Overview Fumigation Research
Western and Southern Nursery Programs
Weyerhaeuser Forest Nurseries

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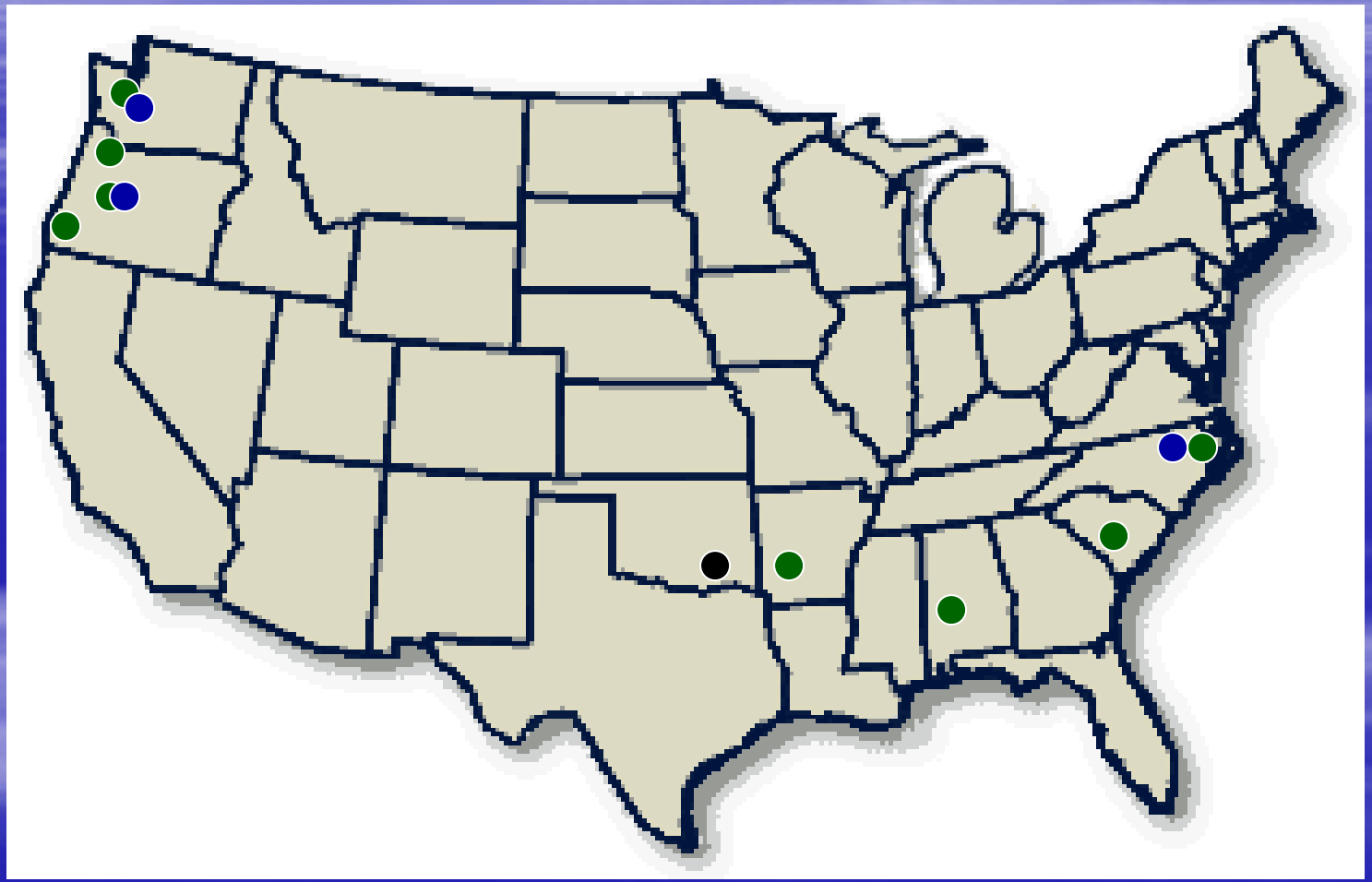
Weyerhaeuser Southern Regeneration

Weyerhaeuser Regeneration Facilities



Bare root
Container
Closed

Annual Production ~300 Million bare-root seedlings

Nursery Culture

West

South

Predominate crop in the West is a 2-year transplant Douglas-fir seedling

1-year in fumigated seed bed

1-year in transplant bed

All seedbeds fumigated

Years 2-3 -transplants

1+0 loblolly pine

3-4 year field rotation between fumigation event

Operational Soil Fumigation

Operational Fumigation Efficacy Metric:

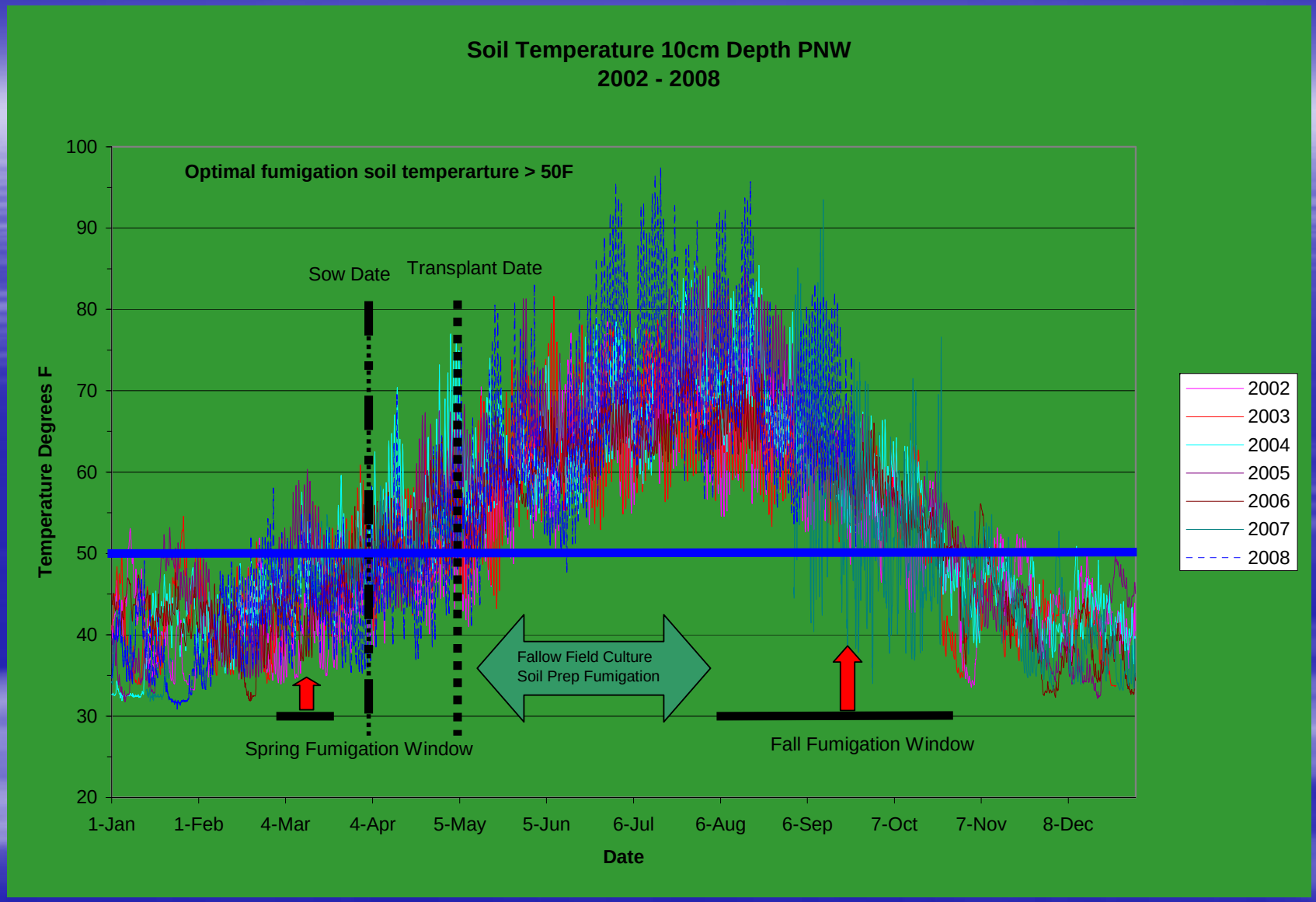
(> 90% reduction in soil disease levels pre- vs. post-fume)

Southeastern U.S.: MBC (98:2) 350 lbs/ac shank injected covered with HDPE

- ***alternatives identified: MBC 67:33; MBC 50:50; Telone Pic C35, Chloropicrin (100%)***

Western U.S. MBC (67:33) 350 lbs/ac shank injected covered with HDPE

- ***Alternatives identified: MBC 80:20, MBC 50:50; Chloropicrin (100%)***



Crop activities and minimum soil temperatures (> 50F) limit the "window" for effective fumigation

Search for the elusive “fumigant silver bullet”

Methyl bromide formulations

Metam sodium, Basamid, Busan, Soil Prep

Objectives

- ✓ **Identify strategy and tactics towards MeBr replacement**
- ✓ **Cover progress to date on finding alternatives to MeBr**
- ✓ **Identify strengths and weaknesses of various fumigant mixtures**
- ✓ **Quantify crop and disease effects**
- ✓ **Current activities**
- ✓ **Conclusions**

Historical Perspective (Weyerhaeuser R&D)

Nursery Culture
"Good Agricultural Practices"

Testing Alternative Chemical Fumigants
(Pilot to operational scale studies)
1979-present

~36 trials

outputs

Ranking
MBC 67:33, 75:25, 98:2, 50:50
Midas350 (early testing)
Chloropicrin/Telone
Chloropicrin
Metam Sodium
Basamid

Optimization Of Cultural Practices
Lower Pathogen Levels
(fallow year)

~10 trials

outputs

Bare fallow
Sudan grass
Compost
Sawdust
Bassica
Other cover crops

(Exploratory)
Soil or Crop Treatments

~10 trials

outputs

Steam pasteurization
Solarization
Hot water
Biological control agents

Post-fumigant Treatment Crop Assessments

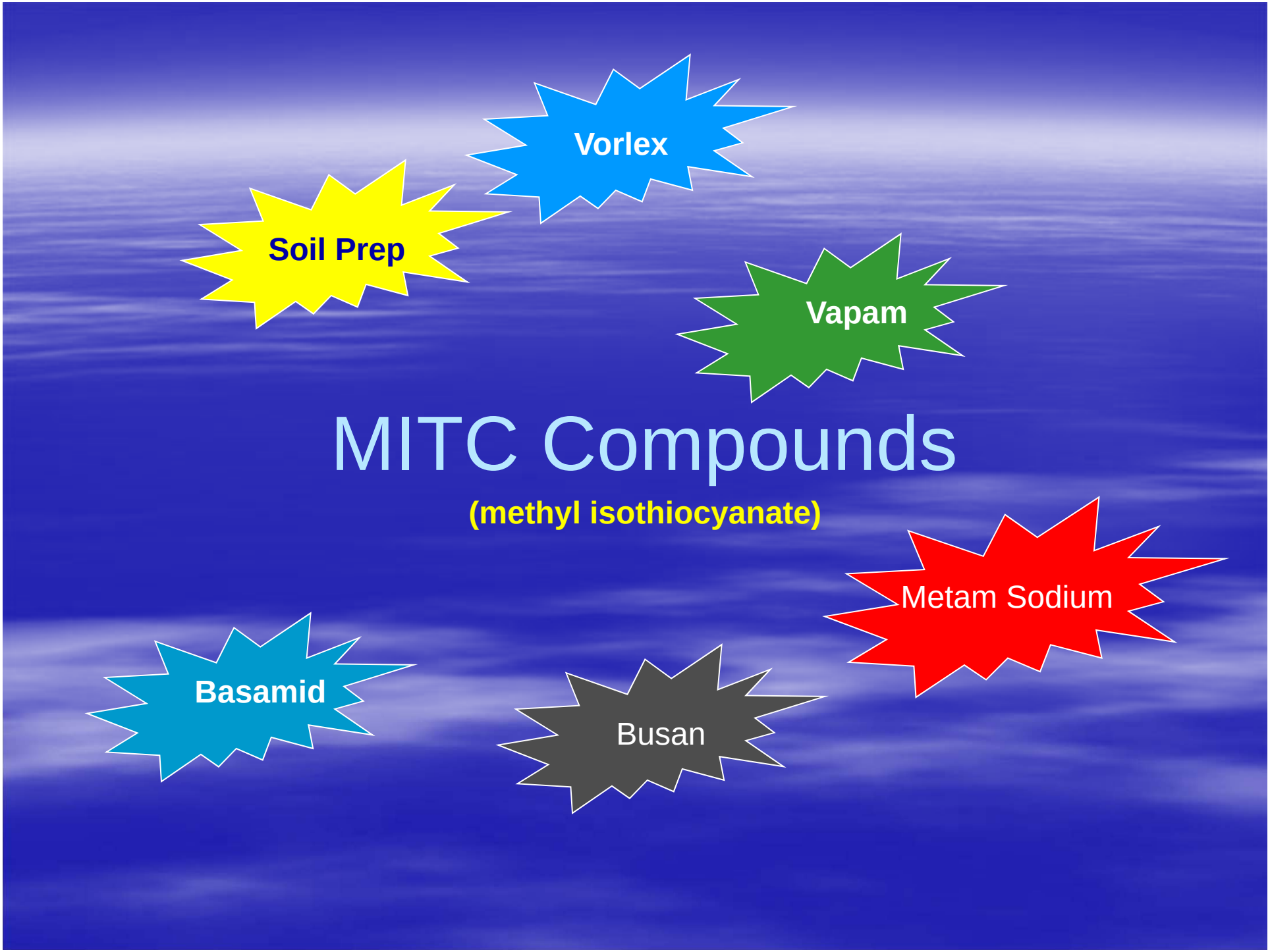
- A number of crop production metrics have been applied to evaluate fumigation efficacy:
  - Safety
  - Germination rates leading to “green tree” inventory
  - Crop growth trajectory and development
  - Mid-summer and late season soil and root pathogen assays
  - Foliar nutrition data
  - Weed cover (weed time + chemical use)
  - Crop morphological and physiological assessments- caliper, height, shoot to root ratio, RGP, etc.
  - Packable yields (cull standards)
  - Storage capacity trials
  - Field performance validation
  - Chemical and application costs

Early study showing differences in loblolly pine germination emergence in non-treated control (front) and MBC 67:33 treated plots (back).

DF transplant beds

Overview of Individual Fumigant Chemical Trials

Mix of Western and Southern Trials to broaden the inference around application of various alternatives


Vorlex
Soil Prep
Vapam
MITC Compounds
(methyl isothiocyanate)
Metam Sodium
Basamid
Busan

Experience with MITC Agents

- **Number of Studies-:**
  - **Basamid (11); Vorlex (1), Busan (1); Soil Prep (2); Metam (+Pic) (5)**
- **Applications:**
  - **Basamid formulation a granular "dust"**
  - **Metam-shank injection or drip**
  - **HDPE and only 1 study (Metam-Pic with VIF)**
  - **Typical Rates: Basamid 250-300 lbs/ac; Metam sodium + Chloropicrin 35-50 gal/ac and 122 lbs/ac respectively)**
  - **All fall applications because of previous experience with spring fumigation "burn" potential because of poor off-gassing.**
  - **Most trials completed by mid 90's**

Experience with MITC Fumigants

- **Disease Control- roughly the same as MBC**
- **Weed Control- better than PIC or Telone alone at 300 lbs/ac rate**
- **Green Tree Count (Germination)**
  - **Metam (range observed: -1 to +12 seedlings/lbf) (best results when used in combination with PIC)**
  - **Basamid (- 30 to + 5 seedlings/lbf) average - 4 seedlings/lbf**
- **Caliper and Height**
  - **Caliper range: - 1 mm to same as MBC**
  - **Height range: - 4 inches to same as MBC**
- **Packable Seedlings (per linear bed foot)**
  - **Metam studies range from – 20 to – 1 seedling/lbf**
  - **Basamid (-33 to +1 seedling/lbf)- *due to small caliper trees***

Performance comparison with operational MBC 350 lbs/ac (67:33 or 98:2)

Packable yields of loblolly pine after various soil treatments

Ft. Towson, OK 1995

Treatment	Total Culls (%)	Height < 7 inches
Basamid (no tarp) 300 lbs/ac	54 (a)	54 (a)
Basamid 250 lbs/ac	43 (a)	43 (a)
Chloropicrin 300 lbs/ac	10 (b)	9 (b)
MBC (98:2) 350 lbs/ac	17 (b)	17 (b)
MBC (75:25) 350 lbs/ac	5 (b)	4 (b)
Pic-Chlor-35 350 lbs/ac	14 (b)	11 (b)
Control	49 (a)	49 (a)

Values separated by different letters are significantly different LSD (P<0.05)

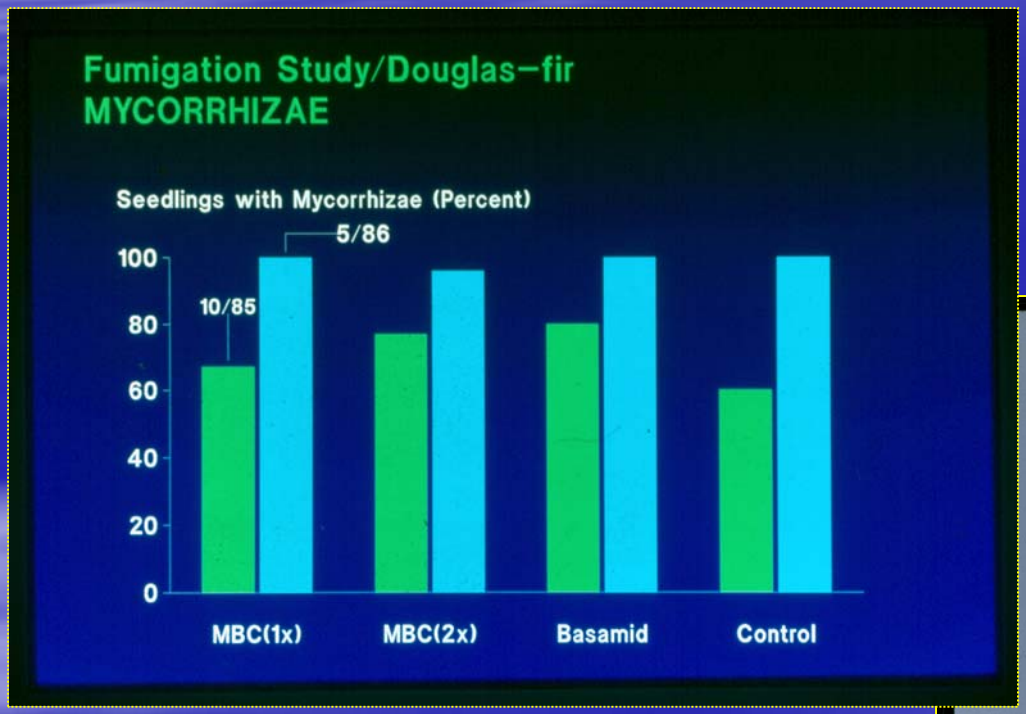
Experience with MITC Generators

Unresolved Issues:

- ***Complaints of adverse smell during off-gassing; granular formulation prone to blowing around prior to incorporation***
- ***Most studies conducted prior to understanding fully the limitations of chemical conversion***
- ***It is difficult to achieve uniform soil incorporation using the granular formulation***
- ***Chemical conversion is temperature and moisture dependent***
- ***Unpredictable rate of conversion and diffusion through soil profile***
- ***Not predictable enough for spring fumigation use (1-month window between fumigation and sowing, and transplanting)***
- ***Liquid formulation (Metam Sodium) application much better***
- ***Center pivot impute possible but with higher emissions potential***
- ***Unresolved negative effect on seedling development***
- ***Small trees (residual fumigant? nutrition? mycorrhizae?)***

The effects of fumigation can disappear by the end of the 1st growing season in bare-root grown Douglas-fir. Seedlings can have equivalent percent mycorrhizae as seedling grown in non-fumigated soil.

Tanaka, Linderman, and Russell 1986. Western Nursery Council Proceedings, Olympia, Washington



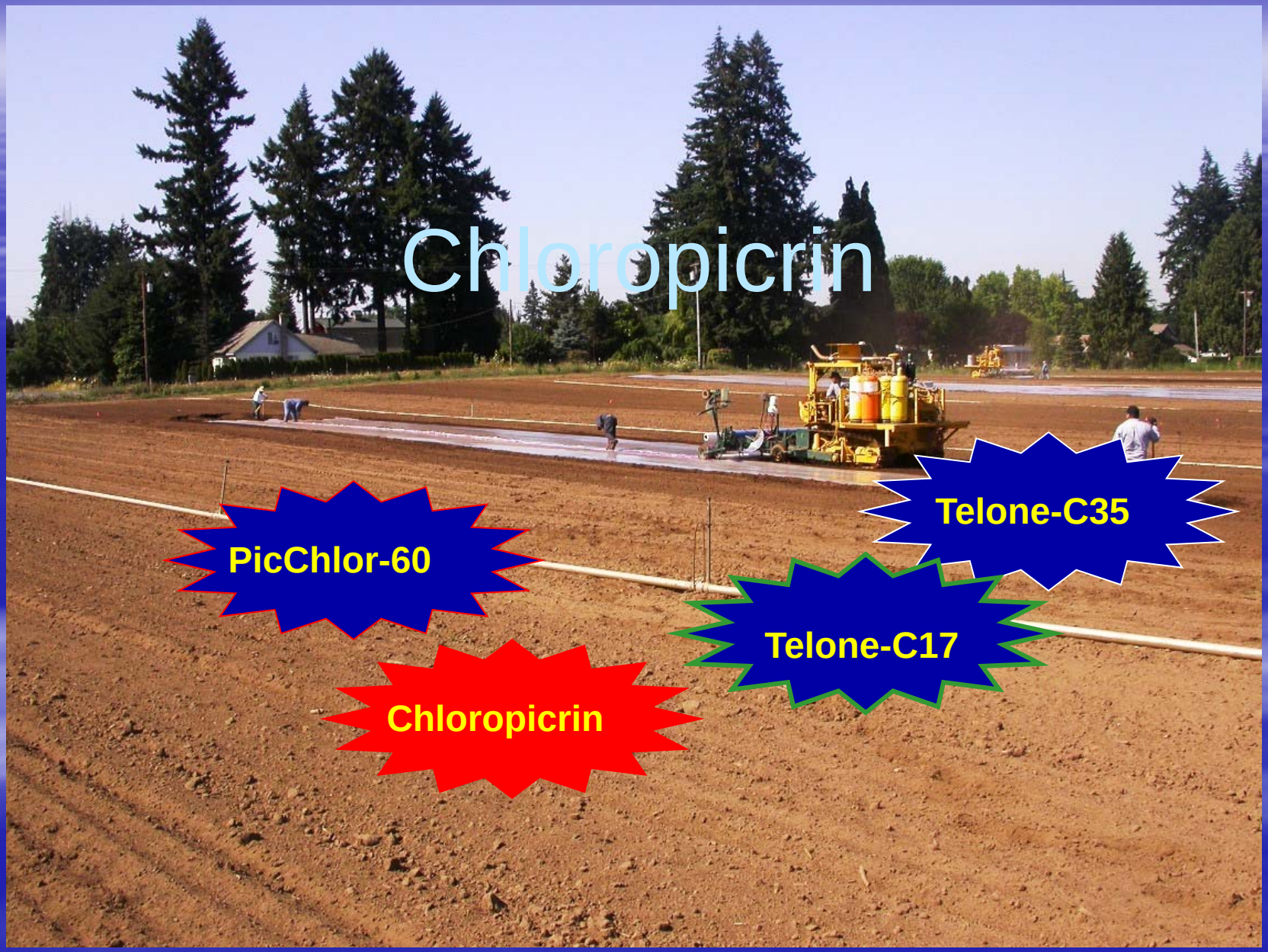
Early infection of Douglas fir root by Laccaria laccata

Methyl bromide chloropicrin was applied at 350 and 720 lb/ac; Basamid 200 lbs/ac)

Summary MITC Generators

- Current Status
  - No current operational use
  - No planned work on granular Basamid formulations
  - Metam sodium formulations (50 gal/ac + 122 lbs/ac) Chloropicrin are being evaluated for disease and weed control in current USDA/ARS 2008 study.

Chloropicrin



Experience with Chloropicrin

- **Number of Studies-:**
  - **Chloropicrin (100%) (4); Telone C-17, Pic-Chlor 35, Pic-Chlor 60 (10); Iodomethane+Pic (1); Pic+Metam Sodium (4)**
- **Applications:**
  - **shank injection**
  - **HDPE and VIF**
  - **Typical Study Rates: 250-300 lbs/ac Chloropicrin (100%); and various amounts (40-50%) with Telone, MBC and MI at 350 lb/ac rates.**
  - **All fall applications because of previous experience with spring fumigation "burn" potential due to slow off-gassing.**
  - **Several multi-year operational field crop studies (SE) demonstrating capability of 100% Chloropicrin and Telone-Chloropicrin (this was in the absence of weed problems)**

Experience with Chloropicrin

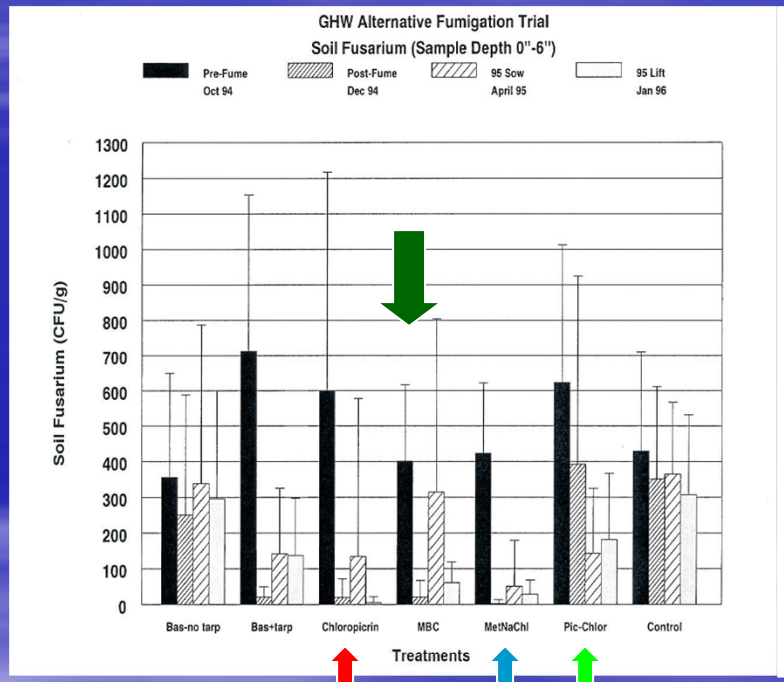
- Disease Control- roughly the same as MBC at 250-300 lbs/ac
- Weed Control- 100% Pic is less effective than when PIC is used with Metam Sodium or when used in combination with Telone
- Green Tree Count (Germination)
  - Chloropicrin (range - 1 to +1 seedlings/lbf)
  - Telone+Pic (- 9 to + 3 seedlings/lbf) (2 early studies clearly detrimental - 15 to -23 seedlings/lbf)
- Caliper and Height
  - Caliper range: same as MBC
  - Height range: - 2 to + 1 inches

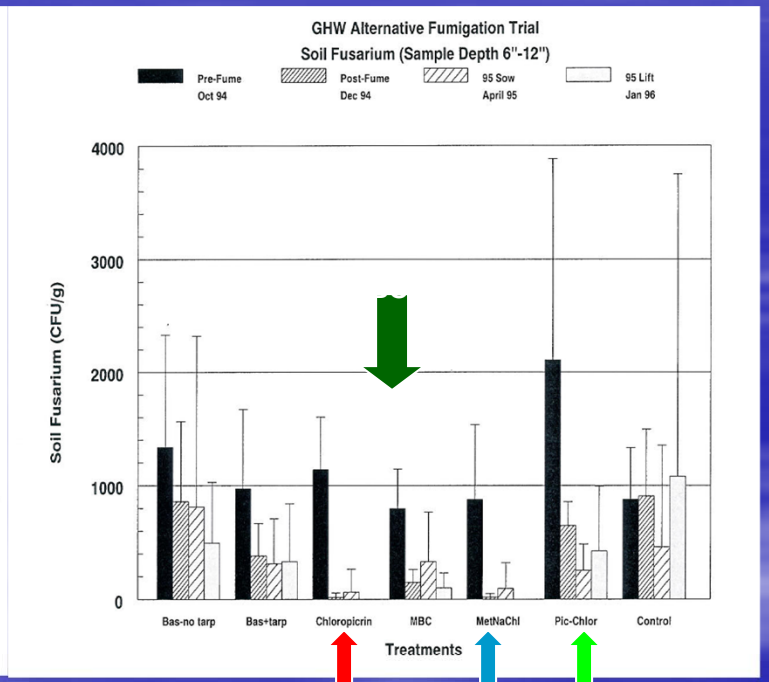
  Packable Seedlings (per linear bed foot)
  - Chloropicrin studies range from – 5 to + 7 seedling/lbf
  - Telone+Pic (-23 to +5 seedling/lbf)

- Performance comparison with operational MBC 350 lbs/ac (67:33 or 98:2)

Comparison of Chloropicrin formulations, MBC (98:2) and Basamid control of soil Fusarium. GHW Nursery Washington, N.C.

Metam-Pic and Chloropicrin were more efficacious than Telone-Pic at controlling soil Fusarium





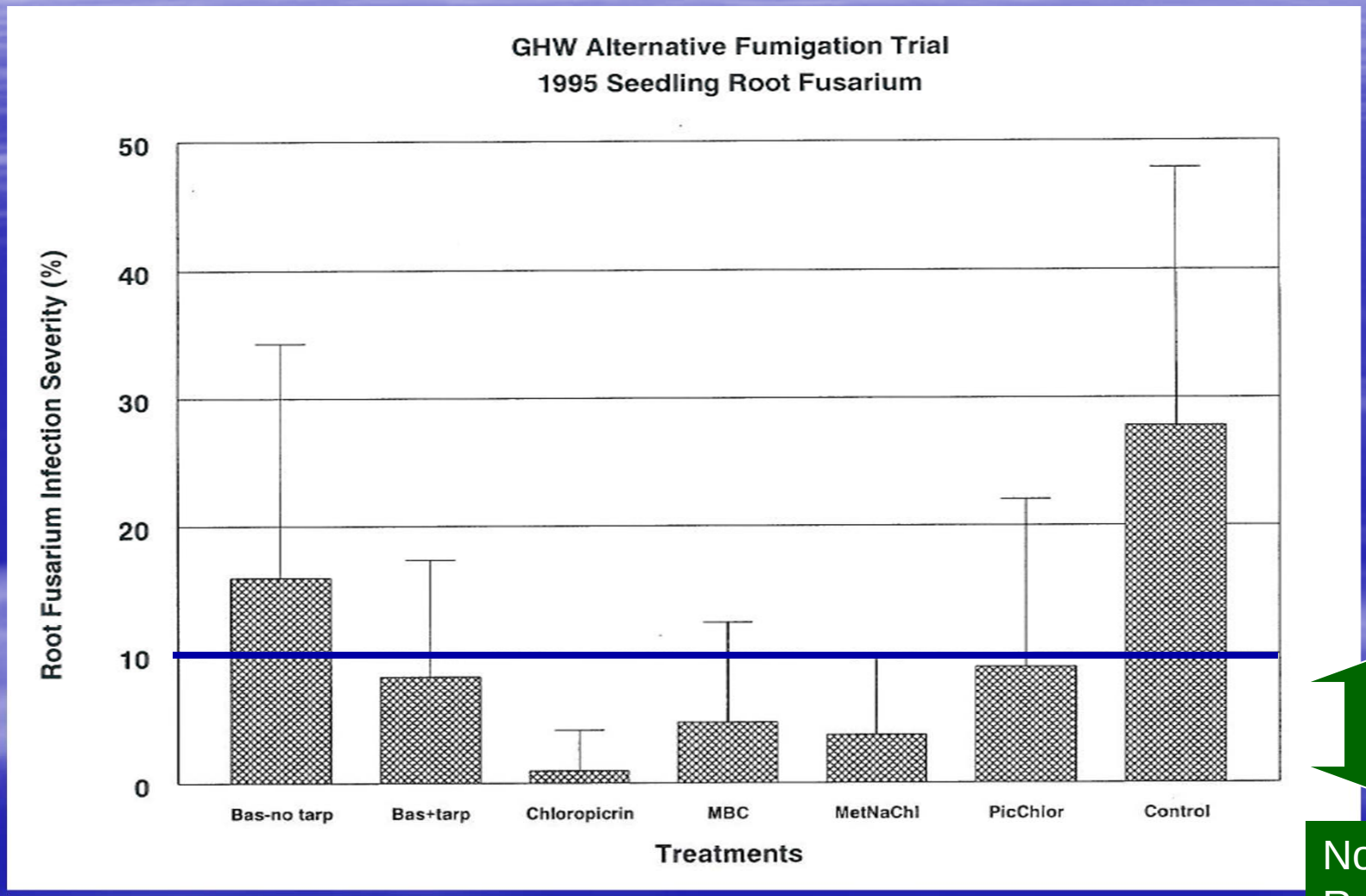
PIC MPIC TPIC

PIC MPIC TPIC

Fusarium population shown for two depths 0-6” and 6-12”

Study Trial: Fumigation Oct 1994 -Lift - Jan 1995

January lift root Fusarium infection severity (% roots infected) in soils treated with various fumigants. GHW (N.C.)



Normal Range

Experience with Chloropicrin

Unresolved Issues:

- ✓ **Currently a drop-in component (South and West?) as 100% or with either MeBr, Metam Sodium and MI**
- ✓ **However, EPA RED's eliminates the use of 100% formulations at the 250-300 lbs/ac levels**
- ✓ **Telone often used in combination with Chloropicrin is an nematicide while Chloropicrin provides disease control- *we seldom see nematodes as an issue***
- ✓ **Spring fumigation issues with Chloropicrin slow off-gassing**
- ✓ **Chloropicrin weed control is lacking; but when combined with Telone or Metam Sodium weed control efficacy is better.**

Summary Chloropicrin

- **Current Status**
  - **No further current work on Telone-Pic formulations; although this treatment has worked well in the SE.**
  - **Trend in incremental % of PIC in MBC formulations from 98:2 to 67:33 80:20, → 75:25 and 50:50**
  - **MBC 350 lb/ac 80:20 and MI+PIC 350 lb/ac (98:2) being tested as a spring treatment substitute for MBC 350lb/ac 67:33 (West)**
  - **Testing in Chloropicrin formulations with Metam Sodium, DMDS and Methyl Iodide (USDA/ARS 2008 Study)**


Midas +PIC 98:2
Iodomethane
Midas+PIC 175
Midas+PIC 350

Experience with Iodomethane

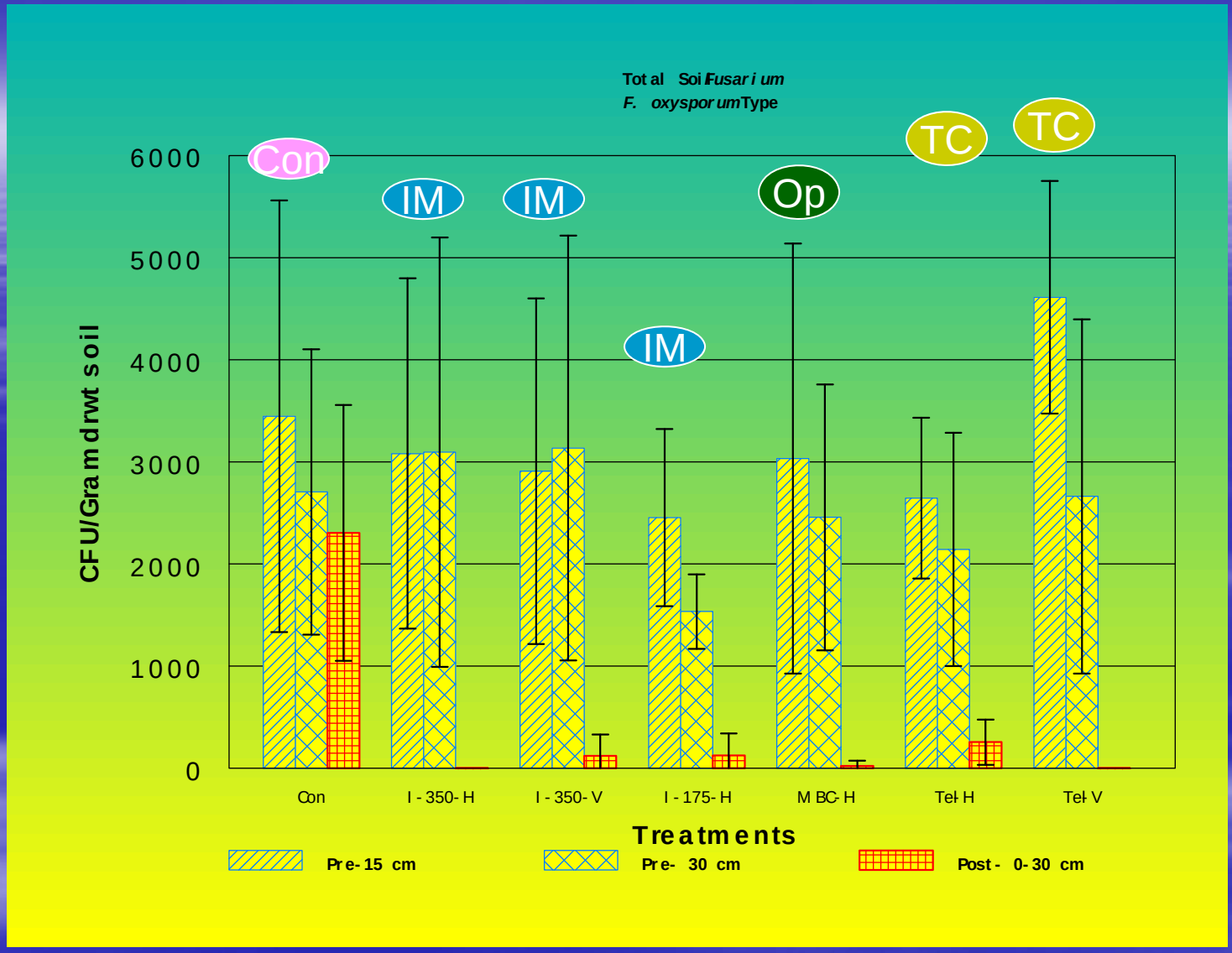
- **Number of Studies:**
  - **Iodomethane+Pic (4)**
- **Applications:**
  - **shank injection**
  - **HDPE and VIF**
  - **Typical Study Rates: MI at 350 lb/ac rates 50:50 with PIC; Spring fumigation MI+PIC 350lb/ac 80:20, and reduced rate MI+PIC 50:50 @ 175 lb/ac .**
  - **3 fall trials and 1 spring trial.**
  - **Current USDA/ARS study installed in three nurseries (2 private, 1 state) WA and OR**

Experience with Iodomethane

- Disease Control- 350 lb/ac rate so far better than MeBr at equivalent rates; 175 lb/ac rate less effective
- Weed Control- yet to be determined part of 2008 USDA/ARS study plan
- Green Tree Count (Germination)
  - Small seed bed trial showed no adverse effects on DF germination but not fully quantified
- Caliper and Height
  - Yet to be determined in 2008 USDA/ARS study

  Packable Seedlings (per linear bed foot)
  - Yet to be determined in 2008 USDA/ARS study

- Performance comparison with operational MBC 350 lbs/ac (67:33)



Pre-fumigation (0-15 cm and 15-30 cm depth) and post-fumigation (0-30 cm depth) *Fusarium oxysporum* propagules (CFU/g soil). (July-Sept)

2007 Mt Vernon WA USDA/ARS Trial

Op **Operational MBC 67:33 350 lbs/ac HDPE**

Experience with Iodomethane

Unresolved Issues:

- ✓ **Relatively new to the testing phase and not yet tested widespread in our system**
- ✓ **350 lb/ac rate with VIF looks like a drop-in component for MeBr**
- ✓ **However the regulatory issues, fumigant price and extra cost with VIF remain to be evaluated (no registered in some states (WA) waiting on CA registration decision!)**
- ✓ **Appears compatible with Chloropicrin for use as a spring fumigant**
- ✓ **Disease control so far looks good at high label rate with VIF**
- ✓ **weed control data is lacking; but is being gathered in current studies**

Future Testing Needs: Smaller buffer treatments Will they be effective?

		Treatments @ 10 acres or less within the buffer zone		
				Credits = 50% max
	Chemical	HDPE =0%	VIF 20%	Organic Matter > 3% 10%
	Iodomethane	feet	feet	feet
2008 Trial	122 lbs/ac	75	60	54
122 lb/ac	131 lbs/ac	75	60	54
Max Rate	175 lbs/ac	100	80	72
	Chloropicrin	HDPE =0%	VIF 40%	Organic Matter > 3% 10%
	87.5	75	45	41
	105	100	60	54
2008 Trial	122.5	175	105	95
122lb/ac	140	250	150	135
	157.5	350	210	189
	175	400	240	216
	Methyl Bromide	HDPE =O%	VIF 25%	Organic Matter > 3% 10%
	79	70	53	47
	94	115	86	78
	110	160	120	108
	125	200	150	135
	141	260	195	176
	Metam	HDPE = 0%	VIF 10%	Organic Matter > 3% 10%
	32	50	45	40.5
2008 Trial	56	100	90	81
50 gal/ac	80	150	135	121.5
	100	200	180	162
	120	250	225	202.5

Buffer Zone Width (Feet)

Assumes: no over-lapping buffers; OM > 3%; VIF Tarp; final buffer width driven by the greater regulated component

Future Testing Needs: Smaller buffer treatments for edge fields (100-foot)

5 acres				
at 100 foot or less buffer	Fumigant Mixtures	Assumes all credits applicable		
Agents	A	B	C	D
Iodomethane	175		175	
Chloropicrin	158	158		158
Methy Bromide		141		
Metam			56	56
Buffer Width	95	95	81	95
	Treatment			
	A	Iodomethane + Pic (53:46) 333 lbs/ac		
	B	Methyl bromide +Pic (47:53) 299 lbs/ac		
	C	Iodomethane + Metam (76:34) 231 lbs/ac		
	D	Chloropicrin + Metam (74:26) 214 lbs/ac		

Assumes: no over-lapping buffers; OM > 3%; VIF Tarp

Conclusions

- Since 1979, alternatives to MB research has identified important cultural improvements to lengthen the interval between fumigation events and improve on the efficacy of applied fumigants.
- Best management practices employed throughout the seedling culture process results in reduced reliance on pesticide impute, lengthens the interval between fumigation events, and allows for less effective fumigants to substitute for MB.
- However, MB and Chloropicrin and other chemicals remain important quarantine and operational fumigation treatments to address disease and weeds, ensuring continued high regeneration survival and performance across the forest landscape.
- It is most likely that no single fumigant agent can meet this challenge.
- A variety of fumigant chemicals may be needed to prevent the potential loss of efficacy from chemical degradation, resistance buildup or pathogen succession issues with repeat fumigation cycles with the same chemicals and rates.

Conclusions

- **Recent VIF tarp trials holds promise of lower fumigation rates and new fumigant combinations; if and when problems associated with tarp integrity and gluing can be solved effectively and economically.**
- **Some promising alternatives will not be selected do to prohibitive costs of application, noxious odors or other adverse effects.**
- **The proposed and amended EPA fumigation buffers and other restrictions will *dramatically alter bare-root conifer nursery production and setback gains made through years of fumigation research.***
- ***Failure to fumigate or the use of inferior combinations leads to unacceptable seedling losses, increased pesticide usage to combat diseases, pests and weeds, and contributes to failed regeneration.***

Healthy Seedlings Are Central To Healthy Forests

2-yr old DF ready for out-plant in OR and WA