LIFE TABLE EVALUATION OF CONELET AND CONE MORTALITY FOR JACK PINE, *PINUS BANKSIANA* LAMB., IN WISCONSIN[1]

Aunu Rauf[2], R. A. Cecich[3] and D. M. Benjamin[2]

Abstract.--The mortality of jack pine conelets and cones was monitored in 1980 using life tables in one natural stand and one plantation in Oneida Co., Wisconsin. The jack pine budworm, *Choristoneura pinus pinus* Freeman, destroyed 12 percent of the conelets. The relationship between conelet abortion and a mirid, *Platylygus tinctus* Uhler, is discussed. Squirrels killed conelets as well as cones. The most prevalent insect attacking cones was the cone borer, *Eucosma monitorana* Kearf., which killed 10 percent. Other insects responsible for lesser amounts of damage were the webbing coneworm, *Dioryctria disclusa* Heinrich; red pine cone beetle, *Conophthorus resinosa* Hopk.; jack pine budworm; and cone midges, which causes a total of 4.5 percent mortality. Radiographs of seeds from surviving cones revealed that feeding by the eastern pine seedworm, *Laspeyresia toreuta* (Grote), accounted for 5.7 percent seed losses, and the shield-backed pine seed bug, *Tetyra bipunctata* (Herrich-Schaffer), 3.3 percent.

Additional keywords: Seed and cone, *Pinus banksiana*, *Choristoneura pinus pinus*, *Eucosma monitorana*, *Dioryctria disclusa*, *Conophthorus resinosa*, *Laspeyresia toreuta*, *Tetyra bipunctata*, *Platylygus tinctus*, *Resseliella silvana*, *Asynapta hopkinsi*.

With the increasing demand for pulp and timber, reforestation has become a widespread interest in modern-day forestry; the future success of reforestation will depend on an adequate supply of quality seeds. The failure of seed crops caused by conelet and cone mortality is not uncommon in pines, and insects have been reported to be a major cause in reduced seed yields.

---

1) Research supported by the School of Natural Resources, College of Agricultural and Life Sciences, University of Wisconsin-Madison; the U.S. Forest Service, North Central Forest Experiment Station, Forestry Sciences Laboratory, Rhinelander, Wisconsin Grant No. 13-696; the Indonesian Higher Agricultural Education Project, Midwest Universities Consortium for International Activities - U.S. Agency for International Development.

2) Research Assistant and Professor of Entomology and Forestry, respectively, University of Wisconsin-Madison.

3) Principal Plant Anatomist - U.S.F.S. Forestry Sciences Laboratory, Rhinelander, Wisconsin.

Notable examples occured in loblolly pine (coyer and Nachod, 1976; Yates and Ebel, 1978), in shortleaf pine (Ebel, 1974), in slash pine (DeBarr and Barber, 1975), in red pine (Mattson, 1978).

Recently, the importance of insects associated with reproductive structures of jack pine has been recognized in the Lake States where jack pine is used extensively in forest tree improvement programs; however, little quantitative data on the impact of insects are available. Therefore, we initiated a life table study in two jack pine stands with the intent of identifying and measuring all mortality that occured during conelet, cone, and seed development. By using life tables we expected to gain information on both seasonal timing and magnitude of insect-caused damage, which can help us understand the losses and, perhaps, plan better control measures as suggested by Yates and Ebel (1978).

METHODS

Sampling Procedures

Twenty 10-year old cone-producing jack pine in a natural stand in the Little Rice area, Oneida Co., Wisconsin, were selected on the basis of their being open grown with well-developed crowns. On 1 June 1980, 12 branches bearing conelets and cones on each tree were tagged. (At that time, most of the corselets had been chewed by the jack pine budworm, *Choristoneura pinus pinus* Freeman; therefore, to avoid bias, selection of branches was based on the presence of cones). All conelets and cones on the tagged branches were examined at 1 to 2 week intervals until mid-August; then examinations continued monthly until the end of October. Records were made of the numbers of surviving conelets and cones, as well as the numbers lost to various mortality factors. On 31 October 1980, one cone was picked from each tagged branch to determine damage by the eastern pine seedworm, *Laspeyresia toreuta* (Grote), and the shield-backed pine seed bug, *Tetyra bipunctata* (Herrich-Schaffer). The seeds were extracted and radiographed using the procedure for jack pine of Rudolph and Cecich (1979). Those damaged by the seedworm and the seed bug were distinguished from sound and empty seeds based on malformation characteristics given by DeBarr (1970). In addition, several cones on jack pines grown close to the laboratory were exposed to seed bug feeding for damage comparison.

At the Harshaw plantation, our study emphasized conelet abortion, since in this area the conelet abortion was recorded as high as 70 percent in 1979 (Cecich, unpublished). A total of 1109 conelets, distributed over 48 trees of 6 families, were tallied in late-May 1980, and the conelet abortion was recorded weekly until early October.

Life Table Method

The form of life table presented in this paper is the cohort type applicable to strictly even-aged populations (Waters, 1969; Harcourt, 1970), and used for evaluating conelet and cone mortality by DeBarr (1975). The mortality-survival record was obtained from periodic observation of the same conelets and cones in the same population. As conelets and cones were lost, no new replacements were added and the population terminated at harvest. The percentage values for the successive mortalities were in absolute, rather than relative, i.e., all were calculated from the number of conelets or cones alive at the start.

RESULTS

Since our observation were not complete for any single flowering cycle, we present partial life tables for 1980 growing season.

Conelet Losses

Flower and conelet mortality from all causes totaled 23.6 percent over 5.5-month period of development, from mid-May through 31 October 1980 (Table 1). The most prevalent insect causing mortality was the jack pine budworm, which destroyed approximately 12 percent of the total number of structures examined. The jack pine budworm attacked the flowers and conelets mostly in late-May and early June, just after pollen was released. Conelets killed by this insect were characterized by webbing across the angle formed by the shoot and conelet. The larvae stayed within the webbing and chewed the conelets. After the conelet dried, the larvae continued feeding on the supporting shoot. In some instances, they might migrate to feed on other conelets.

Abortion, the major concern of conelet mortality for some southern pines (White *et al*., 1977; and references cited by them), accounted for 10 percent in the Little Rice study area. However, in the Harshaw plantation, about 15 miles from Little Rice, conelet abortion was about four times higher than in the Little Rice (Fig. 1). DeBarr and Ebel (1974) demonstrated that feeding by a seed bug, *Leptoglossus corculus* (Say), caused abortion of shortleaf and loblolly pine conelets; however, this species does not occur in Wisconsin. Instead, in the Harshaw plantation, a mirid *Platylygus tinctus* Uhler, was noticebly abundant in late June 1980 followed by increasing rate of conelet abortion about four weeks later. This mirid was observed piercing into conelets as well as shoots and needles. It is thought that *P. tinctus* might be responsible for higher conelet abortion in the Harshaw area. Study of the role of this insect on conelet abortion is now underway.

Other minor insects contributed 1.3 percent of the conelet mortality; these include *Eucosma sp*. larvae boring into shoots bearing conelets, and unknown insects (probably beetles) which chewed the conelets. In addition, 3 conelets (0.3%) were missing and 3 others were lost by accidental breakage during observation.

Table 1. Partial life table for jack pine conelets on sampled branches of 20 trees in Oneida Co., WI., May 1980 - May 1981.

Reproductive Structures	Period (x)	Number of conelets (Lx)	Mortality factors (dxF)	Number dying (dx)	Percent mortality (100rx)
Flower/ conelet	mid-May-1 June 1980	916	*C. pinus pinus*	89	9.7
			Abortion	18	2.0
Conelet	2 - 9 June	809	*C. pinus pinus*	17	1.9
			Abortion	4	0.5
			Missing	1	0.1
			Breakage	1	0.1
	10 - 17 June	786	*C. pinus pinus*	2	0.2
			Abortion	6	0.7
	18 - 25 June	778	*C. pinus pinus*	1	0.1
			Shoot borer	1	0.1
	26 June - 9 July	776	Abortion	3	0.3
			Missing	1	0.1
	10 - 17 July	772	Abortion	4	0.5
			Shoot borer	1	0.1
	18 - 31 July	767	Abortion	11	1.2
			Missing	1	0.1
			Shoot borer	2	0.2
	1 - 13 Aug.	753	Abortion	12	1.3
			Shoot borer	1	0.1
			Breakage	1	0.1
	14 Aug. - 20 Sept.	739	Abortion	25	2.7
			Unknown	5	0.5
			Breakage	1	0.1
	21 - Sept. 3 Oct.	708	Abortion	7	0.8
			Unknown	1	0.1
			Sub-total	216	23.6
Conelet/ cone	1 Nov. 1980 - 23 May 1981	700	Abortion	16	1.7
			Dead branch	76	8.3
			Squirrel (?)	94	10.3
			Missing	2	0.2
Total		512		404	44.1

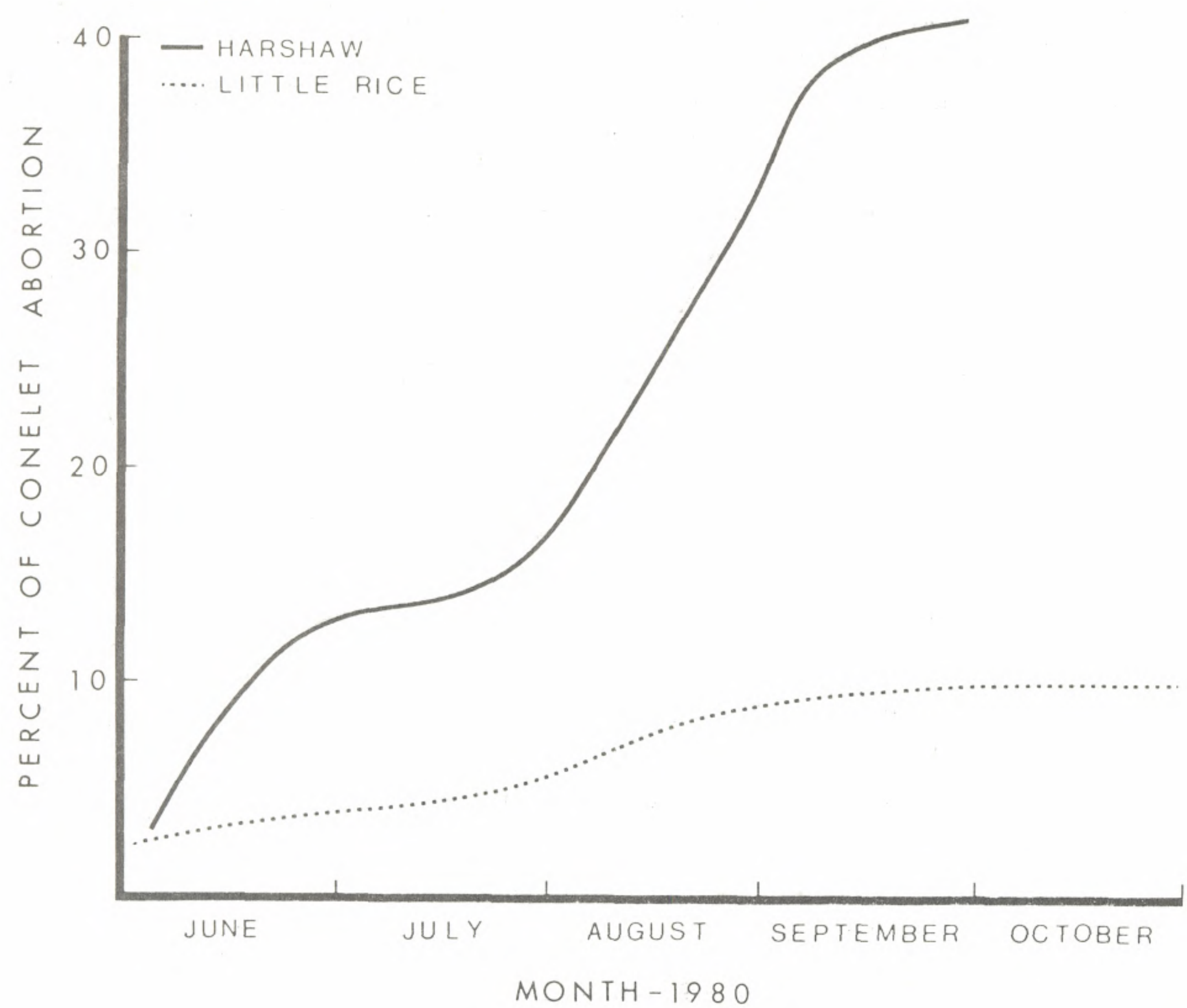

Figure 1.--Jack pine conelet abortion in the Harshaw and Little Rice areas during 1980 growing season.

Additional Losses during Winter and Early Spring

The last observation for 1980 growing season conducted on 31 October revealed 700 conelets that potentially would develop into cones; subsequent observation on 23 May 1981, revealed 512 conelets survived or 21 percent mortality occured during this period.

Forty-two shoots bearing 76 conelets (8.3%) were killed by bark beetles, Pityophthorus cariniceps Le Conte and Pityophthorus pulchellus Eichh. Their attack was confined to twigs injured by squirrels when they clipped cones in the fall. Several shoots sustained damage by pitch nodule maker, Petrova albicapitana (Busck), and these were attacked by the beetles. Pityophthorus spp. are known to attack dying or weakened branches (Chamberlin, 1939). This mortality is classified under heading "dead branch".

About 10 percent of conelets were lost and most likely clipped by squirrels. This mortality can be recognized by the stub left on the branches. Dry resin on the stubs indicated that damage probably occured in the winter.

Sixteen, or 1.7 percent, of cones ceased development and died with no obvious sign of damage. This type of abortion occured during winter and early spring. Such cone abortion probably was caused by physiological imbalances or insects that destroyed their ovules in the previous season.

Cone Losses

When we tagged branches in the spring, only live cones were recorded; aborted cones were not included in the observation. Approximately 34 percent of the cones were killed by various factors over the following 5-month period, from 1 June through 31 October 1980 (Table 2).

Webbing coneworm, Dioryctria disclusa Heinrich, tunneled into the cones and excavated the seed-bearing region of the cones during June. Attacked cones have a characteristic webbed frass over the entry hole. About 0.4 percent of the cones were killed.

Red pine cone beetle, Conophthorus resinosa Hopk., killed 0.7 percent of the cones when female adults bored into the conductive tissue of the cone base to oviposit. Infested cones were characterized by a pitch tube at the point of adult entry. Like the coneworm, the cone beetle attacked the cones during June.

The mature larvae of jack pine budworm also fed externally on the cone surface. Only cones attacked in early and mid-June died; however, damage on scales provided opening for the secondary insects described later. The budworm attacked 1.7 percent of the cones.

The most destructive cone insect was the red pine cone borer, Eucosma monitorana Heinrich, which killed 10 percent of cones. Peak damage periods were early July when the mature larvae left the first attacked cones, dispersed, and infested several fresh cones. The latter then was characterized by oblong entrance holes with extruded frass. Visits to other jack pine stands revealed that the cone borer also was the most common insect attacking cones of jack pine.

Most of the cones attacked by the foregoing insects were reinfested by midges, Lestodiplosis grassator (Fyles), Resseliella silvana (Felt), and Asynapta hopkinsi (Felt). According to Ebel et al. (1975), Lestodiplosis are predators while Resseliella and Asynapta are associated with primary cone damage. Cone infested by the midges occured from June through August. During our study, 1.6 percent of the cones were killed by the midges. Brown shrunken areas on the cone scales or tip of the cones characterized midge infested cones.

About 20 percent of the current cones were clipped by squirrels, mostly toward late-September and October. Before that, their attacks were restricted to old (previous year) cones; however, on an untagged tree having nonserotinous cones, we observed several young-green cones were chewed by squirrels.

Table 2.--Partial life table for jack pine cones on sampled branches of 20 trees in Oneida Co., WI., June - October 1980.

Reproductive structures	Period (x)	Number of living cones (LX)	Mortality factors (dxF)	Number dying (dx)	Percent mortality (100rx)
Cones	1 - 9 June	1324	Midges	2	0.15
			D. disclusa	3	0.23
			C. pinus pinus	3	0.23
	10 - 17 June	1316	*E. monitorana*	1	0.08
			Midges	2	0.15
			D. disclusa	1	0.08
			C. resinosa	3	0.23
			C. pinus pinus	11	0.83
	18 - 25 June	1298	*E. monitorana*	25	1.89
			D. disclusa	1	0.08
			C. resinosa	3	0.23
			C. pinus pinus	7	0.53
	26 June - 9 July	1262	*E. monitorana*	98	7.40
			Midges	7	0.53
			C. resinosa	4	0.30
			C. pinus pinus	3	0.23
	10 - 17 July	1150	*E. Monitorana*	7	0.53
			Midges	1	0.08
	18 - 31 July	1142	*E. Monitorana*	3	0.23
			Midges	4	0.30
	1 - 13 August	1135	Midges	4	0.30
	14 Aug. - Sept. 20	1131	Squirrel	77	5.82
			Breakage	3	0.23
	21 Sept. - 31 Oct.	1051	Squirrel	182	13.75
Harvest:		869	Total:	455	34.4

Seed Losses

Data on seed damage were gathered from 225 cones, instead of 240 cones, because all cones on one tree were harvested completely by squirrels, and on two other trees less than 12 cones remained. Thirty-nine or 17 percent of harvested cones were infested by L. toreuta. In other studies by the authors (unpublished), infestation by this seedworm reached 23 percent. Kraft (1968) reported from Michigan that seedworm infestation on jack pine cones ranged from 10 to 78 percent.

Table 3.--Average total seeds per cone of jack pine and those defective, Oneida Co., WI., Oct. 1980.

Condition of seeds	Mean Seeds per Cone	Percent
Full seed	26.5	57.9
Defective seed	19.3	42.1
L. toreuta	2.6	5.7
T. bipunctata and others	1.5	3.3
Aborted embryo	15.2	33.1
Total seeds	45.8	100.0

The total of developed seeds ranged from 18 to 93 with the average 45.8 17.7 seeds per cone. Radiography of seeds revealed that 57.9 percent of the developed seeds was sound (Table 3). The seedworm destroyed 5.7 percent of the seeds and the seed bugs 3.3 percent; 33.1 percent were lost to unidentified causes, either physiological disorders or insects. The major physiological cause of hollow seed is self-fertilization resulting in homozygous recessive embryonic lethal alleles (Sarvas, 1962).

DISCUSSION

The magnitude of damage given in the life table demonstrates the important role of each mortality factor affecting seed production in jack pine in north central Wisconsin. It is apparent that insects were responsible for most damage to flower, conelets, and cones.

In general, most of the insects reported here also attack red pine cones (see Lyons, 1959; Mattson, 1978). The major difference was that D. disclusa and C. resinosa were not major mortality factors as in red pine cones. We do not know if they are more adapted to red pine, but the presence of nearby red pine might alter their infestation levels on jack pine. On the other hand, C. pinus pinus E. monitorana, and L. toreuta should be considered a potential threat to jack pine seed production in this area.

The ultimate goal of studying cone and seed insects, certainly is to develop information on which to formulate procedures to maintain high yield of genetically improved seeds. Therefore, periodic surveys are necessary to determine current losses. Surveys for the jack pine budworm infestation on conelets should be conducted in late-May and early June, and for the cone borer in early July when damage is most prevalent. Unlike these two insects, there is no apparent external damage on cones being infested by the seedworm. However, since the larvae overwintered inside the cones; the damage potential on the current cone crop can be assessed from the number of adult emergence holes left on the previous year cones. Consequently, harvesting the cones periodically should reduce seedworm infestation for years.

In implementing control measure, it should be considered that the insect feeding activity extended from as early as late-May (budworm) to mid-October (seed bug). Ideally, long lasting systemic insecticides effective on different kinds of cone and seed insects would prevent further seed losses. Particularly, if the major concern is the cones borer whose early instar larvae, as many as 23, concentrated feeding, in one cone, then the mature larvae dispersed and attacked several fresh cones.

Finally, the data presented are based on the study in a natural stand; in seed orchards where the ecosystem is less complex, cone and seed insects may have an even greater impact on seed yield.

ACKNOWLEDGMENT

The authors wish to express thanks to Dr. D. M. Anderson and Dr. R. J. Gagne of the insect Identification and Beneficial Insect Introduction Institute, Beltsville, Maryland; Dr. B. J. Harrington and Mr. Steven. Krauth of the Insect Research Collection, Department of Entomology, University of Wisconsin-Madison, for identifying the insects. Technical assistance of Mr. Edmund A. Bauer, Mr. William Schulstrom, and Miss Sally Browne are greatly appreciated.

LITERATURE CITED

Chamberlin, W. J. 1939. The bark and timber beetles of North America north of Mexico. OSC. Coop. Assoc. Corvalis, Oregon, Litho. 513 p.

DeBarr, G. L. 1970. Characteristics and radiographic detection of seed bug damage to slash pine seed. Fla. Entomol. 53(2): 109--117.

DeBarr, G. L. and B. H. Ebel. 1974. Conelet abortion and seed damage of shortleaf and loblolly pine by a seed bug, _Leptoglossus corculus_. For. Sci. 20(2): 165-170.

DeBarr, G. L. and L. R. Barber. 1975. Mortality factors reducing the 1967-1969 slash pine seed crop in Baker County, Florida - A life table approach. U.S.D.A. For. Serv. Res. Pap. SE-131, 16 p. South. Forest Exp. Stn., Asheville, N.C.

Ebel, B. H. 1974. Cone and seed insects of shortleaf and loblolly pines in the Georgia Piedmont. _In_ J. Kraus (eds.) Seed yield from southern pine seed orchards, p. 26-30. Proc. Colloq. Georgia For. Cent., Macon, Georgia, April 2-3, 1974.

Ebel, B. H., R. J. Gagne, and E. P. Merkel. 1975. Cecidomyiidae from pine cones in Florida, with a generic key to larvae. Fla. Entomol. 58(3): 193-197.

Goyer, R. A. and L. H. Nachod. 1976. Loblolly pine conelet, cone, and seed losses to insects and other factors in a Lousiana seed orchard. For. Sci. 22(4): 386-391.

Harcourt, D. G. 1970. Crop life tables as a pest management tool. Can. Entomol. 102: 950-955.

Kraft, K. J. 1968. Ecology of the cone moth Laspeyresia toreuta in Pinus banksiana stands. Ann. Entomol. Soc. Am. 61(6): 1462-1465.

Lyons, L. A. 1957. Insects affecting seed production in red pine. IV. Recognition and extent of damage to cones. Can. Entomol. 89: 265-271.

Mattson, W. J. 1978. The role of insects in dynamic of cone production of red pine. Oecologia (Berl.) 33: 327-349.

Rudolph, T. D. and R. A. Cecich. 1979. Provenance and plantation location variation in jack pine seed yield and quality. Proc. First North Cent. Tree Improv. Conf., Madison, WI., August 21-23, 1979, p. 10-20.

Sarvas, R. 1962. Investigations on the flowering and seed crop of Pinus silvestris. Commun. Inst. Forest Fenn. 53.4 198 p.

Waters, W. E. 1969. The life table approach to analysis of insect impact. J. For. 67: 300-304.

White, T. L., H. G. Harris Jr., and R. C. Kellison. 1977. Conelet abortion in longleaf pine. Can. J. For. Res. 7: 378-382.

Yates III, O. H. and B. H. Ebel 1978. Impact of insect damage on loblolly pine seed production. J. Econ, Entomol. 71(2): 345-349.