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BIOLOGY OF DWARF MISTLETOE (*ARCEUTHOBIUM AMERICANUM*) IN ALBERTA

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by

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INTRODUCTION

Dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) is widely distributed in Alberta on lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) and jack pine (*P. banksiana* Lamb.). Recent studies (2, 12) have indicated dwarf mistletoe can seriously limit the growth of these tree species. While silvicultural control methods appear promising (8, 11, 15, 18) a greater knowledge of dwarf mistletoe biology will facilitate their application.

Project A/T 243, "A study of factors influencing reproduction and parasitism of *Arceuthobium americanum*", has been undertaken to provide more knowledge of the epidemiology of dwarf mistletoe in Alberta. The general objective of the project is to provide information which will facilitate silvicultural control of the dwarf mistletoe. Since young stands are most affected by dwarf mistletoe, and are the most amenable to silvicultural control measures, the project has been mainly concerned with studies on the development of dwarf mistletoe epidemics in young stands.

The project was initiated in 1962 by N. E. Nighswander and redesigned by the author in 1965. This report and two to follow (Int. Rep. A-16 and A-17) constitute a preliminary review of individual studies and a summary of the progress to date.

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SEED DISPERSAL

At maturity dwarf mistletoe seeds are forcibly discharged from the berries. The seeds are discharged at high velocities (13, 14), to distances of up to 33 ft. (7, 8). The mechanism of discharge and factors promoting discharge are presently unknown.

Methods

Studies to determine the beginning and duration of the seed dispersal period were undertaken in 1966 and 1967. Seed discharge from individual tagged infections was observed in late summer and fall of 1967 in an immature pine stand located 20 mi. south of the Kananaskis Forest Experiment Station (K.F.E.S.). Berries on each infection were counted about twice a week.

Seed dispersal from two infected trees, 8 - 10 ft. in height, was observed in the fall of 1966 at the K.F.E.S. Dispersed seeds were caught on eight strips of cheesecloth, each 2 ft. wide by 40 ft. long, placed around each tree. The strips were run radially from the base of each tree in north, south, east and west directions. Dispersed seed were collected once or twice a day from the time of transplanting until Sept. 22, 1966.

Results

Seed dispersal in the pine stand began shortly before August 25, 1967 and by September 7 approximately 94 per cent of the berries had discharged their seed. At the K.F.E.S. one hundred and sixty two seeds were collected from one tree, four hundred and twenty from the other.

Approximately 90 per cent of the seeds were dispersed between August 29 and September 7. From August 31 to September 2, when seeds were collected twice daily (8 a.m. and 4 p.m.) approximately 85 per cent of the seed were dispersed during the period from 8 a.m. to 4 p.m. Variations in number of seed caught per day could not be correlated with daily mean temperatures or light intensities.

Distributions of seed from the two infected trees are illustrated in Figure 1. Numbers of seed caught decreased logarithmically with increasing distance from the sources, e.g. $\log Y = a - bX$, where Y is the number of seeds, X is the distance, and "A" and "b" are constants. Logarithmic distributions of numbers of seed with distance have also been found with other species of dwarf mistletoe (9, 24). The logarithmic relationship found indicates that there is no finite limit to dwarf mistletoe seed dispersal. Furthermore, the parallel slopes of the two equations for seedfall indicate that the maximum distance of seed dispersal is directly proportional to the number of seed dispersed from a source.

SEED GERMINATION

While information on germination is available for other species of dwarf mistletoe (3, 4, 5, 22, 26, 27) little is known of the time required or factors affecting germination of A. americanum in Alberta.

Methods

Studies on germination were commenced in September, 1966. Seeds were obtained using a method similar to that described by Wicker (27). Polyethylene screens were wrapped around pistillate plants with

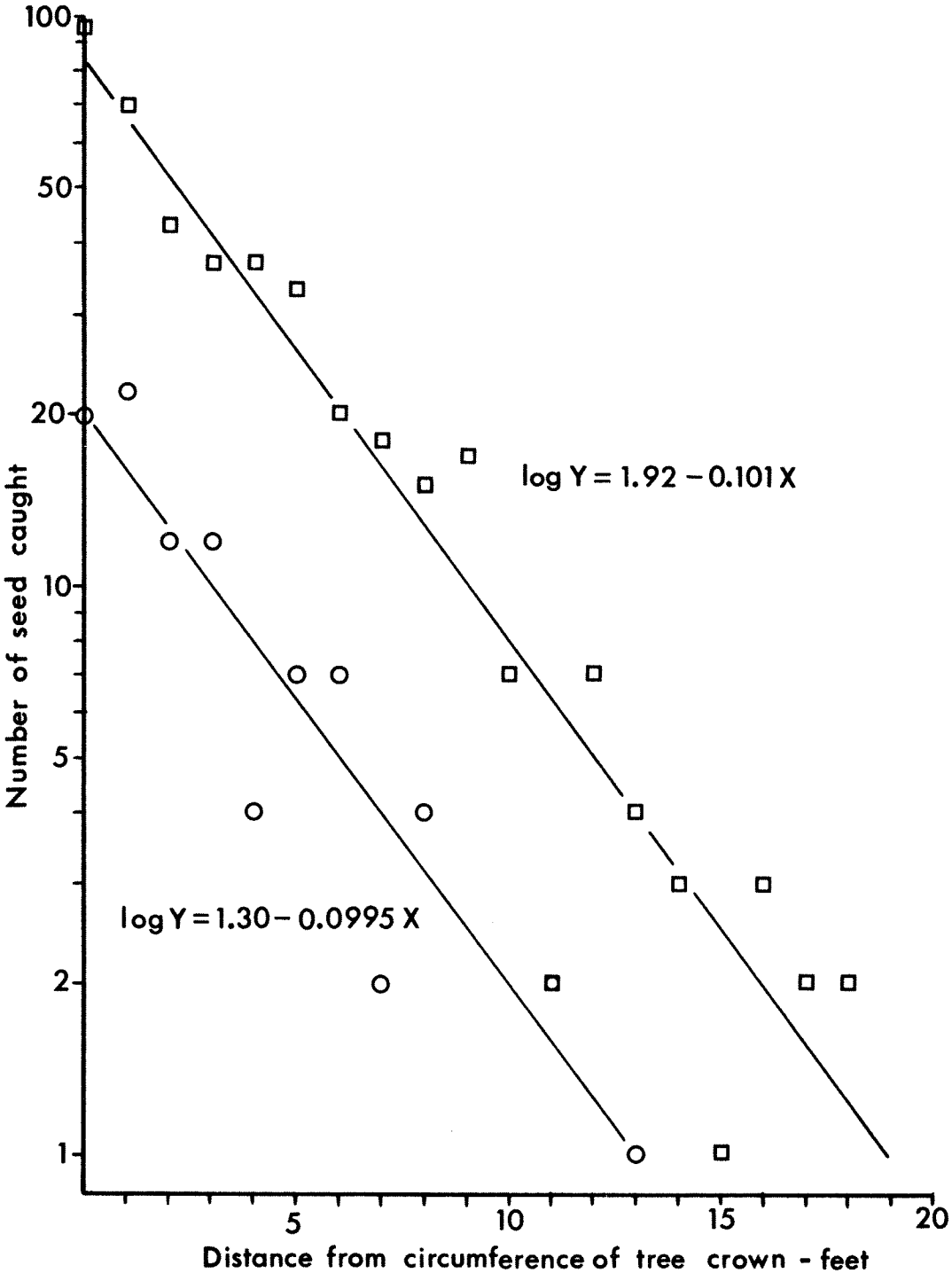


Fig. 1. Distributions of dwarf mistletoe seed fall from two young infected trees.

berries in mid-August before seed dispersal and removed after dispersal was complete. Seeds were obtained from transplanted trees and from trees in the natural stand. Some seeds were allowed to germinate on the screens in the field, while others were stored at 4^{o}C. In the laboratory seeds were surface sterilized and placed in petri plates on moistened sterilized filter paper or on 1 to 2 per cent agar media. The seeds were then incubated in controlled temperature cabinets with 12 hours of light per day, at approximately 350 foot candles intensity. Exceptions to these general treatments are noted.

Results

Germination of seeds in the field on the screens began in mid-April. In 1967 seed germination increased regularly during May, and was completed by mid-June (Fig. 2). The germination curve was similar in 1968, but the per cent germination was lower, 0 to 38 per cent per trap compared to 70 per cent per trap in 1967. High temperatures occurred in the fall of 1967 and these may have detrimentally affected viability of the seed that year.

Germinated seed were removed from the screens after a brief soak in water. Upon drying, the viscin of these seeds again functioned as a natural adhesive. The ability to transfer and use germinated seed for inoculations greatly facilitated our studies.

EFFECT OF SURFACE DISINFECTANTS ON SEED GERMINATION

Two studies were performed to determine suitable disinfectant treatments for germination of dwarf mistletoe seed. Several other investigators (22, 27) have shown that without surface disinfection, most

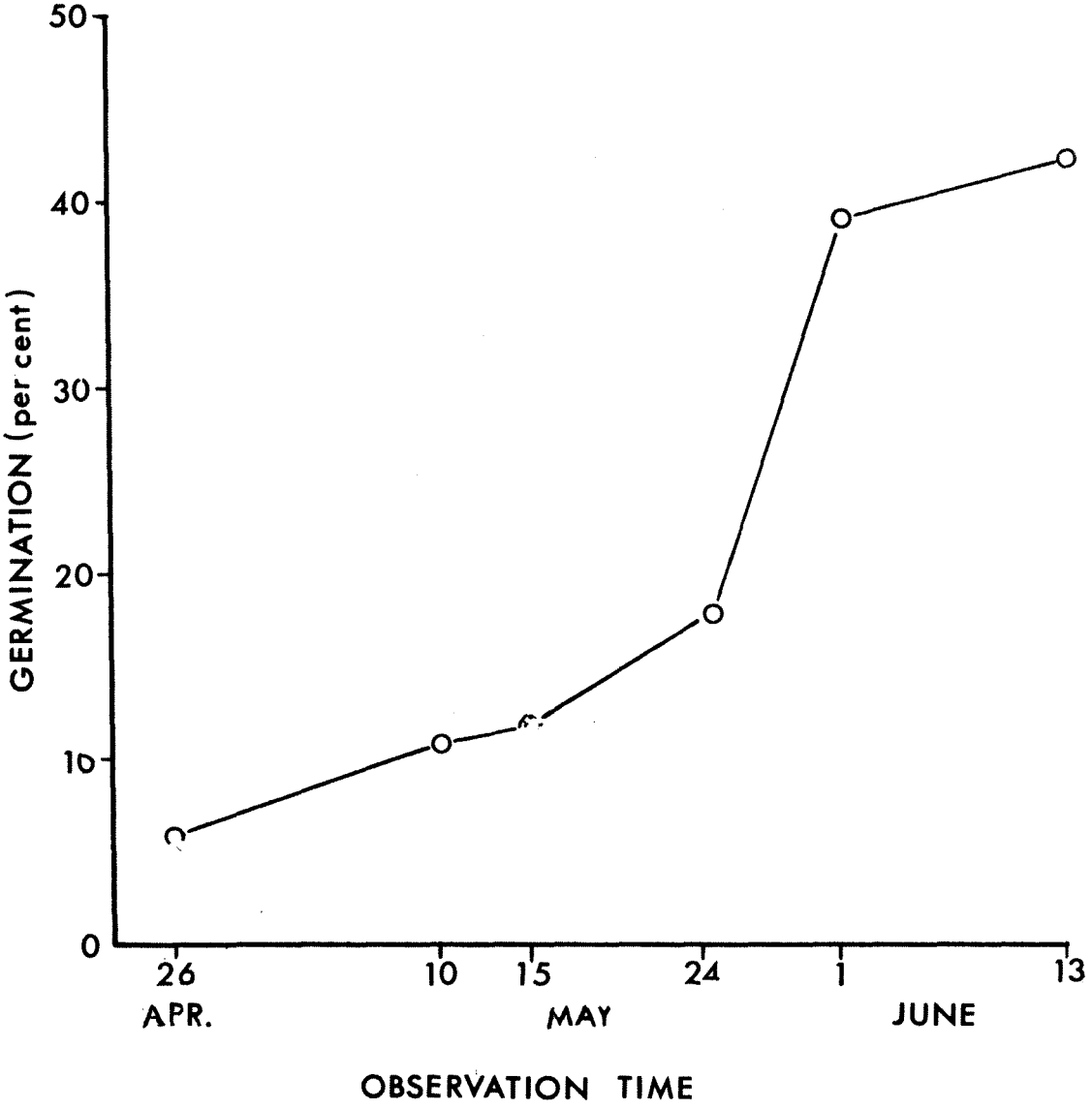


Fig. 2. Germination of dwarf mistletoe seed in field during 1967.

seeds become contaminated by mould fungi which prevent germination. Solutions of mercuric chloride or hydrogen peroxide were found most satisfactory (22, 26). In our first study, the effectiveness of these two disinfectants were investigated. In a second study, the effects of hydrogen peroxide on the rate of germination of A. americanum were investigated.

Methods

In the study comparing effects of hydrogen peroxide and mercuric chloride solutions, different batches of seeds were soaked for 24 hours and for 10 days in a 3 per cent aqueous solution of hydrogen peroxide (26), or for 15 minutes in a 0.1 per cent aqueous solution of mercuric chloride. Three rinses of 5 to 10 minutes duration in sterilized distilled water (22) followed each treatment. Germination and radicle length of seeds were measured following three weeks incubation, and at two to three week intervals thereafter.

An experiment was conducted to determine if hydrogen peroxide stimulated seed germination. Wicker (Ph.D. Thesis 1965 Wash. State Univ., p. 45) found that to occur in A. americanum. Bonga (4), on the other hand found no effect on germination in A. pusillum following a 30-minute shake of seed in 3 per cent hydrogen peroxide. Methods used in our second study were similar to those of Wicker's (op. cit.). Three treatments were tested: a 15 minute, 3 hour, and a continuous soak in 3 per cent hydrogen peroxide. Two hundred seeds were used per treatment, in lots of 20 per vial. To each 25 ml capacity vial, 10 ml of the hydrogen peroxide solution was added. Following the 15-minute and 3-hour soaks the solutions were decanted off, and the seeds were rinsed twice with

10 ml of sterilized water. Ten ml of sterilized water was then added to the vials. Seeds were incubated at 16°C in the dark for 25 days. Examinations were made after 6 days, and at 2 - 5 day intervals thereafter. Radicle lengths were measured at the end of the 25 day incubation period.

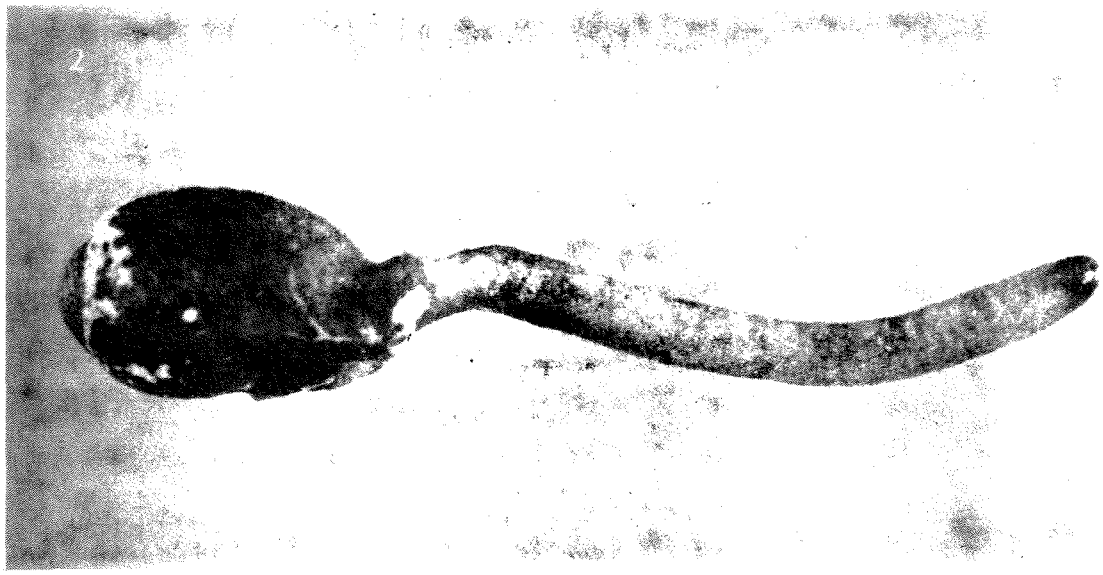
Results

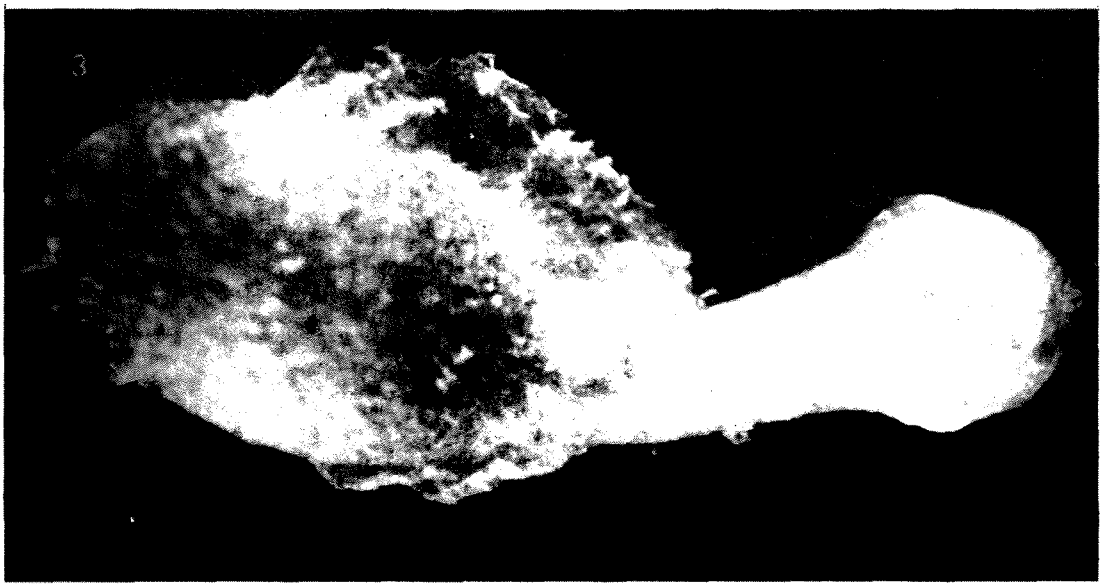
Seed germination and radicle growth following the hydrogen peroxide treatments were clearly superior to germination and radicle growth after the mercuric chloride treatments. After 3 weeks incubation, the average germination percentages per treatment were 51 and 85 for the 24-hour soaks and 38 for the 10-day soak in hydrogen peroxide; and 5 and 25 for the mercuric chloride soaks. Average radicle lengths following 3 weeks of incubation were 1.2 mm for the 24-hour soak and 1.4 mm for the 24-hour soak and 1.4 mm for the 10-day soak in hydrogen peroxide; and 0.7 mm for the mercuric chloride soaks. The mercuric chloride treatments appeared to inhibit seed germination and radicle growth. The inhibitory effect could perhaps be reduced by rinsing the seeds for a longer period in water after the soak in mercuric chloride solution. The hydrogen peroxide treatment was selected for all subsequent surface disinfection of dwarf mistletoe seed.

It was also observed following 6 weeks incubation that three out of 60 seeds soaked in hydrogen peroxide for 10 days formed radicles with swollen tips (Fig. 3). The swollen tips resembled holdfasts which are formed in nature just before penetration occurs. This is the first report of apparent holdfast formation by A. americanum in culture. Bonga and Chakraborty (5) observed holdfast formation by A. pusillum in culture.

Results of the tests to determine if hydrogen peroxide

Figure 3. Germinated dwarf mistletoe seeds: a. normal radicle b. swollen tip on radicle.





stimulated germination are illustrated in Fig. 4. The rate of germination, and per cent germination were greatly improved by the continuous soak in hydrogen peroxide. At 25 days the germination percentages were 56, 26 and 23 for the continuous, 3 hr. and 15 minute soaks respectively. Average radicle lengths for the three treatments were 1.0, 0.5 and 0.4 mm., respectively. Although germination was increased by continuous soaking in hydrogen peroxide, extension of radicles after 10 days was much less than that found by Wicker (op. cit.) for the same period of time.

EFFECT OF SCARIFICATION ON SEED GERMINATION

The removal of the viscous pulp from the seed has been reported to hasten and improve germination in several species of dwarf mistletoe. The effect of scarification on A. americanum seed was investigated.

Methods

An experiment was performed to determine the effect of removal of tissue layers external to the endosperm of the seed (scarification) at constant temperatures of 12, 16 and 20°C. Forty dwarf mistletoe seeds were incubated at each temperature following a 24-hour soak in 3 per cent hydrogen peroxide solution. Twenty seeds at each temperature were scarified. The seeds were examined after 0, 1, 3, 4, 6 and 14 weeks incubation time. Scarified seeds with radicles which grew more than 0.1 mm were considered to have germinated.

Results

Differences in rates of germination and radical growth occurred

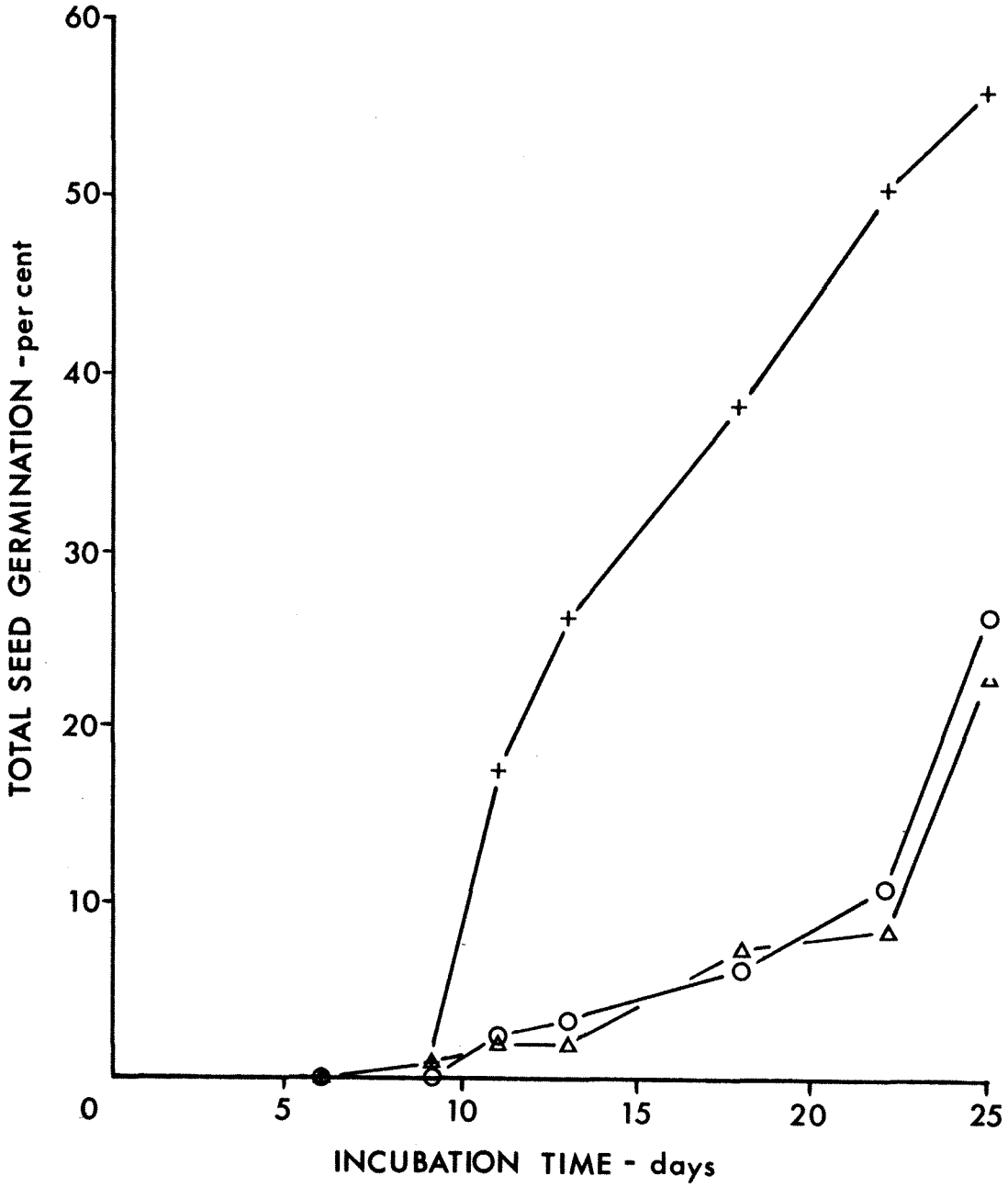


Fig. 4. Dwarf mistletoe seed germination in hydrogen peroxide solutions: continuous soak (+), 3 hr. soak (⊙), 15 min. soak (△).

between scarified and unscarified seeds at different temperatures. However, these differences exhibited no distinct pattern and were not investigated further.

EFFECTS OF TEMPERATURE ON SEED GERMINATION

Best temperature for germination and radicle growth of dwarf mistletoe species other than A. americanum lies between 15° and 19°C. Experiments were conducted to determine best germination temperatures for A. americanum.

Methods

In one experiment, 60 seeds were incubated at constant temperatures of 12, 16 and 20°C. The seeds were examined after 3, 6 and 9 weeks.

In a second experiment the effects of a wider interval of temperatures, and of low, alternating temperatures, were investigated. After surface sterilizing with hydrogen peroxide solution, 320 green seed were incubated at alternating temperatures of 6 and 9° (13 hr. night - 11 hr. day, respectively), and constant temperatures of 16 and 26°C. Seed were examined following 3, 6, 9 and 12 weeks of incubation.

Results

Germination was highest at 16°C throughout the incubation period. At 3 weeks, germination percentages were 3, 52 and 35 for 12, 16 and 20°C, respectively. After 9 weeks incubation these percentages had increased only slightly in the 16 and 20°C regimes. Germinations at 12°C was lower than that which occurred in a previous experiment.

Reasons for this are not known but may have resulted from an artifact introduced during seed preparation. Most of the non-germinated seed at 12°C became yellow after 3 weeks incubation which suggested that the hydrogen peroxide had adversely affected most of the seed at 12°C before they were incubated.

The 16°C temperature was also the most favourable for radicle growth. Average radicle lengths at 9 weeks were 4.2, 5.5 and 4.3 mm, for 12, 16 and 20°C respectively. Differences between averages were highly significant at a probabilty of 0.01.

In the second experiment seed germination was again highest at 16°C throughout the incubation period, 30 per cent at 3 weeks and 51 per cent at 12 weeks. At 26°C the germination was 4 per cent at 3 weeks and 7 per cent at 6 weeks. Further germination at 26°C was prevented by the growth of mould fungi on the seeds. However, 73 per cent of the seed at 26°C at 6 weeks had become yellow, so that the maximum possible germination at this temperature was 27 per cent. Germination at 6 - 9°C was 2 per cent at 3 weeks, 18 per cent at 6 weeks, and 47 per cent at 12 weeks. These low alternating temperatures resulted in good germination, being only slightly less than that which occurred at 16°C after 12 weeks. Germination was initially higher at 26°C than at 6 - 9°C, but subsequent observations indicated that the higher temperature was much less favourable for germination over a longer period.

The 16°C constant temperature was most favourable for radicle growth, and the alternating temperature 6 - 9°C least favourable. Average radicle lengths were 0.5, 1.3 and 0.7 mm at 6 weeks for the 6 - 9°C, 16°C and 26°C temperature respectively; 0.6 and 2.5 mm at 12 weeks for

6 - 9°C and 16°C. Although germination at 6 - 9°C was almost as much as at 16°C after 12 weeks incubation, average radicle length at 6 - 9°C was less than one quarter of that at 16°C. Average radicle length at 12 weeks at 6 - 9°C was also slightly less than that at 26°C for only 6 weeks.

INCUBATION AND LATENT PERIODS OF DWARF MISTLETOE

At present the length of time between seed deposition and development of symptoms of infection (the incubation period) and fruiting (the latent period), are unknown for dwarf mistletoe in Alberta. Knowledge of the incubation and latent periods is necessary for timing of silvicultural control treatments. Preliminary observations of dwarf mistletoe in Colorado (10) indicate that the minimum incubation period is two years. Observations of other species of dwarf mistletoe (23, 25) indicate that infections may require 2 to 6 years for development of symptoms.

The study of incubation and latent periods of A. americanum in Alberta is still in progress. The objectives are to determine the incubation and latent periods, growth and longevity of infections and aerial shoots, and flower or berry production for individual infections.

Methods

Approximately 1000 seed, naturally deposited, were tagged in 1966 and 1967 at Rocky Creek, 20 miles south of the Kananaskis Forest Experiment Station. Seed fall in September 1967 at Rocky Creek was very light and only 300 seeds were tagged in 1968. In addition seeds

were artificially placed in trees at several other locations on and near the Kananaskis Forest Station. Examinations are made twice a year, in May and September. Data recorded include seed germination, radicle growth and colour, swelling of bark, aerial shoots, shoot growth, and seed production.

Results

At present, no definitive results have been obtained from the study and none can be expected until several more years have elapsed. A few seed tagged in 1966 at Rocky Creek developed symptoms by September 1967. However, the possibility could not be excluded that most of these seed had been deposited before 1965. Radicle colour is now used to determine newly germinated seed. The radicle is initially red in the spring, becoming green in the following autumn or in the early spring of the next year. It was also observed that penetration of a radicle at the base of a needle fasicle occasionally resulted in death of the needles. This has also been observed by Scharpf and Parmeter (23) for A. campylopodum in California. Death of the needle generally prevented infection.

FUNGOUS PARASITES OF DWARF MISTLETOE

Examinations of herbarium specimens and field collections, with the assistance of Forest Insect and Disease Survey personnel, have been made to determine the occurrence and distributions of fungal hyperparasites of dwarf mistletoe in Alberta. A preliminary study of the incidence of a fungal parasite on dwarf mistletoe in a young stand of lodgepole pine and its possible effects on intensification of dwarf

mistletoe has also been completed.

The fungal parasites Wallrothiella arceuthobii Peck, Septogloeum gillii Ellis, and Colletotrichum gloeosporioides Penz. sensu Von Arx were discovered in Alberta by Dowding (7), Bourchier (6), and Muir (19), respectively. Distributions of S. gillii and W. arceuthobii in Western Canada were reported by Kuijt (17). In his report, however, specimens of S. gillii and C. gloeosporioides, which have very similar symptoms, were not distinguished and thus the distribution of S. gillii includes that of C. gloeosporioides.

From available data, W. arceuthobii is distributed widely in the boreal forest zone (21) in central and northern Alberta. It also is found occasionally in the subalpine forest zone of the Rocky Mountains, but in only a few locations south of Banff. S. gillii occurs sporadically only in the subalpine zone of the Rocky Mountains, and has not been found on dwarf mistletoe on jack pine in the boreal zone. C. gloeosporioides is widespread in the subalpine zone of the Rocky Mountains, and also occurs occasionally in the boreal forest zone. At several localities in the subalpine zone of the Rocky Mountains, two or three of the fungi are coincident (19).

Several other fungi have been found on dwarf mistletoe in Alberta. Sporomia intermedia Auersw., a common coprophilous ascomycete, was found in 1968 on dwarf mistletoe seed which had been incubated in culture. Inoculations of seed with fungus mycelia indicated that the fungus could rapidly colonize seed and prevent germination in vitro. On a pana-malt-yeast extract medium at room temperature, the fungus produced numerous perithecia with apparently mature ascospores in 10 to 15

days. The original seeds on which the fungus was found were collected from the field in November, 1967 at a location 72 miles southwest of Calgary, Alberta. The seeds were collected using polyethylene screening as described previously in this report, and were incubated at 16°C. The fungus was discovered after 6 weeks incubation. An examination of seeds in the field at the same location in February and May 1968 failed to reveal seeds infected by the fungus.

Two other fungi (Sphaeropsidales, Fungi Imperfecti) have been found on dwarf mistletoe aerial shoots. One fungus, possibly a species of Phoma, was found on A. americanum at the Kananaskis Forest Experiment Station. The other, possibly a Sphaeropis sp., was found on a herbarium specimen (DACFP 990) of A. douglasii from southern British Columbia. More collections of these fungi are needed to determine their pathogenicity and identity.

AN UNUSUAL TREE RESPONSE TO INFECTION

Localized infections of dwarf mistletoe characteristically cause swollen cankers on their hosts (16). During a recent study of the intensification of the dwarf mistletoe in young stands of lodgepole pine, two unusual infections of the dwarf mistletoe which caused distinctly flattened cankers were discovered. This type of tree response has not been noted previously.

The infections were discovered in a young stand of lodgepole pine situated 72 miles southwest of Calgary, Alberta, in the subalpine forest region of the Rocky Mountains (21). The infections were present on the stem of one tree, age 24 years and 8.5 ft. in ht. which had also 9 additional "normal" infections. The infections were identified by

the presence of aerial shoots of the dwarf mistletoe on each infection. One infection, age two to four years, had one aerial shoot of 4 mm length; the other, age three to five years, had three shoots of 2 mm length. These shoots were fewer in number and shorter than shoots on nearby "normal" infections of comparable ages. Additional trees in the infected stand and in other nearby stands were examined in 1965 and in subsequent years, but no other flattened infections were found. Apparently this type occurs only rarely.

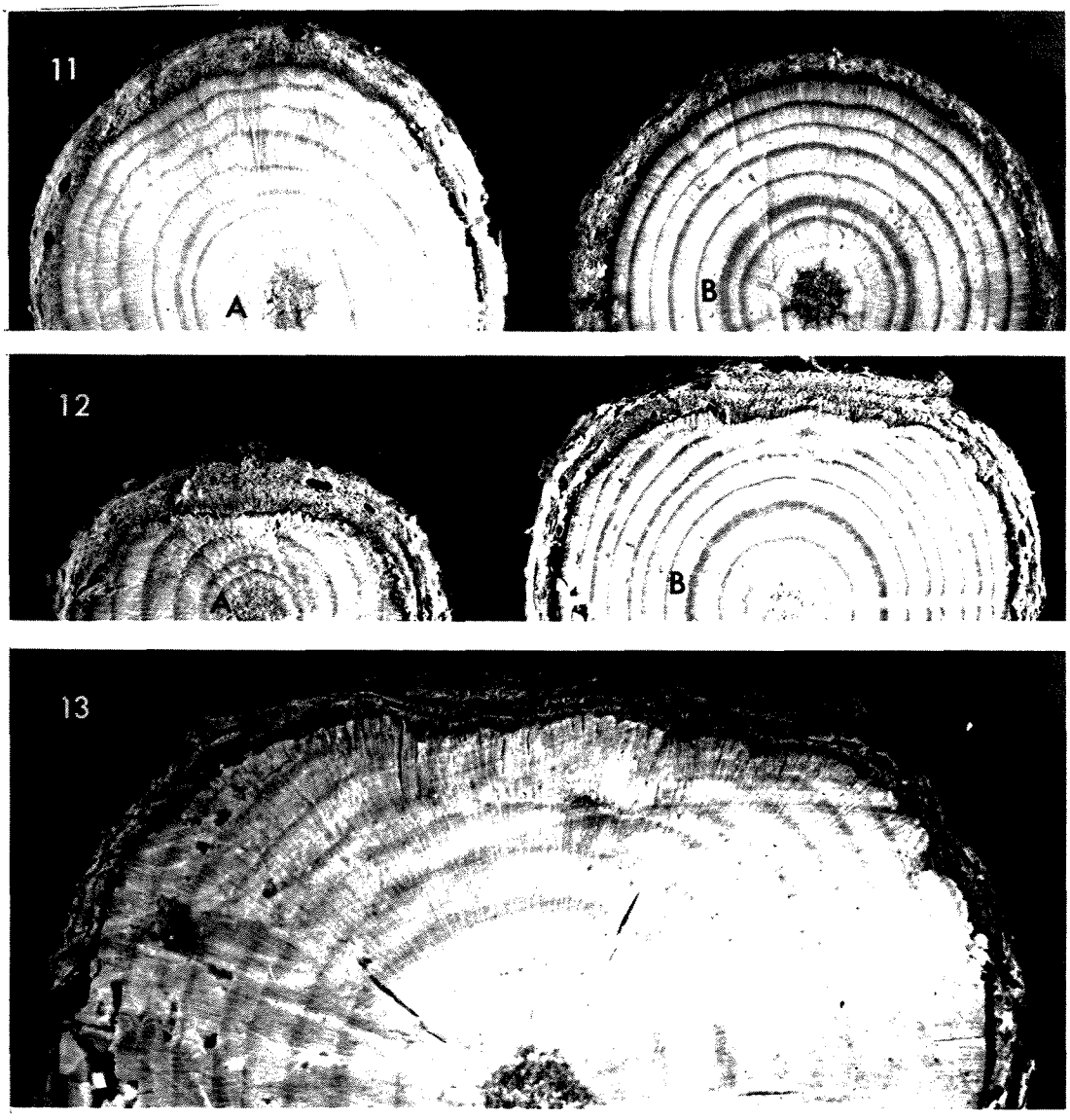
Cross sections of the flattened infections (Fig. 6 and 7), were compared with a cross section (Fig. 5) of a typical normal infection. An outstanding feature of the flattened infections was the inhibition of growth of the infected wood, in contrast to the stimulation of growth of infected wood on the normal infection. There was no marked contrast between early and latewood segments, unlike that on normal infections. The infected wood of the flattened infections was generally light in colour. On both types of infections, hypertrophy of the infected bark had occurred. However, on one of the flattened infections, a secondary layer of bark had been formed (Fig. 6b and 7), and the edge of older bark layer had lifted slightly. The younger layer of bark on this infection was quite thin near the middle of the infection (Fig. 7).

These observations suggested that the flattened cankers were caused by an inability of the dwarf mistletoe infections to elicit the usual host response to infection. Micro-organisms were not involved nor was tree resistance considered a factor. Normal infections had occurred on the same trees. Colonization of the host by the mistletoe appeared normal. Short aerial shoots and absence of flowers on the in-

Fig. 5. Cross section of a "normal dwarf mistletoe infection (A), and a healthy branch (B) 3 inches from infection.

Fig. 6. Cross sections of two abnormal flattened infections.

Fig. 7. Cross section of flattened infection 5 mm from section in Fig. 6b.



fections was less than normal.

LOCALIZED DWARF MISTLETOE INFECTIONS ON SYSTEMICALLY INFECTED BRANCHES

As described by Kuijt (16), dwarf mistletoe infection of lodgepole pine or jack pine causes two types of infection: Localized and systemic. Localized infection is characterized by a fusiform swelling with aerial shoots of the dwarf mistletoe appearing on the swollen tissue. Systemic infection, on the other hand, causes witches brooms. Systemically infected tree branches are attenuated and upright, but not markedly swollen. Aerial shoots of the mistletoe emerge first at the girdles[1] and later from the segments[2] of the branch. Systemic infections apparently develop from the extension of localized infections, causing stimulation of growth in host branches.

In 1967, systemically infected branches of jack pine from a tree located 67 miles south of Fort Smith, N.W.T. were collected by E. Gautreau of the Calgary Forest Research Laboratory. The systemic infection was caused by a pistillate dwarf mistletoe plant. Several staminate and pistillate plants causing localized infections were found on segments of the systemically infected branches (Fig. 8). The aerial shoots of many of the localized infections were distinctly greener than the shoots of the systemic infections on the dried specimen. To my knowledge, this is the first report of the occurrence of localized infections on branches systemically infected by the dwarf mistletoe. Anderson and

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[1] region of the terminal bud scars on a branch (16)

[2] region of a branch located between girdles (16)

Fig. 8. (A) systemically infected branch of jack pine with a localized infection of dwarf mistletoe.

(B) localized infection on same branch.

Kaufert (1) reported the occurrence of secondary brooms on branchlets of older brooms caused by the dwarf mistletoe A. pusillum Peck. on black spruce (Picea mariana (Mill.) B.S.P.). The occurrence of the localized infections suggests that the different dwarf mistletoe plants can co-exist in the same host tissue or that the dwarf mistletoe endophytic system of the systemic infection is initially absent in the segment of the branch. The latter possibility seems most likely because aerial shoots are generally restricted to the girdle regions of systemically infected jack pine branches (16).

The occurrence of the localized infections is also of interest in respect to the hormonal host-parasite relationships. Systemic infections cause proliferation of branches, and a loss of apical dominance in the branches. The ability of the localized infections to induce fusiform swellings on these branches suggests that swelling or brooming is not caused by a hormone produced by the dwarf mistletoe, but is related in some way to the type of host meristem which is infected. However, in some instances, as described previously in this report, dwarf mistletoe infections are apparently unable to cause swellings.

INFECTION ON WHITE SPRUCE

A previously undescribed infection of white spruce by dwarf mistletoe was discovered in 1968 at the Kananaskis Forest Experiment Station near Seebe, Alberta. Dwarf mistletoe usually causes dense, compact brooms on spruce. These brooms seldom bear more than a few aerial shoots of dwarf mistletoe (16). However, Powell (20) found an infected spruce tree at the Kananaskis Station which had abundant aerial shoots.

The infected white spruce, 45 years of age, appeared to be growing vigorously. The tree was located in an area which had been cleared of infected lodgepole pine 34 years previously.

An examination of the infected tree revealed an unusual type of infection. The infection was established on the main stem of the tree at 1.5 ft. above ground level. Ten upright branches, from 3 to 7 ft. high, had developed from the infection (Fig. 9 and 10). Aerial shoots of dwarf mistletoe were not found at the girdles of the upright branches, but were restricted to the swollen portion of the main stem and the bases of the upright branches (Fig. 11). Evidently the growth of the upright branches was not influenced by a systemic infection. Other localized infections were found on the upright branches (Figs. 12 and 13) and on lateral branches of the main stem (Fig. 14) and of the upright branches. On the latter some infections caused typical dense brooming, and some caused very little or no brooming (Fig. 14). Dwarf mistletoe aerial shoots were particularly abundant on the infections with no brooming. Localized infections on the upright branches generally caused very little brooming. However, on one infection on an upright branch, two attenuated, vertical secondary branches had developed (Fig. 13).

The infection on the main stem of the white spruce with the upright branches was similar to the"leader-type" broom described by Anderson and Kaufert (1) for A. pusillum on black spruce (P. mariana) in Minnesota. However, many localized infections with generally little brooming also occurred on the upright branches on the broom. On black spruce, leader-type brooms were formed only at the base of young

Fig. 9. White spruce with broom of upright branches at base of stem caused by dwarf mistletoe.

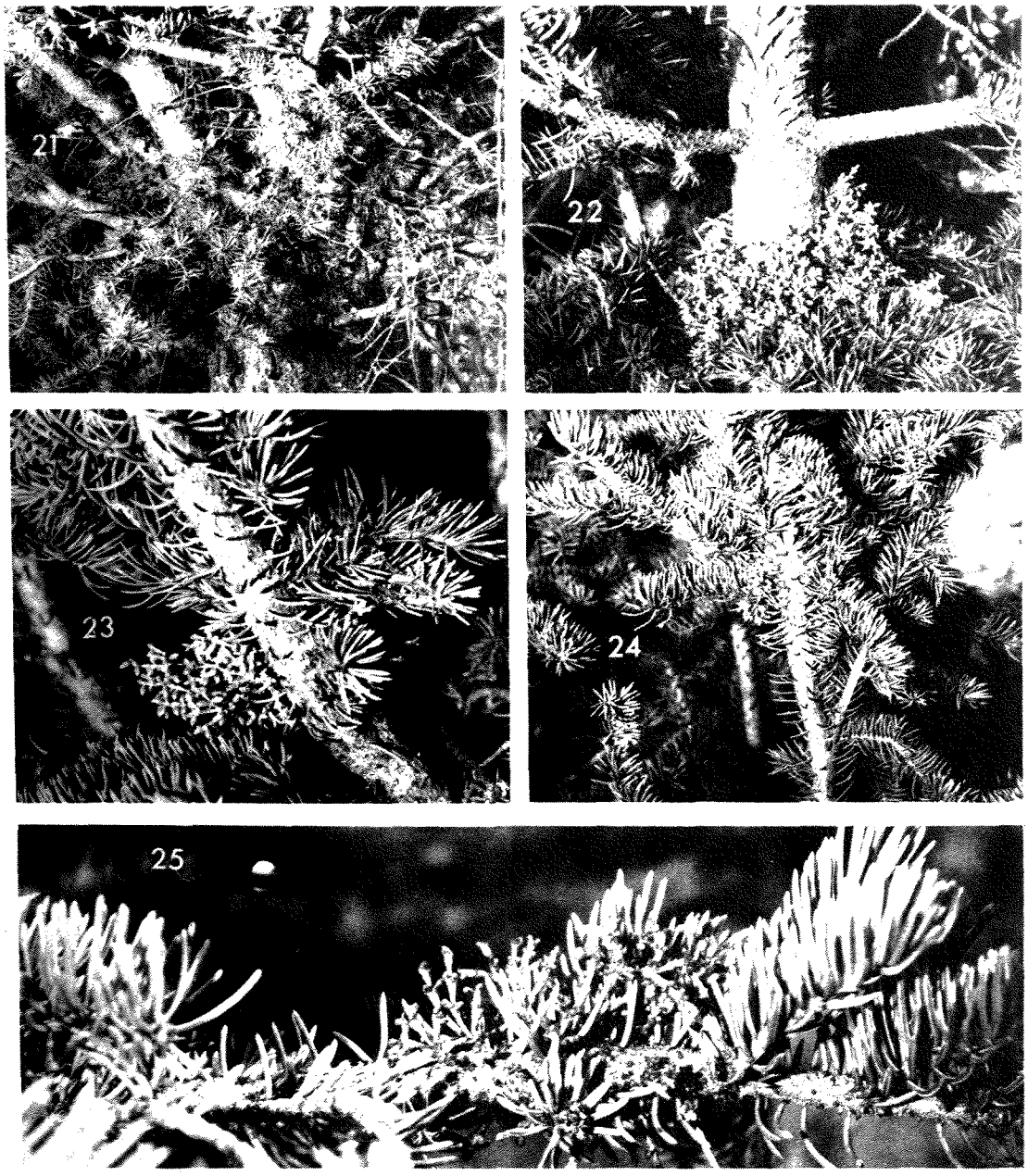
Fig. 10. Main stem of white spruce showing proliferation of upright branches.

Fig. 11. Dwarf mistletoe shoots and berries at base of an upright branch.

Fig. 12. Localized infection on an upright branch.

Fig. 13. Localized infection on an upright branch with secondary upright branches.

Fig. 14. Localized infection with little brooming on lateral branch.



vigorous trees (1).

Dwarf mistletoe infections infrequently occur on the main stems of spruce, and some of the above observations suggest that only compact brooms are formed by infections on lateral branches. The numerous infections and abundant aerial shoots on the tree also suggest that the tree, possibly because of physiological factors, was particularly susceptible to dwarf mistletoe infection. Considering the scarcity of aerial shoots on previously observed infections of white spruce, it was believed (16) that very little new spread of infection could occur from these infections. The abundance of dwarf mistletoe shoots and berries on the white spruce reported here, however, suggests that infection could easily spread to nearby pines (20) or to other spruce trees. Inoculations with dwarf mistletoe seed from the spruce trees are being continued.

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