CONE AND SEED INSECTS--SOUTHERN PINE BEETLE: A CONTRASTING IMPACT ON FOREST PRODUCTIVITY

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Abstract.--As seed orchard production in the South increases, a commensurate recognition of seed losses due to insect attack has developed. It is now evident that value losses resulting from cone and seed insects can be compared with the destruction caused by the southern pine beetle (*Dendroctonus frontalis* Zimm.). While the value losses are comparable, the impact of cone and seed insects on intensive forest management efforts is nearly invisible to all but the tree improvement practitioner. This situation presents a particularly difficult challenge to the researcher as he strives to obtain resources and support to develop control systems which appear attainable with an intensive research and development program of rather finite scope and duration. A similar conclusion is not readily apparent for the research efforts directed toward control of the southern pine beetle. The forestry enterprise is constantly confronted with this dilemma of having to allocate limited resources to investment in production for the long term while simultaneously responding to short-term pressures for these resources which can be spectacular as exemplified by the southern pine beetle attacks.

Additional keywords: Seed value, economic impact, management priorities

INTRODUCTION

First-generation forest tree seed orchards of southern pines are now approaching their full productive potential. Recent reports have shown investments in tree improvement activities to be very profitable. The value of genetically improved seed is surprisingly high when expressed in terms of the present worth of the additional wood available at time of harvest (Porterfield, 1974; Zobel, 1974). However, efficient production of the needed quantities of improved seed is not accomplished without difficulty. Cone and seed insects annually destroy a very significant proportion of the genetically improved seed crop. The dollar value of seed losses is conservatively estimated to be in excess of 25 million dollars annually for the southern forestry enterprise. These heavy losses would seem to be avoidable as the seed orchard insect problems are amenable to solution.

Just a few years ago seed orchard insect pests were known by only a few research entomologists. They are now considered to be the most serious problem confronting seed orchard programs in the South. Even so, the abovementioned financial impact on long-term forest productivity is largely hidden from all but those actively involved with forest tree improvement because it is a loss in potential production, not one easily seen and understood from observing dead and dying trees. In marked contrast is another forest insect pest, the southern pine beetle (*Dendroctonus frontalis* Zimm.). With estimates of damage in epidemic years exceeding 40 million dollars, the southern pine beetle has generally been considered the most economically important insect pest of southern forests.

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Characteristic damage is equally obvious to the forester, the small woodlot owner, and the suburban dweller. The immediate impact, both financially and aesthetically, has historically resulted in public pressure to develop emergency pest control programs for this destructive enemy of the forest. Of recent note is a multimillion-dollar special appropriation by the federal government aimed at developing long-sought-after, and to date elusive, control measures for the southern pine beetle.

It is a constant dilemma for the long-term, high-risk forestry enterprise properly apportion the limited resources available. Priorities must be set amonng efforts directed toward minimizing immediate losses and investments in research and development expected to increase productivity in the future. In an enterprise which is frequently, and many times unavoidably, occupied with crises management, it is not unexpected that the southern pine beetle has received a significant share of the available resources. Yet this is a trend which must be modified if the South is to meet long-term production goals set for the third forest (Anonymous, 1969).

CONE AND SEED INSECTS

Major Insects and Their Habits

The larvae of coneworms (*Dioryctria* spp.) are extremely destructive pests of southern pine seed crops. Among the five species of coneworms, D. *amatella* (Huist) is apparently most widespread and attacks most of the major southern pine species (Goolsby, et al., 1972). The coneworm larvae feed primarily on first- and second-year cones but also on buds, shoots and bases of overwintering cones. Damage is caused by boring into the cone, and, as feeding progresses, the interior of the second-year cone is hollowed out. A damaged cone is all or partially browned prematurely and exhibits one or more larvae entrance holes which are usually clogged with frass and/or a resinous mass. Feeding on first-year conelets can cause complete conelet mortality. Coneworms often have multiple generations per year, the number being dependent on the particular species of insect and latitude. Each generation attacks previously undamaged tissue.

Where chemical control of coneworms has not been practiced, damage has been assessed at 20 to 40 percent of the second-year slash pine (*Pinus elliottii* Engelm.) cone crop (Merkel, et al.). Recent studies in loblolly pine (*Pinus taeda* L.) conducted by the N. C. State Cooperative Tree Improvement Program have shown 20 to 30 percent destruction of the second-year cone crop to be common. Little has been reported with respect to coneworm destruction of first-year conelets, yet losses in the first year may be as much as double those of maturing second-year cones.[1/] It is very clear that an economically significant proportion of the orchard seed crop can be destroyed annually if programs designed to control coneworms are not developed.

The leaf-footed bug (*Leptoglossus corculus* Say) and shield-back bug (*Tetyra bipunctata* H. and S.), both known as seed bugs, are serious pests in all southern pine seed orchards (DeBarr, G. L., 1967). These bugs feed on maturing seed from outside the cone, using a stylet or sucking mouth part to penetrate the cone scales. Enzymes are secreted which digest the developing seed tissues, which are in turn sucked back through the stylet. Because of their feeding habit, damage caused by seed bugs is nearly always imperceptible without magnification.

[1/] Unpublished report from Louisiana State Seed Orchard in DeRidder, La., 1973; and observations in seed orchards of the N. C. State Cooperative

Seed bug damage is frequent on both first-year conelets and maturing second. year cones. In both the first and second year the entire cone may abort when tissue destruction is extensive. Less intensive feeding will result in complete seed destruction, empty seed or partly filled seed. Because seed bug damage is not readily observable, much of the seed and cone damage has been attributed to causes such as inadequate pollination or physiological complications. However, caged conelets subjected to seed bug feeding for as little as a week suffered from 61 to 100 percent abortion, depending on time of year and pine species involved. In the second year of development, loblolly and shortleaf (P. _echinata_ Mill.) cones protected from seed bugs yielded 2-1/2 and 12 times, respectively, more filled seed than unprotected cones (DeBarr and Ebel, 1973). Seed bugs may be the seed orchard managers' most troublesome pest.

There are other insects which collectively can cause significant reductions in orchard seed production. The seed worm, _Laspeyresia_ spp., eggs are laid on second-year cones. Upon hatching, the larvae bore through cone scales into the maturing seed and tunnel from seed to seed within the cone. Not all seed within an infested cone are lost; damage is most common on lower branches of the tree. Pine tip moths (_Rhyacionia_ spp.) find open-grown seed orchard trees ideal for attack. The insect larvae bore into developing shoots of most southern pines. The terminal portion of the shoot which is killed often contains the embryonic reproductive structure. Damage to longleaf (_Pinus palustris_ Mill.) and slash pines is infrequent and control of this insect on loblolly, Virginia (Pinus _virginiana_ Mill.) and shortleaf pines is possible with approved systemic insecticides. The pine flower thrip (_Gnophothrips fuscus_ Morgan) causes significant damage to slash pine female strobili during the very short interval between emergence from the bud and completion of pollination. However brief the damage period, thrips can destroy over 50 percent of the potential slash pine cone crop in a given year if they are not controlled (DeBarr, 1969).

Control

Registered and effective controls for cone and seed inseccs do not generall exist. Notable exceptions are the systemic insecticide Thimet (R) which is used to control tip moth and the foliar spray Guthion (R) which has restricted registration for control of _Dioryctria_ spp. on slash pine. Registration of Guthion is currently under consideration for expansion to all pine seed orchards. Even so, the level of sophistication for cone and seed insect control is minimal. Many additional chemicals need to be examined for efficacy and there is a need for studies directed toward proper timing, dosage, residual activity of the chemicals and application techniques as they relate to insect behavior. Resources to support these critically needed studies have been virtually nonexistent to date.

Economic Impact of Seed Losses

Wood production per acre is expected to increase significantly both in quantity and quality with the use of genetically improved regeneration stock (Zobel, 1974). The amount of growth improvement from first-generation seed orchard seed is conservatively estimated to be 15 percent at time of harvest or rotation age. The value of a pound of loblolly orchard seed can range from $159 to $794 when expressed in terms of the present value of 15 percent additional wood volume produced at the time of harvest (see Table 1). For slash pine, the present value of a pound of seed is 75 percent that of loblolly because 6000 plantable seedlings are generally obtained as compared to 8000 per pound from loblolly. These calculations require assumptions with respect to seedling yields per pound of seed, plantation spacing, growth rate, interest rates and projected stumpage values at rotation age as shown in the table. All assumptions are realistic. The per-pound seed values do not reflect the difference between seed production costs for the orchard and costs for wild seed on the open market. However, recent estimates show that the additional cost of producing orchard seed is in the order of 5 to 10 dollars per pound, an insignificant amount when contrasted to the high values of improved seed. Conversely, the present seed value estimates do not reflect any improvement in tree quality. Although quality improvements are difficult to quantify, they do increase product value, thus the present value of a pound of seed, by an economically significant amount estimated to equal volume gains.

With the value of a pound of seed determined, the economic impact of cone and seed insects can be calculated as the product of the pounds of seed destroyed and the dollar value of each pound. Numerous impact estimates are presented for a representative 40-acre loblolly orchard at three rates of orchard production, 20, 30 and 40 pounds of seed per acre (Tables 2, 3 and 4). The annual reduction in net worth for an organization having such an orchard can range from $25,440 to $508,160, depending on orchard production potential, plantation site quality, and stumpage value 25 years in the future. A reasonable, although probably conservative, estimate of average annual economic losses from insects would be $128,520 for a 40-acre loblolly seed orchard. Southwide, the current value of annual losses could be expected to range from $8,083,908 to $40,419,540 for all loblolly and slash pine orchards combined (Table 5). An approximate Southwide average would be 20 to 25 million dollars in present value of future timber lost per year.

Table 1. Present value of the additional wood obtained from a pound of genetically improved loblolly seed

Stumpage Value ($/cord at harvest 25 years in future)	Present Value of Seed Base growth in cords/acre/year 1.0	 1.5	 2.0
20	$159	$238	$318
25	198	297	397
30	238	357	476
40	317	476	637
50	397	595	794

Assumptions:

1. One pound of seed produces 8000 plantable seedlings.
2. Trees planted at 8' x 10' spacing--approximately 550/acre (1 lb. of seed plants 14.5 acres).
3. Rotation age is 25 years.
4. Genetic gain is 15%.
5. Interest rate is 8%.

Table 2. Present value of 20% seed loss from a 40-acre loblolly seed orchard with potential yields of 20, 30 and 40 pounds of seed/acre/year

Base Growth (cords/acre/year)	Stumpage Value ($/cord at harvest)	Present Value of Seed Lost Seed yields/acre of orchard in lbs. 20	30	40
1.0	20	$25,440	$38,160	$50,880
	25	31,680	47,520	63,360
	30	38,080	57,120	76,160
	40	40,720	76,080	101,440
	50	63,520	95,280	127,040
1.5	20	$38,080	$57,120	$76,160
	25	47,520	71,280	95,040
	30	57,120	85,680	114,240
	40	76,160	114,240	152,320
	50	95,200	142,800	190,400
2.0	20	$50,880	$76,320	$101,760
	25	63,520	95,280	127,040
	30	76,160	114,240	152,320
	40	101,920	152,880	203,840
	50	127,040	190,560	254,080
Total pounds seed lost annually		160	240	320

Table 3. Present value of 30% seed loss from 40-acre loblolly seed orchard wit potential yields of 20, 30 and 40 pounds of seed/acre/year

Base Growth (cords/acre/year)	Stumpage Value ($/cord at harvest)	Present Value of Seed Lost Seed yields/acre of orchard in lbs 20	30	40
1.0	20	$38,160	$57,240	$76,32
	25	47,520	71,280	95,04
	30	57,120	85,680	114,24
	40	76,080	114,120	152,16
	50	95,280	142,920	190,56
1.5	20	$57,120	$85,680	$114,24
	25	71,280	106,920	142,56
	30	85,680	128,520	171,36
	40	114,240	171,360	228,48
	50	142,800	214,200	285,60
2.0	20	$76,320	$114,480	$152,64
	25	95,280	142,920	190,56
	30	114,240	171,360	228,48
	40	152,880	229,320	305,76
	50	190,560	285,840	381,12
Total pounds of seed lost annually		240	360	480

Table 4. Present value of 40% seed loss from 40-acre loblolly seed orchard with potential yields of 20, 30 and 40 pounds of seed/acre/year

Base Growth (cords/acre/year)	Stumpage Value ($/cord at harvest)	Present Value of Seed Lost — Seed yields/acre of orchard in lbs. 20	30	40
1.0	20	$50,880	$76,320	$101,760
	25	63,360	95,040	126,720
	30	76,160	114,240	152,320
	40	101,440	152,160	202,880
	50	127,040	190,560	254,080
1.5	20	$76,160	$114,240	$152,320
	25	95,040	142,560	190,080
	30	114,240	171,360	228,480
	40	152,320	228,480	304,640
	50	190,400	285,600	380,800
2.0	20	$101,760	$152,640	$203,520
	25	127,040	190,560	254,080
	30	152,320	228,480	304,640
	40	203,840	305,760	407,680
	50	254,080	381,120	508,160
Total pounds of seed lost annually		320	480	640

Table 5. Present value of seed losses from insect attack for the combined acreage of slash and loblolly pine seed orchards in the South having seed yield potential of 30 lbs./acre/year

Stumpage Value ($/cord at harvest 25 years in future)	Present Value of Seed Lost Annually — 20% Insect Loss	30% Insect Loss	40% Insect Loss
20	$8,083,908	$12,125,862	$16,167,816
25	10,087,902	15,131,853	20,175,804
30	12,125,862	18,188,793	24,251,724
40	16,167,816	24,251,724	32,335,632
50	20,209,770	30,314,655	40,419,540

Base growth rate assumed to be 1.5 cords/acre/year

Slash pine orchards total	2668 acres
Loblolly pine orchards total	3360 acres
Overall Total	6028 acres

From: Tree Seed Orchards, Forest Service, U. S. D. A., 1974

All insect damage valuations assume that an organization must substitute wild seed for each pound of seed lost in order to meet regeneration needs. Alternatively, if an organization has a surplus of seed, the calculations assume fair market sale values equal to the present values calculated for a pound of seed. These assumptions appear realistic because few, if any, organizations in the South have a surplus of seed either wild or improved. The present scarcit of wild seed is indicative of future conditions. Mature seed-bearing stands are rapidly being harvested and replaced by vigorous plantations which will be harvested on short rotations prior to seed production in meaningful quantities. In the near future almost all seed for the very large regeneration programs will by necessity be produced in seed orchards. As advanced-generation orchards come into production the seed value and the impact of insect damage will increase dramatically because of greater genetic gain. We must learn to minimize seed losses now or pay a high price in the years to come.

The alarming aspect of seed destruction by insects in seed orchards is that the impact will not be evident until 25 or so years from now, at the time of harvest of plantations now being established. All recent projections indicate that demand for wood in the year 2000 will exceed current projections of supply. The need for immediate control of cone and seed insect populations in our southern pine seed orchards is critical. Without seed, there will be no regenerated forests to protect from other pests.

SOUTHERN PINE BEETLE

The Insect and Its Habits

The southern pine beetle (SPB) has historically been known as the most destructive insect pest of southern pines. The beetle normally attacks weak or stressed trees, but can kill very vigorous, healthy trees during epidemic outbreaks. Population buildup and the associated destruction of the southern pine forest by the SPB is very cyclical. Epidemic populations have been known to develop rapidly following periods of prolonged drought or very mild winters; at other times populations grow to epidemic size for no apparent reason. Except during epidemics the SPB is difficult to find; this frequent scarcity has presented great difficulty in controlled study of this insect.

The SPB beetle attacks a tree by boring into the bark and eventually the phloem and cambial tissues. The beetles construct S-shaped tunnels in and under the bark and are believed to kill the tree by girdling and the introduction of blue-stained fungi. Eggs are laid within the crisscrossing tunnels which develop into larvae of the succeeding generation of adults. The life cycle of the SPB is usually completed within 30 to 50 days; depending on latitude, as many as five to six generations may be produced annually (Thatcher, 1960).

Each brood adult bores its own emergence hole and flies to a new site of attack. The parent adults often exit from a host tree when the brood is still in the larval stage. It may reattack the same tree or attack uninfested trees at varying distances from the original attack. Trees are killed in groups that may vary from a few to many thousands in size. In large forested areas, damage spots are often located by aerial spotting of yellowing or brownish-red trees which are dying or dead. When foliar symptoms of insect attack become evident, the beetles have usually left the tree, making control most difficult.

Control

Effective control of epidemic outbreaks of the SPB is complicated by the characteristic infestation of localized stands of pines in an unpredictable pattern over a broad area of forest. Even with remote sensing methods, timely location of active population centers is often difficult, since the SPB is prone to move to a new area by the time damage symptoms are confirmed.

Chemical spray programs have generally proved to be ineffective in checking population buildup of the SPB (Coulson, et al., 1972). Even the traditional salvage cutting coupled with a BHC (benzene hexachloride) spray effort could not be shown statistically effective during a beetle buildup in east Texas. Use of fast-acting herbidides containing cacadylic acid (dimethyl arsenic acid) injected into recently attacked trees has resulted in as much as 97% brood reduction (01lieu, 1969). However, treatment success was considerably reduced if trees were not treated within 3-4 days of the initial attack. Logistic difficulties limit this method as an effective control. Recent research in control techniques has contented on methods of population manipulation by using attractants in conjunction h either chemical control or trapping. Although promising, these methods have yet to be proven economically feasible and biologically effective for large-scale operational control. Recent federal appropriations have been approved which will support an extensive program for developing these and other SPB control measures.

The Economic Impact of the Southern Pine Beetle

The immediate impact of SPB-killed trees can be most dramatic in both a financial and aesthetic sense. It is most often the mature, fully grown, merchantable trees which are attacked. The subsequent mortality can result in considerable financial loss to the industrial forestry concern and the small private owner. In addition, there is aesthetic degradation of parks, recreation areas and residential property, including the attractive tree-lined streets of southern cities.

Although salvage operations are frequently extensive and costly during periods of epidemic SPB attack, such efforts are at best means of minimizing losses. Salvage operations resulting from SPB kill are commonly undertaken on a very large scale by forest industry, yet it is done at a considerable cost. Simply locating the beetle-killed areas can be a continuous and costly task for a large industrial forest landowner. The timber killed by beetles is subject to rapid degrade, first by blue-stain infection and ultimately complete decay results from the action of other wood-destroying insects and fungi. Thus salvage must be fast and continuous if losses are to be minimized.

Sometimes the dead timber is not readily accessible and salvage requires construction of new and previously unplanned roads. Such road construction is often impossible or impractical before the timber undergoes serious degrade or actual decay. Even if accessibility is not a factor, the small scattered clumps of mortality do not present an attractive logging chance. The manager is then forced to either offer the timber at an extremely low stumpage price or to cut a larger section of the stand, including much healthy timber. When the latter course is followed, the forest manager can adversely alter cutting budgets to the extent that years are required to properly rectify the management plans. All of this is extra, unplanned work occurring at unpredictable times and at a very high cost. All too frequently salvage cannot be accomplished and the timber killed is a total loss.

The small woodlot owner experiencing SPB kill is faced with an even more serious dilemma. lie can simply forego salvage and suffer the loss or he can harvest enough of the stand, including the infested trees, to make the logging worthwhile. Timber sales resulting from salvage cuts often occur at a time when open market stumpage prices are depressed due to an oversupply of such wood, causing the small landowner to lose no matter what course of action he follows.

The homeowner with shade trees killed by the SPB is seldom able to recoup any losses from salvage cutting. In fact, he must frequently pay a substantial fee to have dead trees removed. Residential property can suffer serious devaluation if a significant portion of the trees is lost. The aesthetic losses resulting from the mortality of large trees in parks and recreation areas is very difficult to assess. Yet in such areas we all may experience a very distinct, albeit intangible, reduction in the quality of our recreational experience.

An effort has been made to estimate and quantify in economic terms the Southwide losses resulting from SPB attack. These data (Table 6) have been collected for a 14-year period extending from 1960 through 1973 by the Southern Forest Insect Work Conference Committee on Losses Caused by Forest Insects. The present value (year 1975) of the loss estimates ranges from a low of $423,500 to a high of $48,473,600; the 14-year average is nearly 10 million dollars per year. The committee has cautioned that these data are incomplete. However, these data should allow assessment of the relative impact of SPB damage as compared to other forest insects. This assumption is given credence from the enormous magnitude of loss, particularly in epidemic years such as 1973. The southern pine beetle deserves its reputation as one of the most economically important pests in the southern forest.

Table 6. A yearly assessment of losses sustained Southwide from southern pine beetle attack: 1960 through 1973

Year	Annual Estimate of Damage Assessment 1/	Year	Annual Estimate of Damage Assessment 1/
1960	$6,056,100	1967	$228,800
1961	1,259,900	1968	664,310
1962	4,554,300	1969	1,740,400
1963	1,094,000	1970	1,296,000
1964	553,300	1971	4,143,000
1965	701,870	1972	28,802,700
1966	974,920	1973	41,558,300
		Total	$93,607,900
		Avg./Year	9,686,200

1/ From reports of the Southern Forest Insect Work Conference Committee on Losses Caused by Forest Insects

CONE AND SEED INSECTS VERSUS THE SOUTHERN PINE BEETLE-- A DISCUSSION OF CONTRASTS

It is the objective of this discussion to show, by contrasting the value losses resulting from cone and seed insects to those of the SPB activities, that the destruction of seed orchard crops is of critical importance. Damage from cone and seed insects can be of the same order of magnitude as damage from the worst known insect pest of the southern forest, yet there is a distinct lack of general awareness and knowledge about these long-term losses. This situation mus be corrected.

The most recent epidemic outbreak of SPB (1972-1975) has raised the public concern over this pest to an all-time high. As a result, federal support in the millions of dollars has become available for a five-year program directed toward research and development of SPB control measures. Certainly the problems are serious and the need for additional research effort cannot be denied. However, many have questioned whether significant positive results can be expected from such a crash program. Research on control of this insect has been underway for at least two decades and positive results have been elusive. Recent concern over environmental consequences of extensive insecticide applications has greatly reduced that option. The development and evaluation of less traditional control systems is threatened by the unpredictable likelihood of complete SPB population collapse. It is not possible to study means for operational control of epidemic conditions after the insect has virtually disappeared.

The support for research and development of cone and seed insect control has always been limited and has not increased commensurate with its need. In contrast to recent appropriations for SPB research, cone and seed insect work is at the present time virtually fundless. This situation exists despite an excellent probability of developing very effective and operationally feasible control measures with a research program that is relatively moderate in size and duration. Similar pest problems have been solved in horticultural crops such as fruit and nut orchards. A suggested experimental program to attack the problem would include:

1. Select the most promising insecticide(s) on the basis of laboratory and field screening.
2. Determine the proper timing, dosage and application method of the insecticide(s) on the basis of the insect life cycle(s).
3. Operationally demonstrate the effectiveness of control methods with regionwide studies.

. Continue studying the biology of the insect(s).

Development of control techniques for cone and seed insects is lacking in complexity when compared to the problems encountered with the SPB. Controls are to be concentrated on limited acreage, under 10,000 total. In addition, cone and seed insect populations are more predictable; they do not undergo the cyclical extremes ranging from epidemic outbreaks to virtual disappearance that is so characteristic of the SPB.

Some have argued that research support for cone and seed insect control should be the responsibility of forest industry. The rationale has been that industries own the seed orchards and they will derive the benefits from insect control. This argument is not justified. Latest statistics indicate that 51% of the southern seed orchard acreage is under the control of state and federal governments. The seed and subsequently the trees produced from these orchards will be used to regenerate public and private lands alike. In the long run, increasing the productivity of such plantings will benefit the consumer at large by increasing wood supply and thus reducing the price of wood products. Control of cone and seed insects as an integral part of seed orchard management is an activity which can benefit all, including forest industries.

A final contrast involving the SPB versus cone and seed insects has the characteristics of a continuous dilemma confronting managers of the forestry enterprise. By virtue of the long-term nature of forest production, long-range planning is a necessity. However, forestry organizations are never immune to short-term pressures which demand the best available crisis management. The dilemma is to strike a proper balance in setting priorities among the long- and short-term demands. The control of SPB with its highly visible and abrupt impact is a current problem needing immediate attention. The impact of cone and seed insect attack will generally be realized in the long term. Yet if serious financial losses and wood shortages with higher prices are to be avoided in the future, investment in research and development of control measures must be initiated today. With limited resources available, the priority decisions are never easy. It would not be appropriate to advocate increased funding of cone and seed insect research at a major expense of SPB efforts. It is proper, however, to recognize the importance of cone and seed insect destruction, and for each organization to adjust priorities in a manner that will balance the expenditure of resources among the short-term demands and the long-term investment in increased forest production.

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