of its use and at periodic intervals thereafter. The results indicated that there is a strong relationship between measurements made on large-scale, color 35mm aerial photos and ground conditions in young pine plantations. In general, the 1:6000-scale photographs produced estimates of roughly equal or better quality than 1:4000-scale photos. Photo-based prediction equations of this type likely have a use in determining where to concentrate field efforts. Stands that are clearly developing well can be identified with confidence on the photos and thus may need only limited ground surveys. Plantations that have clearly failed can also be confidently identified on the large-scale, 35mm aerial photos. □

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Chemicals for Control of Common Insect and Mite Pests in Southern Pine Nurseries

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ABSTRACT. Several pests of agricultural crops can cause low-level and occasionally catastrophic damage in southern pine nurseries. Although cultural control methods can help prevent or minimize pest damage, chemical control methods are sometimes needed. To effectively control these pests, nursery managers need up-to-date information on the rates and costs of the pesticides that are legal for use on trees. Pesticides currently labeled for controlling eight common pests of pine seedlings are listed along with their approximate costs.

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In southern pine nurseries, insect feeding damage is usually low, but occasionally high mortality can occur (Boyer and South 1984, Davis et al. 1974, Dixon 1982, Edelson and Hyche 1980, Foster and Harrison 1957, Holopainen 1986, Shenefelt and Simkover 1950, Shrimpton 1985, USDA 1985, Wakeley 1954). In a survey of southern nurseries (Boyer and South 1984), managers reported that mortality resulting from insects averaged about 5% of the seedling crop. Other studies have reported large-scale insect outbreaks that have killed or damaged up to 2 million seedlings in individual nurseries (Dixon 1982, Oak 1985, Shenefelt and Simkover 1950, Wakeley 1954).

Since the ban on chlordane (see Table 1 for chemical names), insects commonly found in field crops may be causing more problems for nursery managers (Edelson and Hyche 1979). Lesser cornstalk borer (*Elasmopalpus lignosellus* (Zeller)), a troublesome pest of grains, soybeans, and peanuts, can cause mortality of seedlings of several different coniferous species (Davis et al. 1974, Dixon 1982, USDA 1988). White grubs (*Phyllophaga* spp.), spider mites (*Tetranychus* spp. and *Oligonychus* spp.), mole crickets (*Scapteriscus* spp.), Lygus bugs (*Lygus* spp.), and cutworms (Order Lepidoptera, Family Noctuidae) can all cause damage to seedlings (Knight and Heikkenen 1980, Shenefelt and Simkover 1950, Speers and Schmiege 1961, Wakeley 1954, USDA 1985, 1988), and reports of their occurrence in southern pine nurseries have increased. The Nantucket pine tip moth (*Rhyacionia frustrana* [Comstock]) has always been a potential pest in pine nurseries. Although only occasionally a problem in pine nurseries, the pales (*Hylobius pales*

Table 1. Common, trade and chemical names of selected insecticides.

Common name	Trade name	Chemical name
acephate	Orthene	*O,S*-dimethyl *N*-acetylphosphoramidothioate
azinphos-methyl	Guthion	*O,O*-dimethyl *S*-[4-oxo-1,2,3 benzotrianzin-3(4*H*)-yl)methyl] phosphorodithioate
bendiocarb	Turcam	2,2-dimethyl-1,3-benzodioxol-4-yl methylcarbamate
carbaryl	various (Sevin)	1-naphthyl N-methylcarbamate
carbofuran	Furadan	2-3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate
chlordane	Chlordane	1,2,4,5,6,7,8,8-octrachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane
chlorpyrifos	Dursban, Lorsban	*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridyl)phosphorothioate
diazinon	Diazinon	*O,O*-diethyl *O*-(2-isopropyl-6-methyl-4-pyrimidinyl)phosphorothioate
dicofol	Kelthane	1,1-bis(*p*-chlorophenyl)-2,2,2-trichloroethanol
diflubenzuron	Dimilin	N-[[(4-chlorophenyl)amino]carbonyl]-2,6-difluorobenzamide
dimethoate	Cygon	*O,O*-dimethyl *S*-(*N*-methylcarbamoylmethyl)phosphorodithioate
endosulfan	Thiodan	hexachlorohexahydromethano-2,4,3-benzodioxathiepin oxide
esfenvalerate	Asana	(S)-cyano(3-phenoxyphenyl)methyl -(S)-4-chloro-alpha-(1-methylethyl) benzeneacetate
ethion	Ethion	0,0,0',0'-tetraethyl S,S'-methylene bisphosphorodithiote
fenvalerate	Pydrin	cyano(3-phenoxyphenyl)methyl-4-chloro-*alpha*-(1-methylethyl)benzeneacetate
fluvalinate	Mavrik	(*N*-[2,chloro-4-(trifuoromethyl)phenyl]-*DL*-valine(d)-cyano (3-phenoxyphenyl)methyl ester
hexakis	Vendex	(2-methyl-phenylpropyl)distannoxane
malathion	various	*O,O*-dimethyl phosphorodithioate of diethyl mercaptosuccinate
mercaptodimethur	Mesurol	3,5-diethyl-4-(methylthio)phenol methylcarbamate
methomyl	Lannate, Nudrin	*S*-methyl *N*-[(methylcarbamoyl)oxy]thioacetimidate
methyl parathion	Niran, Penncap	O,O-dimethyl)-p-nitrophenyl phosphorothioate
naled	Naled	1,2-dibromo-2,2-dichloroethyl dimethyl phosphate
oxamyl	Vydate	Methyl *N'N'*-dimethyl-*N*-[(methylcarbamoyl)oxy]-1-thiooxamimidate
permethrin	Pounce, Ambush	(3-phenoxyphenyl)methyl(+)cis-trans3-(2,2dichloroethenyl)-2,2-dimethylcyclo-propanecarboxylate
propargite	Comite	2-(p-tert-butylphenoxy) cyclohexyl 2-propynyl sulfite
phosmet	Imidan	*N*-(mercaptomethyl)phthalimide, *S*-(*O,O*-dimethylphosphorodithioate
trichlorfon	Dylox, Proxol	dimethyl(2,2,2-trichloro-1-hydroxyethyl)sphsphonate

[Herbst]) and pitch-eating (*Pachylobius picivorus* [Germar]) weevils are of interest to nursery managers because preventative control measures for outplanting are sometimes applied at the nursery.

While the major insect pests in nurseries have been fairly well defined, and many cultural control methods described (Dixon and Foltz 1984), information on chemical control measures has not been readily available. In some reports, information provided lists insecticides that are not legal for use on trees. Therefore, this paper reviews the kinds of damage caused by eight insect pests of pine seedlings and provides a list of insecticides that can be legally used on pines.

DAMAGE RECOGNITION AND CONTROL MEASURES

Awareness of the effects of pesticides, particularly insecticides, on the environment has led to the development of integrated pest management (IPM). In IPM, emphasis is placed on utilizing cultural control methods, enhancing natural control mechanisms, and maximizing the effect of chemical controls on target organisms while minimizing effects on nontarget organisms (Branham and Hertel 1984).

The decision of whether to use chemicals to control insect pests is ultimately based on economics. The nursery manager must weigh the treatment cost against the projected increase in crop value. In general, it usually takes about a 0.3% savings in plantable seedlings (2000 seedlings/ac) to justify applying an insecticide (assumming a cost of about $50/ac).

In order for pesticides to be used effectively in an IPM program, it is important for the nursery manager to (1) identify which type of arthropod is causing damage, (2) be familiar with available control measures, and (3) understand the proper timing and method of application. Although there may be a number of insecticides that are active on various insect pests, not all are registered for use on trees. However, there are a number of pesticides that include nursery or ornamental uses on their labels and that can be applied to pine seedlings (see Table 2 for selected pesticides that may be applied to pines).

Lesser Cornstalk Borer

The larval stage of the lesser cornstalk borer can damage seedlings. Newly hatched caterpillars are pink and approximately 2 mm long. Mature larvae are bluish-green with dark transverse bands and reach a length of approximately 16 mm. As they develop, they construct a series of silken tubes around the base of the seedling where they feed on the outer and inner bark. Damaged seedlings frequently die after becoming severely weakened and wilted (seedlings may either remain upright or fall over). Usually, several adjacent seedlings in a drill will be attacked. Specific damage signs are girdling of the stem just below the soil surface, scarring of roots, and the formation of gall-like structures or callous tissue near the point of attack. Infestations are most common during dry, hot weather and on sandy soils (Chalfant et al. 1982, Dixon 1982, Dixon and Foltz 1984).

Preventative applications of granular insecticides are recommended for controlling this pest in cover crops (USDA 1988).

Table 2. Chemical names, formulations, rates, and costs of selected insecticides for controlling various pests (this is not an all-inclusive list).

Pest	Chemical	Formulation	Rate (lb. ai/A)	Cost[1] ($/A)
Lesser cornstalk borer	chlorpyrifos	50W, 4EC	1–2	20–40
White grubs	bendiocarb	76WP	2	80
	chlorpyrifos	4E	2–4	27–74
	diazinon	4EC, 50WP	12	83–96
	trichlorfon	80SP	8	53
Spider mites	acephate	75S	1.0	9
	azinophos-methyl	50WP	0.375–0.5	3–6
	*azinophos-methyl	2L, 2S	0.375–0.5	3–5
	diazinon	4EC	0.5	4
	dicofol	35WP	0.35–1.0	6–18
	endosulfan	3EC	2.0–2.5	18–23
	ethion	4EC	0.5	3
	fluvalinate	2F	0.10–0.16	12–19
	hexakis	4L, 50W	0.5–1.0	9–32
	malathion	5E	0.1–0.2	4–8
	*methyl parathion	7.5EC	0.23–0.94	1–4
	mercaptodimethur	75WP	0.375–0.75	22–44
	naled	8EC	0.5–1.0	3–6
	*oxamyl	2L	1.0–2.0	6–12
	propargite	30W	0.3	3
Mole cricket	chlorpyrifos	0.5% bait	0.375–0.75	35–70
	diazinon	5G	4–5	40–50
	malathion	2% bait	2	38
Cutworms	carbaryl	XLR, 50W	1.0	4
	chlorpyrifos	50W	0.15–1.0	3–20
	diazinon	4EC, 50WP	2.0–3.0	14–21
	endosulfan	50WP	1.0–2.0	9–18
	*esfenvalerate	1.9EC	0.025–0.05	3–7
	*fenvalerate	2.4EC	0.1–0.2	4–8
	fluvalerate	2F	0.05–0.16	6–19
	*methomyl	1.8L	0.45–0.9	8–15
	*methyl parathion	7.5EC	0.23–0.94	1–4
	*permethrin	3.2EC, 2EC	0.1–0.2	4–8
	trichlorfon	80SP	1.0	7
Lygus bugs	acephate	75S	0.5–1.0	5–9
	azinophos-methyl	50WP	0.25–0.5	3–6
	*azinophos-methyl	2L, 2S	0.25–0.5	3–5
	dimethoate	2E	0.25–0.5	2–4
	endosulfan	3EC	0.5–1.25	5–11
	*esfenvalerate	1.9EC	0.025–0.05	3–7
	fluvalinate	2F	0.16	10
	*fenvalerate	2.4EC	0.1–0.2	4–8
	*methomyl	1.8L	0.45–0.9	8–15
	*methyl parathion	7.5EC	0.23–0.94	1–4
	naled	8EC	0.5–1.0	3–6
	*permethrin	3.2EC, 2EC	0.1–0.2	4–8
	trichlorfon	80SP	1.0–1.5	7–10
Nantucket pine tip moth	acephate	75S	0.75	7
	azinophos-methyl	50WP	0.375–0.75	4–9
	*azinophos-methyl	2L, 2S	0.375–0.75	4–8
	carbaryl	XLR, 50W	1.0	4
	chlopyrifos	50W	0.25	5
	*diflubenzuron	25W	0.0625	6
	dimethoate	2E	0.25–0.5	2–4
	*esfenvalerate	1.9EC	0.025–0.05	3–7
	fenvalerate	2.4EC	0.1	4
	*permethrin	2EC, 3.2EC	0.1–0.2	4–8
	trichlorfon	80SP	1.0	7
			Rate (lb. ai/1,000 seedlings)	Cost ($/1,000 seedlings)
Weevils	phosmet	50WP	0.175	1.1
	*carbofuran	4F	0.25	3.8

* Restricted use pesticide.
[1] Approximate cost of chemical, plus bait or clay.

Chlorpyrifos is often used to control this pest in corn, grain sorghum, and soybeans. For pines, chlorpyrifos (Dursban) is usually applied after injury from the lesser cornstalk borer is detected. When using the emulsifiable concentrate (EC) formulation, the spray should be directed to the soil, applied at dusk (to reduce photodecomposition), and followed by irrigation. Excessive volatilization of the EC formulation of chlorpyrifos can occur when soil temperatures are high at time of application.

White Grubs

Several species of white grubs, the larval stage of scarab chafers (commonly called May or June beetles), can cause damage to pine seedlings. Grub damage in nurseries can be detected as early as June. Injury is usually first recognized when patches of previously healthy seedlings begin to exhibit drought-like symptoms, turn a faded green to brown color, and die. These seedlings are easily pulled out of the soil with just a gentle tug, revealing damaged root systems (Speers and Schmeige 1961, Wakeley 1954). Commonly, the lateral roots and main tap root are absent, and feeding scars may be present on the larger roots.

Nursery managers should attempt to identify potential problem areas at the beginning of seedbed preparation and should check suspect areas in midsummer (Shenefelt and Simkover 1950) The grubs can be easily recognized by their white color and curled, C-shaped resting position. Unfortunately, significant damage has already occurred by the time symptoms are visible.

Preventative applications of granular insecticides can be used in cover crop areas. Soil fumigation with methyl bromide will kill grubs in the upper soil horizon; however, larvae that reside below the zone of fumigation can escape injury. Postemergence applications of insecticides will sometimes be needed. The insecticides should be applied before there is

an average of one grub per square foot of soil (USDA 1988). There are several registered insecticides available for suppression of grub populations (Table 2). If the soil is dry, it should be watered before treatment so the grubs return to the root zone. After treatment, the area should be irrigated with 0.5 to 1.0 in. of water to help move the insecticide into the soil. Since the recommended rate of application is usually higher when controlling grubs in the soil, the cost of the insecticide application will be greater than when spraying for insects that reside on the soil surface (Table 2). Fortunately, spot treatments will be adequate in some situations because the grubs are relatively immobile.

Spider Mites

There are several species of spider mites that can be pests of southern pine seedlings. Damage appears as pale yellow or reddish-brown discoloration of the foliage where spider mites have fed. In addition, the affected needles curl, and a very fine silk webbing or matting develops on or between the needles. The presence of red spider mites can be verified by brushing or rubbing an infested seedling against a white sheet of paper and looking for very small, mobile, dark spots. Damage peaks in hot, dry weather (Dixon and Foltz 1984, Metcalf et al. 1962, Wakeley 1954).

Currently registered miticides are listed in Table 2. Since the population of spider mites can rapidly increase (1 generation in as few as 4 days), 2 or more applications at 10-day to 2-week intervals may be needed to keep damage to a minimum in hot, dry weather.

Mole Crickets

Damage by mole crickets in southern pine nurseries is caused by the adults and older nymphs eating seeds, feeding on roots, or cutting off stems of seedlings just above the soil surface. A great deal of damage can also be caused indirectly by the tunneling habit of the mole crickets, which disturbs the soil and sometimes uproots seedlings causing them to dry out. Mole cricket damage is easily recognizable by the characteristic ridges and mounds in the soil that are similar to, though much smaller than, those of moles (USDA 1985, Cobb 1986, Thomas 1928).

Since mole crickets come to the soil surface at night to feed, the insecticide baits (Table 2) should be applied late in the day. The baits are most effective when applied from mid-July to mid-September, when the mole crickets are in the early nymphal stages. Baits containing chlorpyrifos or malathion are effective, although chlorpyrifos has performed better. Due to the higher cost of commercial baits (Table 2), some individuals have lowered the cost to less than $5/ac by preparing a bait on site. The treated area should be watered the day before treatment and, for best results, the area should not be irrigated for at least 2 days after the baits are applied. A diazinon spray can be used for spring treatments.

Cutworms

Cutworms are the larvae of several related species of underwing moths. Damage due to cutworms occurs on the young, succulent growth of the seedlings in spring and early summer. Cutworms damage or sever cotyledons and primary needles, produce stem lesions, and cut off seedlings at the groundline. Because of the nature of the damage and the early occurrence, it can be mistaken for damping off (Dixon and Foltz 1984). Although spring fumigation with methyl bromide will control existing populations in the soil, insecticides should be applied early in the season if damage becomes evident. It should be noted that some labels warn that carbaryl may damage sand pine (*Pinus clausa* [Chapm.] Vasey) and Virginia pine (*Pinus virginiana* Mill.).

Lygus Bugs

Lygus bugs feed by puncturing tissues with their mouthparts and sucking out sap. They have the ability to injure the growing tips of several conifers and can cause multiple leaders or "bushy-topped" seedlings (Holopainen 1986, Overhulser et al. 1986, Schowalter et al. 1986, Shrimpton 1985, South 1986). In the South, the tarnished plant bug (*Lygus lineolaris* [Palisot de Beauvois]) can cause problems in pine nurseries. Cultural control includes keeping surrounding areas clear of weedy vegetation especially during winter and spring to minimize possible overwintering and egg-laying sites. If such treatment is unsuccessful, multiple application of certain insecticides (endosulfan, fenvalerate) can reduce the amount of seedling damage caused by Lygus feeding (Overhulser et al. 1986). Although it has been recommended that insecticide treatments begin about 2 weeks after seedlings show symptoms (USDA 1988), treatment at southern pine nurseries, where the tarnished plant bug has been a problem, should begin about 2 weeks before symptoms occur. In the South, symptoms of injury to pines can occur as early as mid-May.

Nantucket Pine Tip Moth

The Nantucket pine tip moth normally infests seedlings in plantations but occasionally can be found in nurseries in mid- to late summer. The top 1 to 2 inches of infested seedlings will turn brown and die back. If allowed to overwinter as pupae in the shoot, the insect will mature and can infest plantations. Early seedling infestation is detectable by the delicate webs which the larvae construct, first in the axil of a needle, then later between buds or buds and needles (Wakeley 1954, Yates et al. 1981).

If the seedlings are tall enough, top-clipping may reduce the problem. When insecticide applications are used, they must be carefully timed since the larvae are protected by plant tissues once they bore into the shoots. Optimum spray dates can be calculated with the use of pheromone traps and recording the degree-

day accumulation (Berisford et al. 1984).

Pales and Pitch-eating Weevils

Pales and pitch-eating weevils are sometimes serious pests of first-year southern pine plantations. Control measures for high risk areas (site preparation occurs during or after July (Nord et al. 1984)) include either waiting a year before planting or treating the seedlings with an insecticide. Treatment is sometimes done at the nursery with either a phosmet top-dip or a carbofuran and clay root-dip just before seedlings are packaged for shipping (Table 2). The phosmet treatment also can be applied as a 4% spray just before lifting. A special boom should be used that will bend the seedlings over while they are sprayed to ensure that the base of the stem is treated. The label indicates that 1000 seedlings should be treated with 2 quarts of the 4% solution.

Although not normally found in pine nurseries, these pests can occur after removal of a pine windbreak or when a pine stand adjacent to the nursery is harvested. When this occurs, chlorpyrifos may be applied to protect the seedlings.

SUMMARY

Nursery managers should employ cultural practices to minimize the risk of an increase in pest populations (Dixon and Foltz 1984). However, when cultural practices prove ineffective, nursery managers should respond quickly when significant seedling injury develops. Nursery managers are encouraged to preselect a pesticide to use for each of the previously discussed pests. The decision on which product to select should be made after consulting with entomologists and extension agents who are familiar with which pesticides have activity on specific pests. The nursery manager should be sure that the pesticide selected can be legally applied to his crop. Registrations of the pesticides listed in Table 2 are under constant review by the Federal Environmental Protection Agency. In addition, pesticide regulations will vary from state to state. For these reasons, the manager should consult with the county or state extension specialist to be sure the intended use is permitted. □

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