Terminal Pests of Forest Plantations

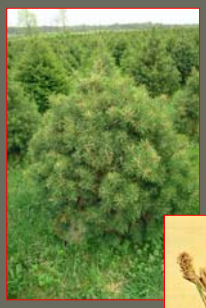
- The worst kind of pest associated with plantation forestry is one that would upset forest management goals.
- For example fast growing pine plantations that are destined for high quality saw log production or Christmas trees.

(1) The Nantucket pine tip moth, *Rhyacionia frustrana.*

Shoot of any eastern pine species, except white pine and longleaf pine.

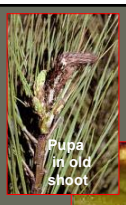
Range of Nantucket pine tip moth with its 2 - 5 generations per year!

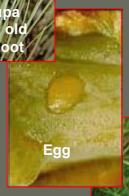
1971 introduction



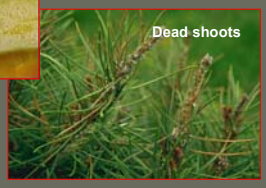
(a) prevents growth of straight, fast growing trees, and

(b) infests conelets in spring -- bad problem in seed orchards.





Biology-- ov/w as pupa and emerge in late winter, early spring; eggs at base of new growth; 1st instar feeds on needles and surface of new growth -- later instars move into growing tips and shoots.



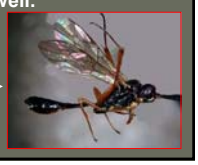
<u>Management of the Nantucket pine tip moth</u>

• Pesticide control not cost effective in plantations, but can be used in high priced products: seed orchards, nurseries and Christmas tree plantations.

• Eggs hatch 5-10 days after peak adult emergence. Sprays directed at early instars feeding on foliage.

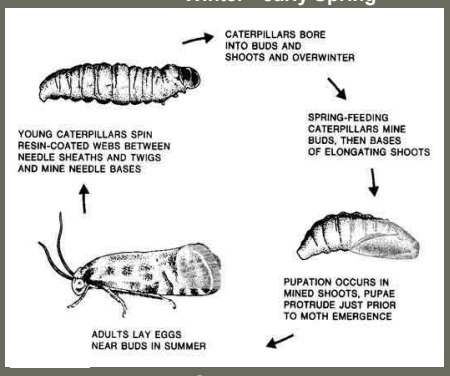
• A parasitoid from Georgia has been introduced into California and it seems to be working well.

Campoplex frustranae →



(2) The scariest one of them all: The European pine shoot moth, *Rhyacionia buoliana*

Winter - early Spring



Late-summer Autumn

Spring

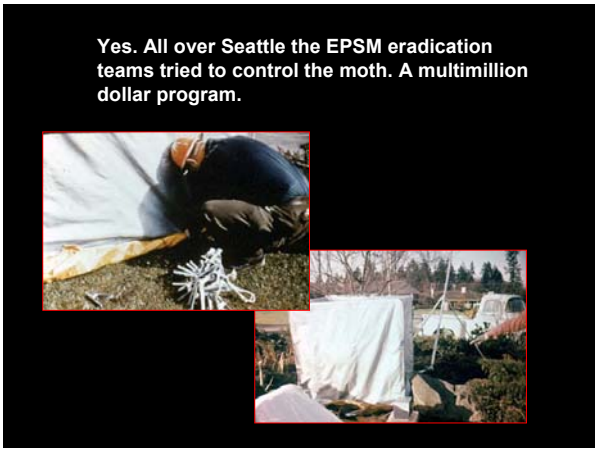
Summer

Summer eggs

Spring larvae mine buds and elongating shoots

Summer pupation


1973 EPSM eradication program
in Seattle. True!


Yes. All over Seattle the EPSM eradication
teams tried to control the moth. A multimillion
dollar program.


How the EPSM operates
This is the tree *you* desperately want
This was a tree the *EPSM*
desperately wanted
This is a tree a *bird*
desperately wanted

EPSM devastated radiata pine plantations in Argentina near Cordova.

More destruction of radiata pine plantations near Cordova, Argentina

…and the Chileans were worried to death the EPSM might cross the Andes. It did!!

Lunch in Cordova and having a great time watching the Argentineans

A Fiat already pushed out into street

The EPSM crossed the Andes and now infests radiata pine plantations of Chile

<u>Approaches to control EPSM in Chile</u>:

- An IPM program with initial insecticide application to knock down the population;

2. Release of *Orgilus obscurator*, a parasitoid important from Europe;

3. New effort at transgenic control.

O. obscurator

Osvaldo and Luis started a bio-control business to raise parasitoid and other biological control agents.

← EPSM laying eggs

← Incubation

Picking out early instars for rearing in artificial media →

Raising the parasitoid (feeding them sugar-water)

Putting O. obscurator in with EPSM pupae.

Field tests near the laboratory

Princeton, New Jersey and Santiago, Chile
July 20, 1999
Biogenetic S.A., a joint venture between Fundacion Chile (Santiago, Chile) and InterLink Associates Inc., (Princeton, NJ) announced today the creation of a new venture for the development of improved forestry species using the tools of biotechnology. GenFor S.A., a joint venture with Silvagen Inc. (Vancouver, BC), will provide the forestry industry in Chile and Latin America with a comprehensive array of technologies for genetic improvement[1].

With an initial investment of $5 million partially supported by the Chilean development agency Corfo, GenFor is in a position to develop products and services such as: clonal development programs on a commercial scale using Silvagen's proprietary technology of somatic embryogenesis, consulting services in genetic improvement including molecular markers programs, management of genetic resources and access to genetic engineering technologies for the development of transgenic radiata pine with improved production and wood quality characteristics.

[1]Development of radiata pine resistant to EPSM infestation!

Western pine shoot borer, *Eucosma sonomana.*

This tortricid bores down the leaders of ponderosa pine.

MATING DISRUPTION WITH SYNTHETIC SEX ATTRACTANTS CONTROLS DAMAGE BY *EUCOSMA SONOMANA* (LEPIDOPTERA: TORTRICIDAE, OLETHREUTINAE) IN *PINUS PONDEROSA* PLANTATIONS

II. AERIALLY APPLIED HOLLOW FIBER FORMULATION[1]

D. L. OVERHULSER,[2] G. E. DATERMAN,[3] L. L. SOWER,[3] C. SARTWELL,[3] and T. W. KOERBER[4]

Abstract

Can. Ent. 112: 163–165 (1980)

Hollow fibers containing a mixture of synthetic sex attractants of western pine shoot borer, *Eucosma sonomana* Kearfott, were applied by an airplane to 19 ha of ponderosa pine plantations in southern Oregon. Nominal dosage was 15 g active ingredient per hectare. A behavioral evaluation of treatment effects, based on moth responses to pheromone-baited traps, showed nearly 100% disruption of female to male sex pheromone communication. Tree damage in treated areas was reduced by an average of 67% for terminal shoots and by 79% for terminal and lateral shoots combined.

Embedding synthetic sex pheromone of the western shoot borer in plastic fibers or plastic flakes: male confusion!!

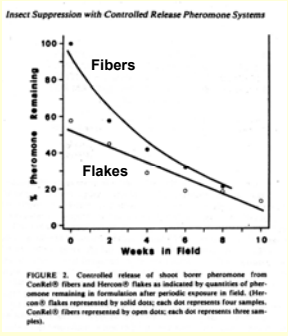


FIGURE 2. Controlled release of shoot borer pheromone from ConRel® fibers and Hercon® flakes as indicated by quantities of pheromone remaining in formulation after periodic exposure in field. (Hercon® flakes represented by solid dots; each dot represents four samples. ConRel® fibers represented by open dots; each dot represents three samples).

Western shoot borer control: applying fibers and flakes impregnated with synthetic pheromone

Table I. Numbers of shoots infested by *Eucosma sonomana* per 50 trees in treated and untreated mating disruption plots, Keno, Oreg., 1978

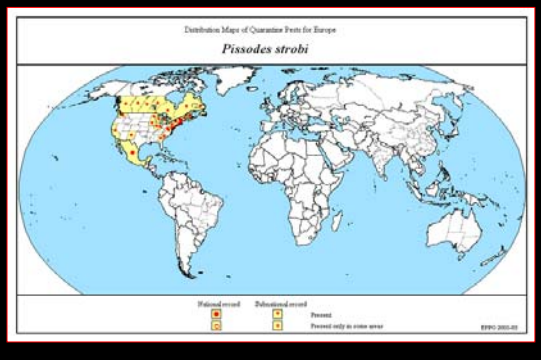
Pine shoot category	Untreated $\bar{X} \pm SD$	Treated $\bar{X} \pm SD$	Control[1] (%)
Infested terminals:			
Pretreatment (1977)[2]	22 ± 8	19 ± 8	
Posttreatment (1978)[3]	30 ± 6	8 ± 0	67 ± 6
All infested shoots:			
Pretreatment (1977)[2]	90 ± 30	100 ± 63	
Posttreatment (1978)[3]	87 ± 20	18 ± 8	79 ± 7

[1]Abbott's formula.
[2]Pretreatment infestation levels were not significantly different ($P > 0.05$, paired t-test) in treated and untreated plots.
[3]Posttreatment infestation levels for terminals and all shoot data in treated and untreated plots were significantly different ($P < 0.05$, by χ^2 paired t-test, respectively).

Abbot's formula

$$\%\text{Mortality} = \frac{\text{survival in control - survival in treatment}}{\text{survival in control}}$$

The tip weevil of eastern white pine & Sitka spruce: that terrible pest, *Pissodes strobi.*



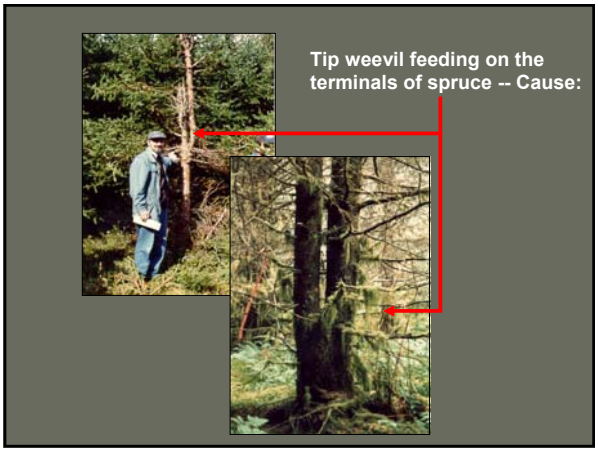
Industrial forestry would like to grow Sitka spruce on the Olympic Peninsula -- why?

- It grows fast and could be harvested in short rotations;
- Large mammals don't feed on it as it grows;
- It is rather shade tolerant and grows up through slash and other competing vegetation;
- The wood is most desirable for construction and specialty purposes, e.g. sounding boards for pianos and the basis for great string instruments.

The Spruce Tip Weevil

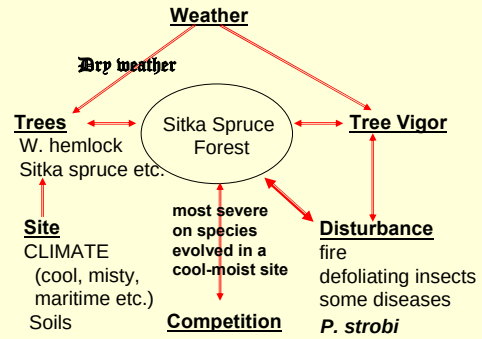
Weevil lays eggs inside inner bark of Sitka spruce

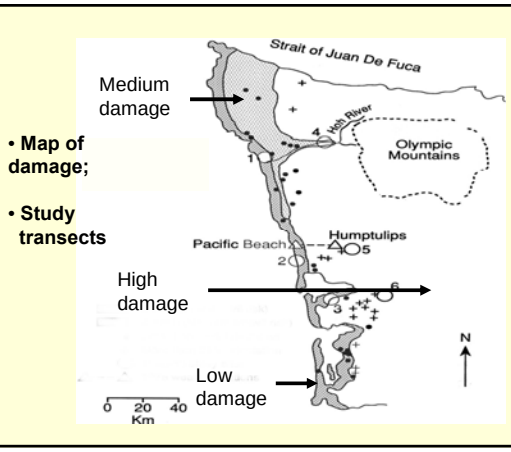
Weevil larvae mine down the stem, killing the terminal shoots of spruce.



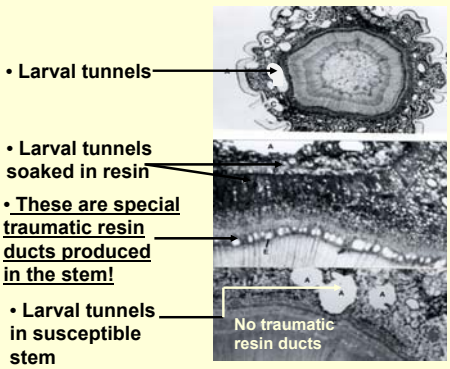
Range of Sitka spruce: a tree whose best development is in coastal Canada and SE Alaska. The southern most part of its range is northern California

Knowing that Sitka spruce evolved in the cool misty forests of the Pacific Coast Forest Region why don't weevils occur north of BC?

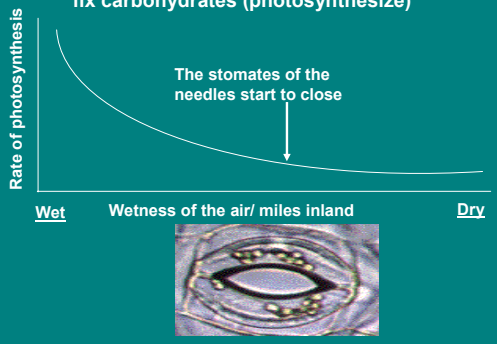




Spruce tip weevil attacks in stems

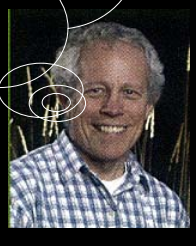


Look at this relationship between air moisture and ability of Sitka spruce to fix carbohydrates (photosynthesize)



Trees partition or prioritize their energy budget, i.e. where do they send their carbohydrates?

1. Cones and seed,
2. Buds & shoots
3. Small roots,
4. Defensive products
5. Diameter growth, &
6. Large roots

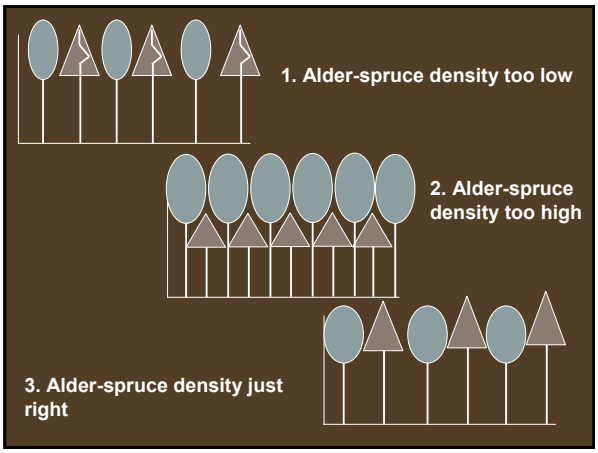


So?

(1) To understand the spruce tip weevil problem it took detailed studies of the ecosystem and tree-weevil interactions.

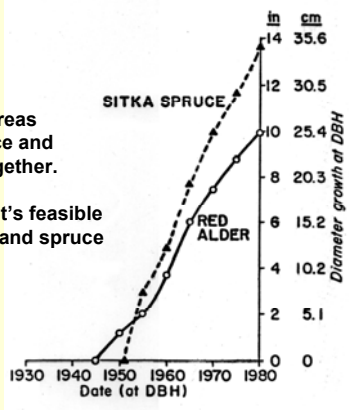
(2) By knowing key interactions between the ecosystem and the disturbance we can now design ways to prevent or mitigate the effects of these interactions.

(3) We are looking into growing Sitka spruce under red alder canopy. This combination would keep the spruce environment cooler and more moist -- stomates would remain open all day.



We found many areas where Sitka spruce and red alder grew together.

You can see that it's feasible to plant red alder and spruce together.

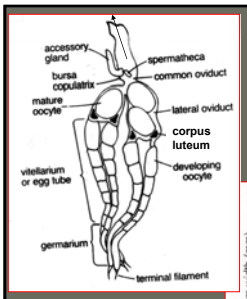


That's not all folks!

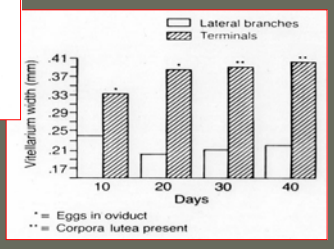
- We've been studying relationships between the Sitka spruce weevil and its host for over 20yrs.
- So we know quite a bit the weevil's host selection behavior and some of Sitka spruce's defenses.
- Bottom line -- all that we understand can be used in developing an IPM program against the weevil.

Some notes on *Pissodes strobi*:

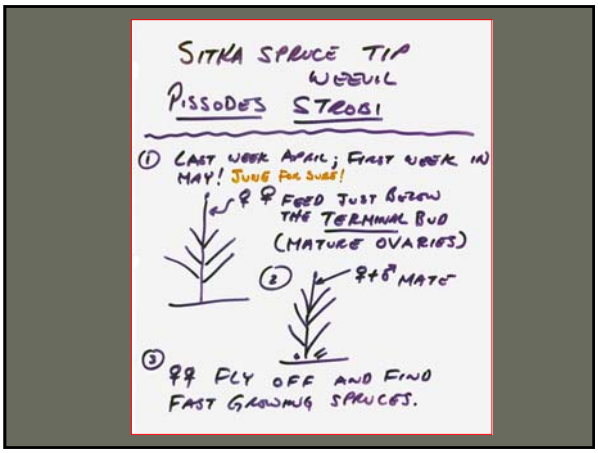
1. New adults emerge in late summer and overwinter on laterals,
2. Overwintering females have to feed on terminals to mature their ovaries in the spring.

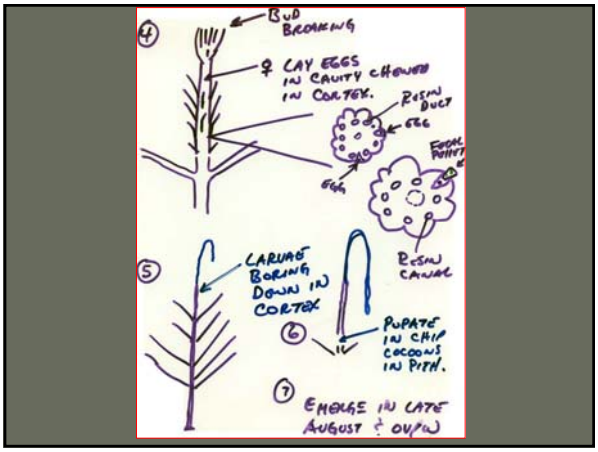


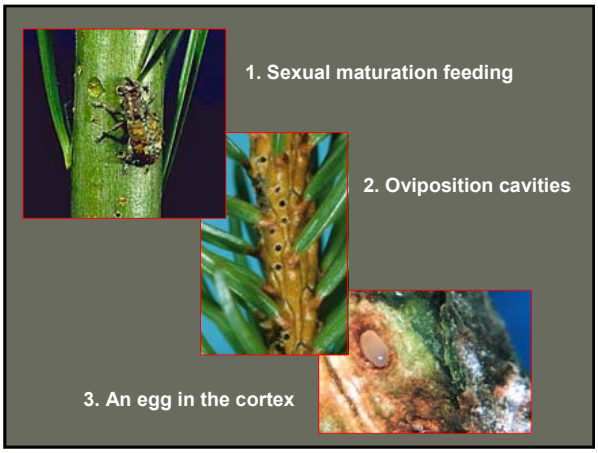
Sexual maturation of ♀♀ Sitka spruce tip weevils in spring: after feeding in leaders.



corpus luteum -- mass of material left after discharge of eggs

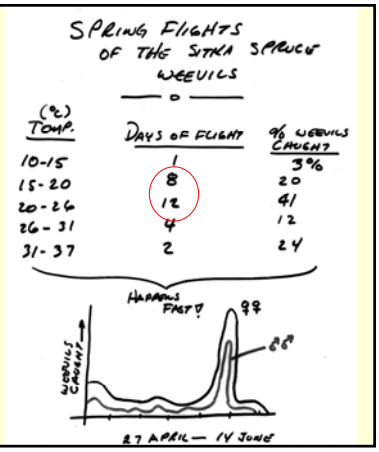

SITKA SPRUCE TIP WEEVIL
PISSODES STROBI
① LAST WEEK APRIL; FIRST WEEK IN MAY! JUNE FOR SURE!
♀♀ FEED JUST BELOW THE TERMINAL BUD (MATURE OVARIES)
② ♀♀♂ MATE
③ ♀♀ FLY OFF AND FIND FAST GROWING SPRUCES.


④ BUD BREAKING
♀ LAY EGGS IN CAVITY CHEWED IN CORTEX.
RESIN DUCT
EGG
EGG
⑤ LARVAE BORING DOWN IN CORTEX
RESIN CANAL
⑥ PUPATE IN CHIP COCOONS IN PITH.
⑦ EMERGE IN LATE AUGUST ♀ OVIP.


1. Sexual maturation feeding
2. Oviposition cavities
3. An egg in the cortex

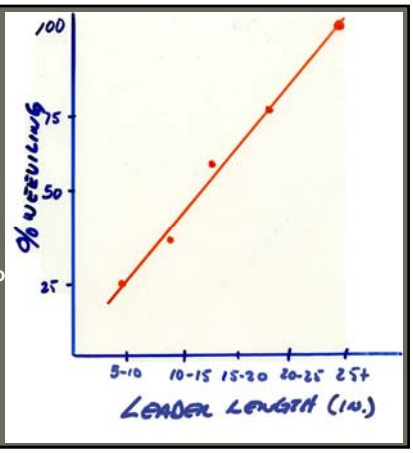
Trapping devices used in studying host selection behavior of the Sitka spruce tip weevil.

Spring flights are temperature triggered & begin after 1st days after 19C° !

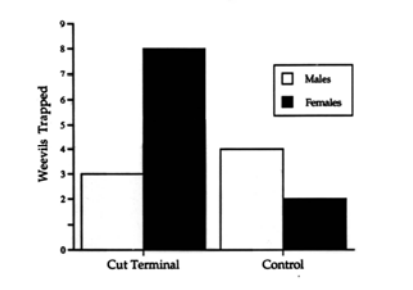


• Huge problem as you can see: ♀♀ prefer the tallest, fattest leaders in which to oviposit!

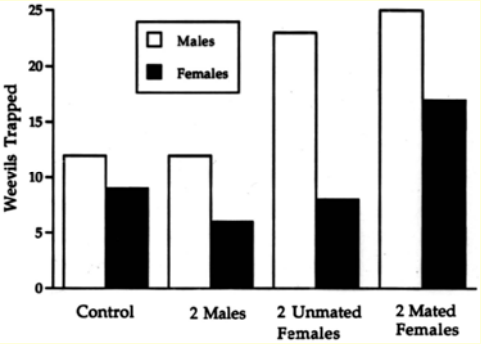
• Do ♀♀ respond to some host cue?



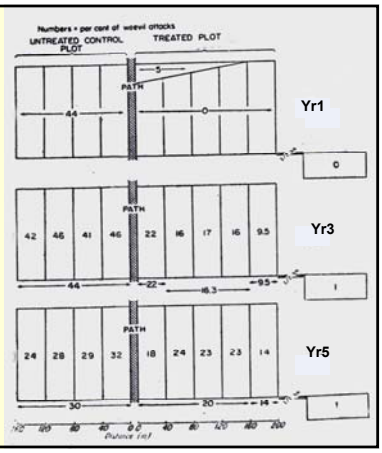
There does seem to be a 1° attractant that attract females: couldn't figure out what kind of volatile it is.



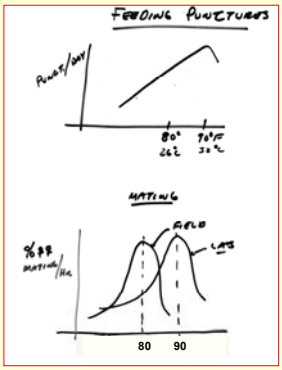
A search to see if *P. strobi* have either a sex attractant or an aggregant: unresolved still.



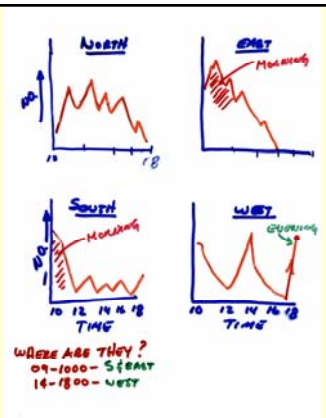
Tip weevils disperse slowly



Final weevil statement: they love warmth



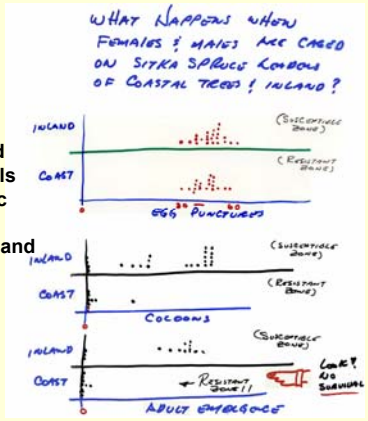
Tip weevil diurnal movement around stem to maintain maximum heat.



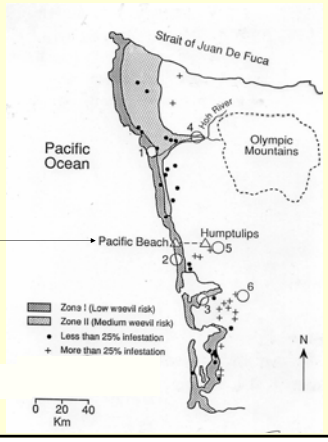
Some words on Sitka spruce

- **As mentioned there is a weevil-tolerant zone within 1-2 miles of the coast;**
- **It seems that coastal trees are being close to resistant to weevil attack;**
- **So we caged gravid females on leaders of coastal trees as well as trees growing inland.**

P. strobi ♀♀ caged on spruce terminals close to the Pacific Ocean and on terminals 2.0mi inland



Hygrothermographs established from Pacific Beach to Humptulips.



(1mm Hg = 0.1Kp)

We found that around 1.2 Kpa the stomates closed: no photosynthesis is possible.

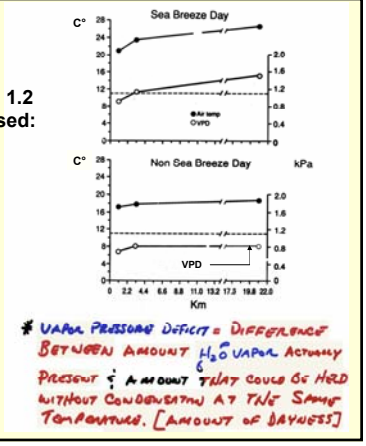
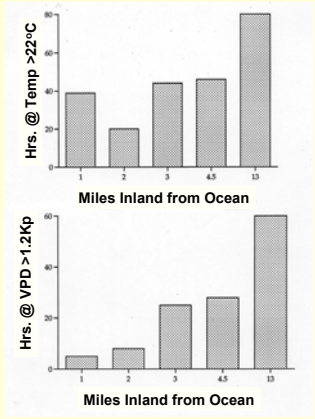


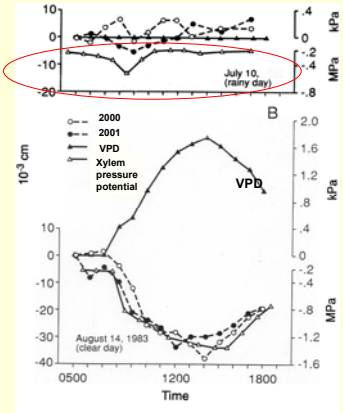
Table 9. *Vapor pressure deficit and vapor pressure as related to relative humidities at different temperatures.*

Temperature		Vapor pressure deficits (mm of Hg), reading down, at given relative humidities										
		Relative Humidities										
C°	F°	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
50	122	.0	9.25	18.50	27.75	37.00	46.26	55.51	64.76	74.01	83.26	92.51
45	113	0	7.19	14.38	21.56	28.75	35.94	43.13	50.32	57.50	64.69	71.88
40	104	0	5.53	11.06	16.60	22.13	27.66	33.19	38.72	44.25	49.79	55.32
35	95	0	4.22	8.44	12.65	16.87	21.09	25.31	29.53	33.74	37.96	42.18
30	86	0	3.18	6.36	9.55	12.73	15.91	19.09	22.27	25.46	28.64	31.82
25	77	0	2.38	4.75	7.13	9.50	11.88	14.26	16.63	19.01	21.38	23.76
20	68	0	1.75	3.51	5.26	7.02	8.77	10.52	12.28	14.03	15.79	17.54
15	59	0	1.28	2.56	3.84	5.12	6.40	7.67	8.95	10.23	11.51	12.79
10	50	0	0.92	1.84	2.76	3.68	4.60	5.53	6.45	7.37	8.29	9.21
5	41	0	0.65	1.31	1.96	2.62	3.27	3.92	4.58	5.23	5.89	6.54
0	32	0	0.46	0.92	1.37	1.83	2.29	2.75	3.21	3.66	4.12	4.58
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
		Vapor pressures (mm of Hg), reading up, at given relative humidities.										

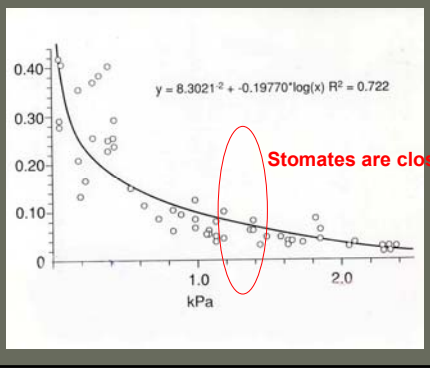
- **The Sitka spruces are shutting down their stomates;**
- **The carbohydrate budget just can't support a defense budget!**



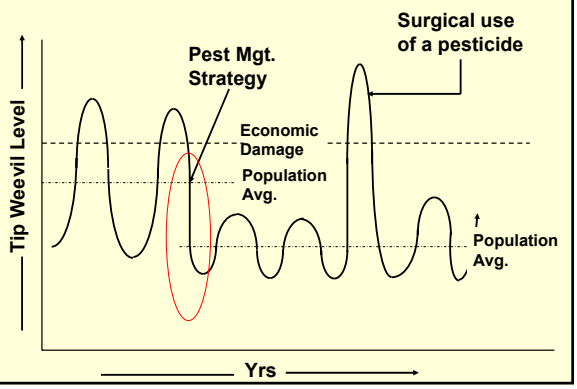
Sensitivity of Sitka spruce to environmental conditions.



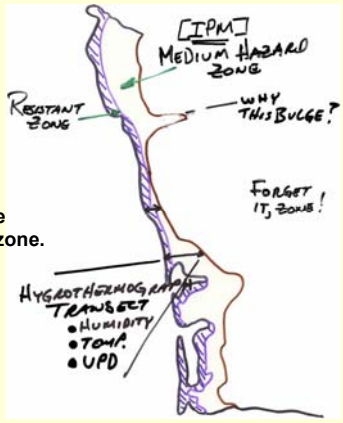
Vapor Pressure Deficits and Gas Exchange in Sitka Spruce



Integrated Pest Management



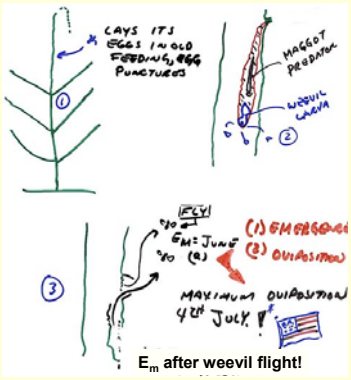
Plant Sitka spruce in the resistant zone and in the medium zone.



1. The first IPM step is not only know all you can about the key pest (*P. strobi*);

2. …but also about natural controls. The tip weevil has one control, *Lonchea corticis.*

3. This is a fly predator that's been found to control ~43% of a weevil population.



Aspects to consider in developing mgt. system to lower weevil GEP:

1. …plant spruce where it resists weevil attack; near coast up major drainages, wherever there is strong maritime influence;

2. … let's remember some "weevil facts:"
   - short flight that's highly dependent on a temp-window;
   - ♀♀ find suitable leaders and feed, mature ovaries, & call in males;
   - aha! this is a time when the population is pretty concentrated, time to consider an insecticidal knock down.

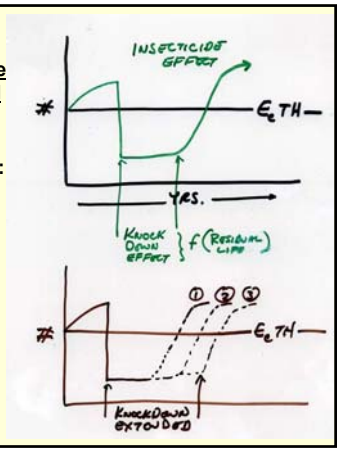
3. …after this "concentrating phase" on selected leaders, weevils fly only short distances to attack new hosts;

4. …it's not until later that *Lonchea* takes of to find old weevil cavities.

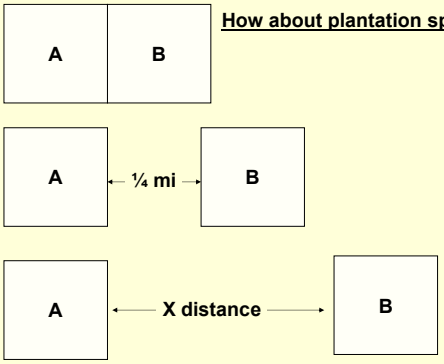
Alright, what can you do with this information.

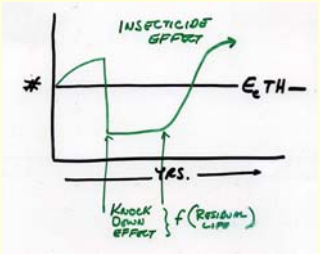
Early in the season, while weevils are concentrated

(I) The Insecticide Effect: can this get you started on a way to lower the weevil GEP?



How about plantation spacing?



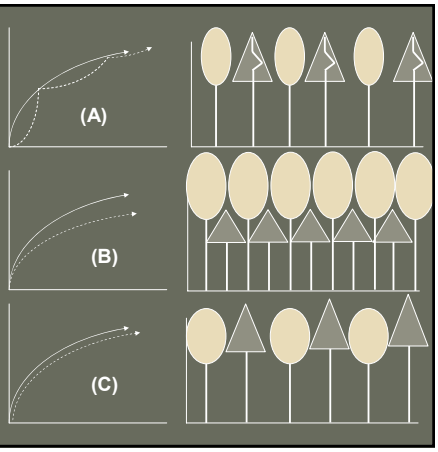


The knock down effect is definitely a function of that ideal X-distance between plantations.

Primary mgt. component:

- **Establish plantations within 2mi of the coast;**
- **When plantations are within the medium hazard zone:**
  - **plantations of the same age should be apart by the X distance (~one mile);**
  - **when plantations reach susceptible age, spray with a sustained release formulation when the predator is not active;**
- **Start experimental red-alder Sitka spruce mixtures;**

Hardwoods at wide spacing allow spruce to emerge through the canopy and be constantly attacked by P. strobi (A); hardwoods at narrow spacing suppress spruce growth (B), and: hardwoods at ideal spacing allow for fast spruce growth, but not fast enough to emerge above the canopy and become liable to weevil attack.



Finally, establish a monitoring system:

- **weevil populations**
- **damage**
- **natural regulation of weevil population**
- **research needs etc.**