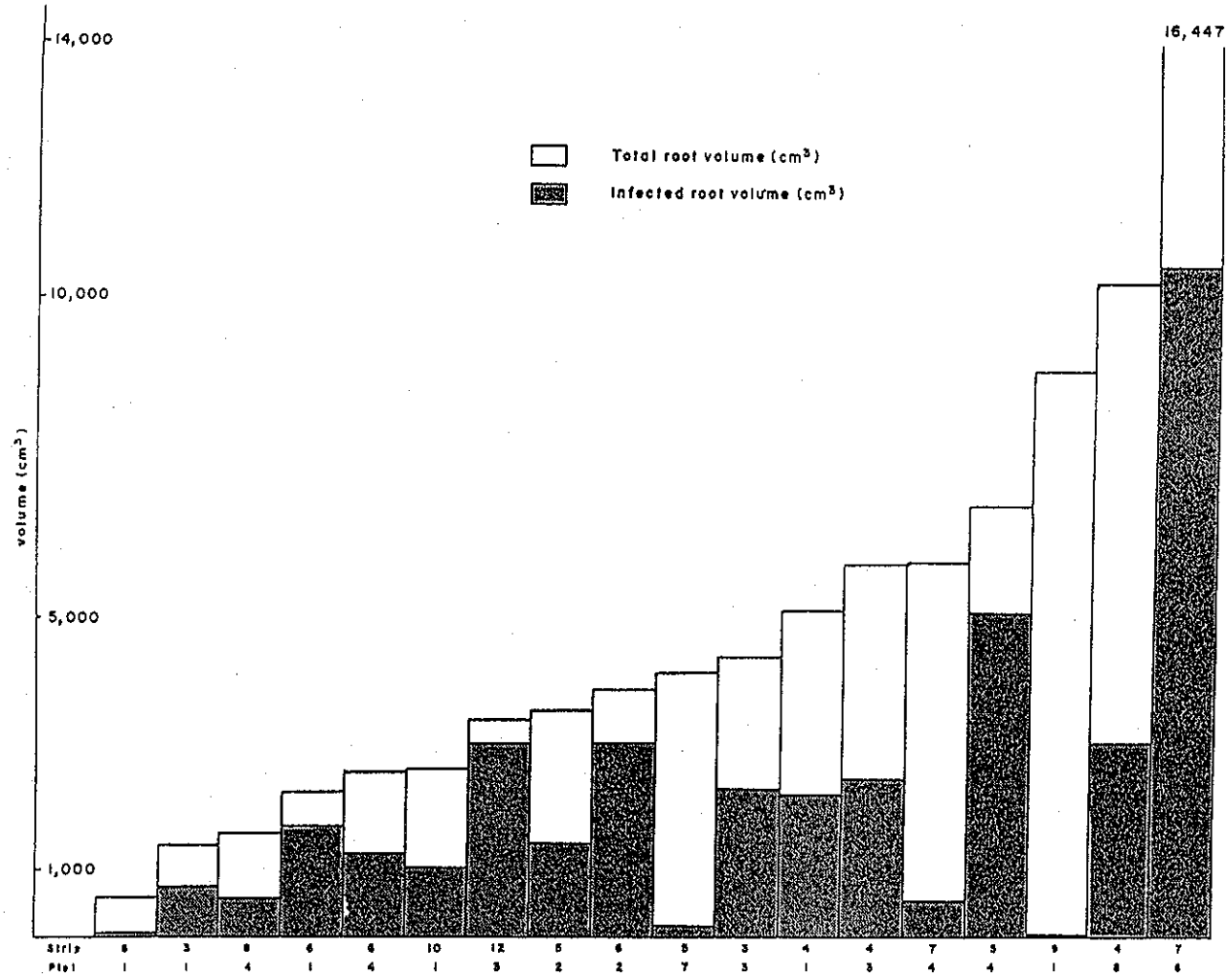
FIGURE 6 **TOTAL AND INFECTED ROOT VOLUME PLOTS CONTAINING INOCULUM, POWELL RIVER**