A Southwide Rate Test of Azinphosmethyl (Guthion®) for Cone and Seed Insect Control in Loblolly Pine Seed Orchards

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ABSTRACT. *A southwide efficacy test of reduced rates of azinphosmethyl (Guthion®) for control of seed and cone insects in loblolly pine seed orchards was conducted in 1992. In each of nine loblolly pine* (Pinus taeda *L.) seed orchards, an untreated (no protection) check and two of five possible rates of Guthion® (1.0, 1.5, 2.0, 2.5, or 3.0 lb ai/ac/application) were randomly assigned to three test plots. Insecticide treatments improved first-year conelet survival, second-year cone survival, sound seeds per cone, and sound seeds per conelet at nearly every rate. There was no trend of better protection with increasing rates of Guthion®. The 1.0 lb ai/ac rate was as efficacious as the EPA-registered maximum aerial rate of 3.0 lb ai/ac. Based on these results, orchard managers should consider reduced rates of Guthion® for operational cone and seed insect control programs. South. J. Appl. For. 22(2):106-110.*

Cone and seed insects can severely limit seed production in southern pine seed orchards which produce genetically improved seed for regeneration programs. Important insect pests include the coneworms (*Dioryctria* spp.) that feed in the flowers, cones, and stems of pines; and the leaf-footed pine seed bug (*Leptoglossus corculus* [Say]) and the shieldbacked pine seed bug (*Tetyra bipunctata* [Herrich-Schaffer]) that suck out the contents of developing seeds in cones and conelets (Ebel et al. 1980). Untreated, these insects can destroy as much as 90% of the potential seed crop (Fatzinger et al. 1980).

Azinphosmethyl (Guthion®)[1] is one of several insecticides registered for cone and seed insect control (Nord et al. 1984) and is extensively used for this purpose (Lowe et al. 1991). Guthion® was registered by the Environmental Protection Agency (EPA) for use in loblolly (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm.) seed orchards (high-and low-volume ground applications) in 1975 (vanBuijtenen 1981). Since 1980, Guthion® has been applied aerially at a standard rate of 3 lb ai/ac/treatment with four to six sprays in

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a growing season (Nord et al. 1985). Evidence suggests that lower application rates may be effective. Guthion® controlled coneworms in slash pine when applied at 1.5 lb ai/ac in 100 gal of water applied four times per season (Merkel 1964).

Environmental and economic concerns are generating pressure to minimize chemical pesticide use. In addition, because the total amount of pesticides applied, in seed orchards is very small relative to that in other agricultural uses, it is difficult to maintain the registrations for seed orchards. High costs of developing and registering new pesticides make the situation critical. Consequently, the need for further testing of presently registered insecticides is apparent.

The Seed Orchard Pest Management Subcommittee (SOPMS), of the Southern Forest Tree Improvement Committee, was established to address the critical need for insect pest management in southern seed orchards (Lowe et al. 1994, VanBuijtenen 1981). A priority of the SOPMS is to retain the registration of current pesticides, including Guthion®. A reduced application rate which is efficacious while minimizing costs and environmental hazards is a strong positive factor in favor of continued registration. During the early 1980s, aerial applications of Guthion® were tested at a single rate because funds and test sites were limited. As tests on an operational level require large areas of seed orchards to test the efficacy of aerially applied chemicals, no single organization has the necessary resources or expertise available. Consequently, in 1992, the SOPMS coordinated a southwide test of various rates of Guthion® for control of cone and seed insects in operational seed orchards involving several organizations.

Materials and Methods

Nine loblolly pine seed orchards were used for the test (Table 1). Each orchard had three treatment plots at least 5 ac in size. Treatments in each orchard consisted of an unprotected check plot and two of five possible rates of Guthion® (1.0, 1.5, 2.0, 2.5, or 3.0 lb ai/ac/application) randomly assigned to the test plots. Each rate/treatment combination was present in at least three orchards. Six monthly applications were made from March to August; the first application was within 7 days after peak pollen flight. Applications were applied aerially by fixed-wing or rotary-wing aircraft adhering to the following standards: 60 ft swath width, 5 gal/ac of solution applied on each of two passes in opposite directions, 350 micrometer volume-mean-diameter droplet size, and release height of 10-20 ft above the trees. Two ramets from six clones in each plot were monitored. A sample of 50 healthy first-year conelets and second-year cones were tagged in the spring on each ramet, and survival counts made in the fall prior to cone harvest. In June, *D. disclusa*-infested cones were counted on the south side of the crown of the selected ramets in each orchard. At harvest, all cones were collected from each ramet and classified as healthy or damaged according to Nord et al. (1984) and the damaged cones were examined by entomologists to determine extent of coneworm infestation. A sample of ten healthy cones was taken from each ramet. Seeds from these cones were extracted and radiographed to determine total seeds, filled (sound) seeds, empty seeds, and seed bug-damaged seeds (Bramlett et al. 1977). Traits evaluated were first-year conelet survival, second-year cone survival, cone yields, insect damage and seed yields for each sample ramet. The design was an incomplete randomized block design, with orchards serving as blocks. Statistical analyses were done with SAS (SAS Institute 1987) using a planned f-value of 0.10. This probability level is often used for operational tree-improvement studies where practical significance is of more concern than statistical precision and a greater specified risk of Type I error is acceptable.

Each orchard had an unprotected plot but only two of the five Guthion® rates, thus efficacy estimates for the rates were made relative to the unprotected plot in each respective orchard. For each variable, two different expressions of data were examined: (1) the *absolute increase* in the variable calculated as the treatment mean minus the unprotected mean ($\bar{x}_t - \bar{x}_c$), and (2) the protection *efficiency*, calculated as ($\bar{x}_t - \bar{x}_c$)/($y_{max} - \bar{x}_c$), expressed as a percent, and where y_{max} is the maximum possible value for the dependent variable y given ideal conditions. For example, the traits conelet survival and second-year cone survival are measured as a percentage of the initial flower crop. Since both survival measures are in percent, y_{max} for these variables is 100%. For the traits sound seed per conelet and sound seed per cone, y_{max} is the seed potential, the biological capacity of each individual

Table 1. Cooperators and treatment rates for the 1992 southwide Guthion® rate test.

Orchard no.	Cooperator	Location	Treatment rate (lb ai/ac/spray)		
1	Bowater, Inc.	York County, SC	0	2.0	2.5
2	Champion International Corporation	Santa Rosa County, FL	0	1.5	2.0
3	Champion International Corporation	Polk County, TX	0	1.0	1.5
4	Container Corporation of America	Escambia County, AL	0	1.0	3.0
5	Deltic Farm and Timber, Inc.	Columbia County, AR	0	2.5	3.0
6	Mississippi Forestry Commission	Lamar County, MS	0	1.5	2.5
7	Mississippi Forestry Commission	Lamar County, MS	0	1.5	3.0
8	Temple-Inland Forest Products	Jasper County, TX	0	2.0	3.0
9	Westvaco Corporation	Charleston County, SC	0	1.0	2.0

[1] The mention of a trade name is solely to identify material used. All pesticides must be registered by the appropriate state and federal agencies before use.

cone to produce sound seed (Bramlett and Godbee 1982). For sound seed per cone and sound seed per conelet, y_{max} equals 155, the maximum seed potential for loblolly pine cones (Bramlett 1977).

The protection efficiency measures the benefit achieved by treatment (e.g., higher survival or more seed per cone) relative to the maximum benefit possible if a treatment prevented all loss due to insects (Hodge et al. 1993). For our purposes, we assume that all loss is due to insects; and if all the insects are controlled then y_{max} will be realized. For example, if all insects are killed, there will be 100% first-year conelet survival.

Results and Discussion

Nearly every rate of Guthion® increased first-year conelet survival, second-year cone survival, sound seeds per cone, and sound seeds per conelet. However, losses caused by insects varied among the orchards. Consequently, o&discussion will focus on treatment responses relative to the unprotected plot in each orchard. Infestation by *D. dislusa* was less than 5% in all the orchards; therefore, no further analysis of these data was done.

First-Year Conelet Survival

Average first-year conelet survival in the unprotected plots of the nine orchards was 7 1% and ranged from 46% to 87%. Survival in treated plots was higher in all orchards. Average first-year conelet survival for the 1.O lb ai/ac treatment was 15% greater than for the unprotected plot in the three orchards where the 1.0 lb ai/ac treatment was applied. The corresponding values were 15%, 18%, 23%, and 18% for the 1.5, 2.0, 2.5, and 3.0 lb ai/ac treatments, respectively (Figure la). Although there was slightly higher survival at rates 2.0, 2.5, and 3.0 lb ai/ac, a linear regression of absolute increase on the independent variable rate was not significant, indicating no tendency for higher levels of control with increasing rate. The larger increases in first-year conelet survival at the higher Guthion® rates were related to the lower survival (suggesting larger insect populations) in unprotected plots of the orchards where thoserates were applied (Figure la). When control was expressed in terms of protection efficiency, differences in efficacy among the various rates of Guthion® (Figure 1 b) were small. A linear regression of protection efficiency for first-year conelet survival on rate was not significant, again indicating no tendency for higher levels of control with increasing insecticide rate.

Second-Year Cone Survival

Average second-year cone survival was 84% in the unprotected plots and ranged from 72.5% to 93.5%. Second-year cone survival was increased above survival in the unprotectedplots by 7.6%, 10.6%, 6.5%, 6.2% and 0.4% by the 1.0, 1.5, 2.0, 2.5, and 3.0 lb ai/ac/treatments, respectively (Figure lc). Similar results were observed with the protection efficiency for second-year cones (Figure 1d).

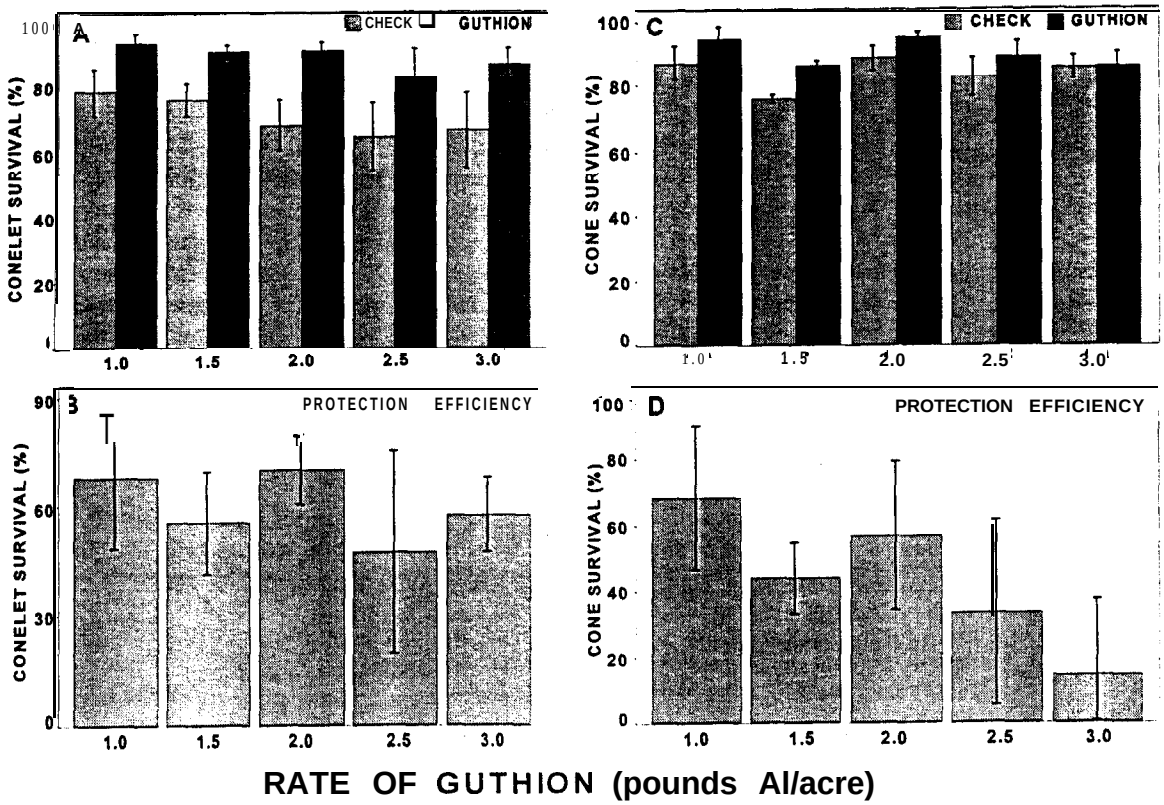

Figure 1. Effects of operational aerial application of five rates of Guthion® on (a) average first-year conelet survival, (b) average protection efficiency for first-year conelet survival, (c) average second-year cone survival, and(d) average protection efficiency for second-year cone survival for loblolly pine seed orchards participating in the rate test. Each orchard had a check (unprotected) plot but only two of the five Guthion® rates; hencevalues represent averages from orchards with the specified treatment and their respective check plots. Lines on bars signify standard error of the mean. The protection efficiency measures the benefit achieved by treatment (e.g., higher survival or more seed per cone) relative to the maximal benefit possible if a treatment prevented all loss due to insects.

The very Small increase in second-year cone survival observed in the 3.0 lb ai/ac rate led to a significant regression (P = 0. 10) of absolute increase and protection efficiency on rate: however, the coefficients in both equations were negative indicating a tendency for lower levels of control with increasing rates of Guthion®. However, this is difficult to reconcile biologically and is probably spurious.

Sound Seed Per Conelet

Average sound seeds per conelet in the unprotected plots of the nine orchards was 35.4 seeds. Sound seeds per conelet increased above the control by 35.8, 22.7, 36.5, 35.1, and 2 I .7 seeds for Guthion® rates | .O through 3.0 lb ai/ac/treatment (Figure 2a). Linear regression of sound seeds per conelet on rate was not significant. Similar results were obtained with protection efficiency (Figure 2b). In every case, sound seeds per conelet from the Guthion® treatments was increased approximately two-fold over the control.

Sound Seeds Per Cone

Average sound seeds per cone in the unprotected plots of the nine orchards were 55.9 seeds and ranged from 27.1 to 85.7 seeds. Average sound seeds per cone were increased 30.6, 17.6, 23.3, 20.6, and 18.6 seeds for GuthionB rates 1.0 through 3.0 lb ai/ac/treatment (Figure 2c). Linear regression of seed per cone on rate was not significant. Similar results were obtained with protection efficiency (Figure 2d).

Conclusions

Guthion® applications reduced losses to cone and seed insects at all of the rates tested in the 1992 southwide study. Furthermore, there was no trend of increasing insect control with increasing rates of Guthion®. The 1.0 lb/ac rate was as efficacious as the EPA registered rate of 3.0 lb/ac. However. Guthion® persistence on loblolly pines. and in turn. its effectiveness for cone and seed insect control, can be greatly reduced by rainfall (Nord and Pepper 199 I, Nord and DeBarr 1992). Aerial applications of GuthionB at a rate of 1.5 lb/ac should provide adequate coverage for good cone and seed insect control. GuthionB is the only organophosphorus insecticide currently registered for seed orchard use (DeBarr 1993). and it is important that it remain available to seed orchard managers. Guthion® has provided effective insect control in southern pine seed orchards for more than 20 yr, without evidence of insect resistance (DeBarr, unpublished), or serious secondary pest outbreaks that have accompanied the use of pyrethroids (Clarke et al. 1990, Clarke et al. 1992). This test suggests that the rate of GuthionB used in operational cone and seed insect control programs could be reduced to lessen risk and cost.

Literature Cited

BRAMLETT, D.L., ET AL. 1977. Cone analysis of southern pines. A guidebook. USDA For. Serv. Gen. Tech. Rep. SE-13. 28 p.

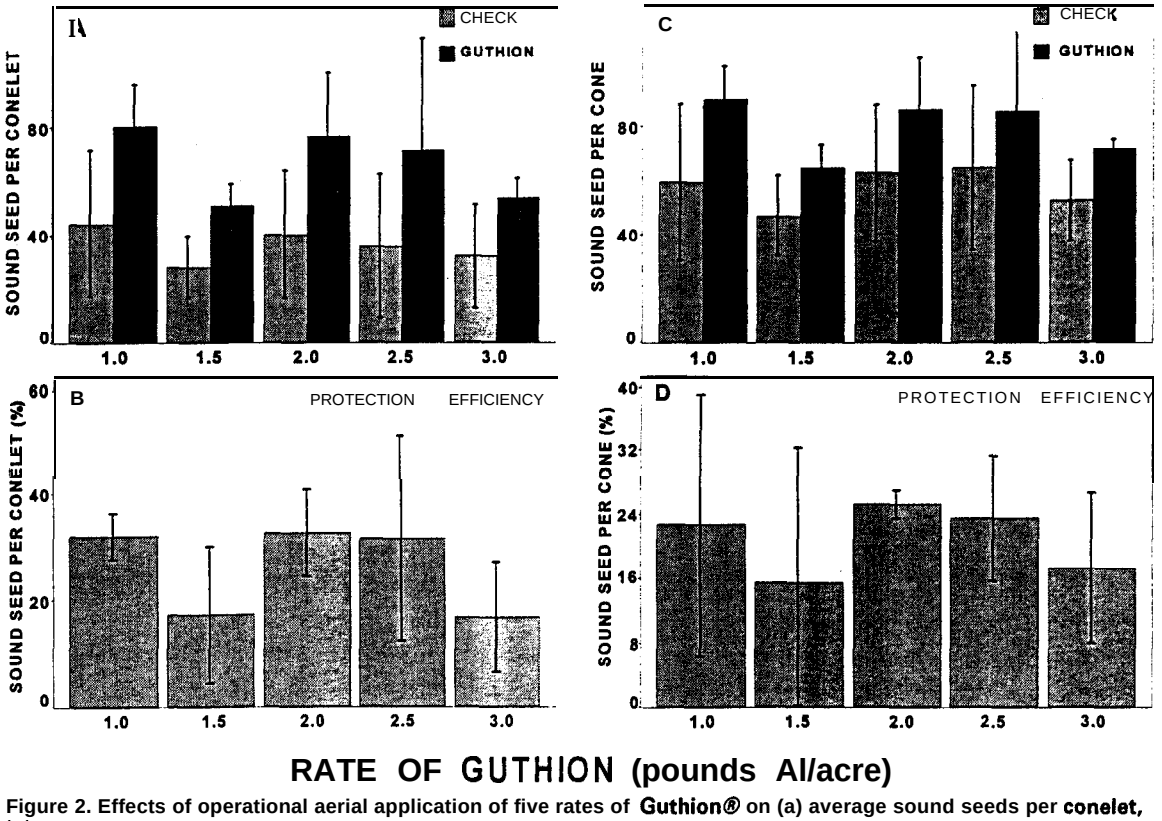

Figure 2. Effects of operational aerial application of five rates of Guthion® on (a) average sound seeds per conelet, (b) average protection efficiency for sound seeds per conelet, (c) average sound seeds per cone, and (d) average protection efficiency for sound seeds per cone for loblolly pine seed orchards participating in the rate test. Each orchard had a check (unprotected) plot but only two of the five Guthion® rates; hence values represent averages from orchards with the specified treatment and their respective check plots. Lines on bars signify standard error of the mean. The protection efficiency measures the benefit achieved by treatment (e.g., higher survival or more seed per cone) relative to the maximal benefit possible if a treatment prevented all loss due to insects.

BRAMLETT, D.L., and J.F. GODBEE, JR. 1982. Inventory monitoring system for southern pine seed orchards. Georgia For. Comm. For. Res. Pap. 28. 17 p.

CLARKE, S.R., G.L. DEBARR, AND C.W. BERISFORD. 1990. Effects of fenvalerate and azinphosmethyl on scale insects and their natural enemies in loblolly pine seed orchards. USDA For. Serv. Res. Pap. SE-279. 14 p.

CLARKE, S.R., J.F. NEGRON, AND G.L. DEBARR. 1992. Effects of four pyrethroids on scale insect (Homoptera) populations and their natural enemies in loblolly and shortleaf pine seed orchards. J. Econ. Entomol. 85(4):1246–1252.

DEBARR, G.L. 1993. Challenges for insect pest management in forest tree seed orchards. P. 464-473 *in* Proc. 22nd South. For. Tree Improve. Conf.

EBEL, B.H., ETAL. 1980. Seed and cone insects of southern pines. USDA For. Serv. Gen. Tech. Rep. SE-8.44 p.

FATZINGER, C.W., ETAL. 1980. Identification and sequential occurrences of mortality factors affecting seed yields of southern pine seed orchards. USDA For. Serv. Res. Pap. SE-216. 43 p.

HODGE, G., ET AL. 1993. Cooperative forest genetics research program, 35th annual progress report. Dep. of For., School of For. Resour. and Conserv. Univ. of Florida, Gainesville. 46 p.

LOWE, W.J., ET AL. 1994. A southwide test of bifenthrin (Capture@) for cone and seed insect control in seed orchards. South. J. Appl. For. 18:72–75.

MERKEL, E.P. 1964. Hydraulic spray applications of insecticides for control of slash pine cone and seed insects. USDA For. Serv. Res. Pap. SE-9. 7 p.

NORD, J.C., AND G.L. DEBARR. 1992. Persistence of insecticides in a loblolly pine seed orchard for control of the leaf-footed pine seed bug, *Leptoglossus corculus* (Say) (Hemiptera:Coreidae). Can. Entomol. 124:617–629.

NORD, J.C., ET AL. 1984. High volume applications of azinphosmethyl. fenvalerate, permethrin, and phosmet for control of coneworms (Lepidoptera:Pyralidae) and seed bugs (Hemiptera:Coreidae and Pentatomidae) in southern pine seed orchards. J. Econ. Entomol. 77:1589–1595.

NORD, J.C., ET AL. 1985. Low volume applications of azinphosmethyl, fenvalerate, and permethrin for control of coneworms (Lepidoptera:Pyralidae) and seed bugs (Hemiptera:Coreidae and Pentatomidae) in southern pine seed orchards. J. Econ. Entomol. 78:445–450.

NORD, J.C.. AND W.D. PEPPER. 1991. Rainfastness of insecticide deposits on loblolly pine foliage and the efficacy of adjuvants in preventing washoff. J. Entomol. Sci. 26(2):287–298.

SAS INSTITUTE INC. 1987. SAS/STAT guide for personal computers. Version 6. SAS Institute Inc. Cary, NC. 1028 p.

VANBUIJTENEN, J.P. 1981. Insecticides for seed orchards-a case study in applied research. South. J. Appl. For. 5:33–37.