TRICKLE IRRIGATION AND SYSTEMIC INSECTICIDES FOR CONTROLLING TIP MOTH IN YOUNG SEED ORCHARDS

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Abstract.--Initial investigations indicate that liquid formulation, systemic insecticides can be successfully applied through trickle irrigation systems for pine tip moth control. Furadan and Di-Syston are the favored chemicals. Trickle irrigation system design is an important consideration when planning insecticide applications.

Additional keywords: Rhyacionia spp., carbofuran, disulfoton, irrigation design.

Trickle irrigation has proven to be a cost-effective approach to the application of water and certain fertilizers in seed orchards (O'Loughlin 1979) Additionally, various other agricultural chemicals have been applied through irrigation systems in various agronomic crops (Anonymous 1979). Insecticide application through trickle irrigation systems is attractive for several reasons including:

1. Tractors, associated labor and equipment are not required for application.

2. Lack of soil moisture that could prevent root uptake of soil-applied insecticides is not a concern.

3. Heavy single applications with accompanying hazards to man and wildlife are avoided.

4. Lower levels of the insecticides can be applied periodically as required for tree protection.

5. Fading insect control late in the growing season, associated with a single early-season insecticide application, is avoided.

6. Savings in chemical costs by a potential reduction in the amount of insecticide required.

Pine tip moths (Rhyacionia spp.) cause a significant growth reduction in young seed orchard trees. International Paper Company has a number of trickle irrigation systems established in their orchards and, in an effort to utilize these systems to their best advantage, investigations into insecticide application through these trickle systems were begun.

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Since a successful insecticide application through a trickle system would be similar to a soil drench application, various systemic liquid-formulation chemicals that held promise of effective soil drench application were field tested. Several questions had to be resolved regarding the feasibility of this approach.

1. Would any of the potential insecticides be harmful to various trickle irrigation components?

2. Would a trickle irrigation pattern of water placement (7.5' x 20' grid) and timing of application prove adequate for root uptake and insect protection?

3. Which insecticides and rates of application would be most effective in controlling tip moth?

4. Could the insecticides be successfully metered into the trickle system and uniformly applied to the trees?

METHODS

The six chemicals that were field tested in 1979 (Table 1) were evaluated for irrigation component deterioration by soaking various plastic components in a 1:1 mixture of each liquid insecticide and water for 48 hours at room temperature.

Table 1.--Liquid Formulation Insecticide Rates (1979)

		Annual Application Rate (Pounds Active Ingredient)	
Chemical	Pounds Active Ingredient/Gal.	Per Tree	Per Inch Basal Diameter
Furadan (carbofuran)	4.00	0.050	0.020
Di-Syston (disulfoton)	6.00	0.046	0.018
Systox (demeton)	2.00	0.040	0.016
Bidrin (dicrotophos)	8.00	0.012	0.005
Cygon (dimethoate)	2.67	0.040	0.016
Metasystox-R (oxydemeton-methyl)	2.00	0.100	0.040

Various insecticides and rates of application were evaluated during the springs of 1979 and 1980 on loblolly pine (*Pinus taeda L.*) grafts at the Bellamy Seed Orchard located near Marianna, Florida. Tree spacing is 15 x 20 feet. Soils on this orchard are well drained, moderately fertile Orangeburg loamy sand and Red Bay fine sandy loam which were previously under cultivation. Subsoil, beginning at 6 to 18 inches, is a sandy clay loam. The 1979 insecticide applications (Table 1) were begun in early April on vigorous young grafts beginning their third growing season in the orchard. Tree diameter at the ground line was 2 to 3 inches and tree height was 4 to 6 feet. Each treatment plot consisted of five trees and was replicated three times. Tip moth infestation was evaluated in June and September by determining the proportion of the 10 uppermost shoots attacked per tree. Insecticide (diluted with an equal volume of water) in one experiment was applied as a single dose at the beginning of the season (early April) and, in another experiment, was split into eight smaller applications evenly distributed over the growing season. The total amount of active insecticide in the eight smaller applications was equivalent to the single April application. A total of 210 trees were included in the studies. The insecticide for a particular tree was applied to the soil in a very small area (<10 sq. in.) immediately adjacent to the two 1/4-inch water delivery tubes, each located about 3.5 feet opposite the bole in a N-S orientation. The irrigation system was run normally throughout the growing season, thus a trickle system application was simulated.

The 1980 evaluations were primarily rate tests. The first phase (late May) was a shadehouse evaluation of phytotoxicity in potted (1 gallon nominal) rootstock plants 18 to 24 inches tall that were somewhat rootbound. Each insecticide rate was diluted in a half gallon of water and applied as a soil drench on four potted seedlings. A mid-June evaluation was completed.

The second phase of the 1980 evaluations involved a single soil drench around vigorous, well-established young orchard grafts that were beginning their second growing season in the orchard. Tree height was 2 to 3 feet and ground diameter was 1 to 1-1/2 inches. The June insecticide application (Table 2) involved five trees/treatment in each of three replicates for a total of 225 grafts. September shoot infestation was evaluated according to the previously-mentioned method. Unlike the 1979 test, the insecticides were diluted in one quart of water and the soil was drenched within the 4 square feet immediately around the tree. Irrigation continued normally throughout the growing season. The trees in this test were irrigated with both water delivery tubes at the immediate base of the tree, which is the standard orchard practice on these size trees.

Table 2.--Liquid Formulation Insecticide Rates (1980)*

		Annual Application Rate (Pounds Active Ingredient)			
		Low Rate		High Rate	
Chemical	Ingredient/Gal.	Per Tree	Per Inch of Basal Diameter	Per Tree	Per Inch of Basal Diameter
Furadan	4.00	0.013(¼x)	0.010	0.025(½x)	0.020
Di-Syston	6.00	0.138(3x)	0.110	0.276(6x)	0.221
Systox	2.00	0.120(3x)	0.096	0.240(6x)	0.192
Bidrin	8.00	0.036(3x)	0.029	0.072(6x)	0.058
Orthene (acephate)	0.75/Pound of Wettable Powder	0.055	0.044	0.110	0.088

*Chemical rates are noted as multiples of the 1979 per tree test rates (x).

One of the chemicals that performed successfully in the above evaluations (Furadan) was actually metered into the irrigation system and discharge samples taken at various tree locations within a subsection of the orchard. Twelve locations were selected (two sample stations 20 feet apart/location) to give a selection of the various distances the insecticide would be carried within the irrigation piping system. An initial run indicated that, to bracket the application curve for each location, a 30-minute injection cycle required a minimum of six samples (per location) at the following times (zero minutes = start of the injection cycle): 10, 20, 30, 45, 60 and 75 minutes. A total of 144 samples were analyzed from these stations. Using the ppm (parts per million by weight) analyzed in each sample and multiplying this by the number of minutes the sample represented (ppm minutes), the total amount of chemical sampled can quickly be compared with an expected value.

Prior to injection, liquid Furadan was mixed with water in a 1:11 ratio, and was continuously agitated during the 30-minute injection cycle. After the discharge samples were collected, the irrigation was continued for 24 operating hours, then the system was flushed. The water that was pumped through the system during the flush was also sampled at various flush ports 1, 4 and 8 minutes from the beginning of the flow cycle. Six of the sample points were located on submain flushing ports, and 12 of the sample points on lateral flushing ports. A total of 54 flush samples were taken. If any of the chemical settled in the irrigation piping system during the injection cycle, the high water velocity of the flush cycle would have picked it up along with any other sediment.

A high pressure liquid chromatograph analyzed the samples for the insecticide by light absorption at 274.3 micrometers. Detection limit of the analysis was one part/million by weight.

RESULTS AND DISCUSSION

The 1979 tip moth population was relatively low and the June evaluation showed very little infestation. The lack of data from the June evaluation prevented an estimate of the initial protection provided by the various treatments. Counts from the September evaluation were transformed by $\sqrt{X+1}$ and ANOVA's indicated that treatments were different at the .05 level. The September evaluation (Table 3) indicates that a trickle irrigation application

Table 3.--Mean Percentages of Terminal Buds Attacked by Tip Moth September 17, 1979

Treatment	%Infestation Single Application	%Infestation Multiple Split Application
Control	33	29
Furadan	0**	0**
Di-Syston	22	16*
Systox	40	15*
Bidrin	19*	17*
Cygon	22	17*
Metasystox-R	25	23

*Significant at .05 level for Dunnett's test for comparisons involving a control mean when actual counts are transformed by $\sqrt{X+1}$.
**Significant at .01 level for Dunnett's test for comparisons involving a control mean when actual counts are transformed by $\sqrt{X-1-1}$.

(localization of the chemicals in two spots near the tree) worked exceptionally well with Furadan in both types of applications. A lower application rate would have been effective. Of the other chemicals tested, only Bidrin provided significant response compared with the control in the single application. In the split application, Di-Syston, Systox, Cygon and Bidrin were significantly different from the control. Thus, it seems that a split application tends to decrease the severity of fading insect control late in the growing season, when compared to single early-season applications. The split application technique, when viewed for all chemicals, was significantly different from the single applications when compared by a Wilcoxon sign rank test at the .05 level. Since a multiple split application approach would allow less chemical to be utilized if infestation remained low during part of the season, and since late season fading of control can be reduced, this is the preferred method. In this particular case, for instance, only seven of the planned eight applications were actually applied demonstrating the potential effectiveness of a lower annual rate with multiple applications. No insecticide phytotoxicity was noted in any trees.

The 1980 test was based on information gained from the 1979 test and on information developed regarding the effect of the chemicals on irrigation components. It was determined that none of the chemicals harmed polyethelene (PE) components, but Metasystox-R and, to a lesser degree, Cygon, were damaging to polyvinyl chloride (PVC) pipe. Thus, these two chemicals were eliminated from further evaluations. The rates of the remaining chemicals were varied upward in the 1980 test with the exception of Furadan which was decreased (Table 2). Since the trees in the 1979 location had grown well, they were judged as being too tall for the 1980 test and younger trees in an adjacent part of the orchard were utilized. It was also felt that the smaller trees would be more representative of the tree size that is usually given tip moth protection in a seed orchard. Although the split application approach was determined to be the best operational method, a single application was utilized in order to simplify the test and more strenuously evaluate the residual effect of the chemicals. Since these smaller trees were not large enough for the previous configuration of the trickle system to be most effective, both water delivery tubes were placed near the base of the tree as is standard practice in the orchard. Thus, a drench application was made at the base of the study trees to simulate a trickle application.

As a pilot evaluation of the potential phytotoxicity of the chemicals involved in the 1980 test, high rates were applied to potted rootstock. The results (Table 4) show that Systox killed all seedlings and Orthene burned needle tips.

Table 4.--Insecticide Rates and Phytotoxicity on Potted Pine Stock (1 Gallon Container)

Chemical	Application Rates Pounds/Active Ingredient/Pot In 1/2 Gallon of Water	Tree Response 30 Days After Application
Di-Syston	0.068	No Noticeable Effect
	0.136	No Noticeable Effect
Systox	0.060	All Seedlings Died
	0.120	All Seedlings Died
Bidrin	0.018	No Noticeable Effect
	0.036	No Noticeable Effect
Orthene	0.026	Needle Tip Burn on All Trees
	0.052	Needle Tip Burn on All Trees
Control	0.000	No Noticeable Effect
	0.000	No Noticeable Effect

Table 5.--Mean Percentages of Terminal Buds Attacked by Tip Moth October 2, 1980

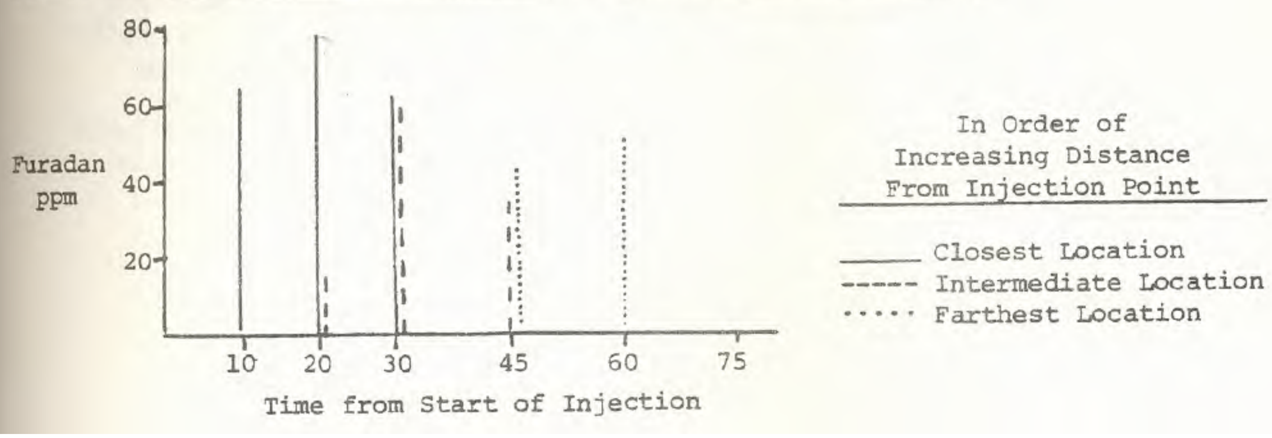
Treatment	% Infestation		
	Zero Rate	Low Rate	High Rate
Furadan	74	33*	17*
Di-Syston	66	1*	6*
Systox	62	23*	21*
Bidrin	60	62	56
Orthene	67	67	52*

*Significant at the .01 level for Dunnett's test for comparisons involving a control mean.

Results of the 1980 field test (Table 5) indicate that the tip moth population was at a normal level. Analysis of variance for infestation percentage indicated that treatments (and blocks) were different at the .01 level. Dunnett's test was utilized to compare the zero rate of each treatment to the low and high rates. June applications of Orthene and Bidrin, for all practical purposes, were ineffective in controlling tip moth during September. Furadan and Systox were effective. Di-Syston was extremely effective at the tested rates. Some slight needle tip burn was noted on about half the trees treated with Systox (6x) and Furadan (.5x). The experience in these 1980 evaluations was that Di-Syston is the only effective chemical that did not cause any phytotoxic symptoms. It is interesting to note that, although the higher rate of Furadan caused some needle burn, it had begun to fade in its effectiveness three months after application. A multiple application of the high rate Furadan would have helped avoid the needle burn. With Furadan, the higher rate was more effective in this single application. For Di-Syston and Systox, the low rate was as effective as the high rate for all practical purposes. Based on the 1979 test experience, splitting the lower rates of the three effective chemicals into several applications, with the last one nearer September, would likely have decreased the incidence of infestation.

Of the three chemicals that are good potential candidates for the control of tip moth through a trickle irrigation system (Furadan, Di-Syston, Systox), there was some question as to whether Furadan would stay in suspension long enough to be successfully piped through the irrigation system (McCalley 1978). The Furadan detected in the samples taken at various tree locations indicated that the chemical usually took 10 to 45 minutes from the start of the injection cycle until the chemical was first registered, depending on the piping distance from the injection point. The Furadan detected indicated that the chemical would still be in the system 30 to 45 minutes after the end of the injection cycle. The time of peak concentration at locations nearest the injection station (via the piping system) tended to be between 20 and 30 minutes from the start of the injection cycle, and 45 minutes for locations farthest from the injection station. There seems to be a tendency for higher peaks to be reached by locations adjacent to the submains when compared to those farther down the lateral line (Figure 1). The standard deviation (670 ppm-minutes) of the detected chemical rate delivered per location was approximately 45% of the mean (1,467 ppm-minutes), thus the rate of application per tree can be controlled only within broad boundaries (although it is within the boundaries indicated by the range of rates encountered in granular applications). The expected mean for the injection was estimated between 2,000 and 2,600 ppm-minutes. Inexact estimates of the amount of water pumped through the system, the small number of sample locations, the non-random placement of sample points, and the relatively long-time interval between samples at a location, prevent a close accounting of the Furadan injected into the system during this trial run.

Figure 1.--Furadan Detected in Water Samples at Three Locations



Water samples that were obtained when the system was flushed after 24 hours of operation (since the beginning of the injection cycle) revealed no traces of Furadan. Thus all the injected Furadan passed through the system during normal operation. Based on this data, Furadan should work well when piped through this trickle system.

Trickle irrigation systems that have very low water velocities in the lateral lines could possibly have problems with settling of the Furadan within the pipes. The Bellamy irrigation system utilized 1/2-inch PVC lateral lines with emitted junctions every 15 feet that deliver water to the surface at 4 to 5 GPH (gallons per hour). Lateral lines are located every 20 feet on the tapered submains and tap from the submain approximately 4 gallons of water per minute. Submains are headed by a pressure regulator and are tied to a 6-inch main.

When any pesticide is injected into an irrigation system, backflow-preventing devices should be installed in the main lines. This will avoid the possible seepage of the chemical into the water supply (pond, river, aquifer, etc.). The Bellamy system has three backflow-prevention devices on the main line: two check valves in the pump and filter sections and a foot valve on the suction line. Also each pressure regulator on the submains is of the backflow-prevention type.

Based on the test results to-date, the effective rates for the liquid formulation of Furadan, Di-Syston and Systox can be estimated (Table 6).

Table 6.--Tentative Rate Recommendation Regarding Trickle Irrigation Application of Liquid Formulation Systemic Insecticide for Control of Tip Moth

Chemical	Per Tree Rate/Application Pounds Active Ingredient/Inch Basal Diameter	No. of Applications Per Year
Furadan	0.005	2 to 5
Di-Syston	0.015	2 to 5
Systox	0.030	2 to 5

These rates are generally equivalent to annual rates utilized in other types of applications. A comparison of chemical cost for controlling tip moth on vigorously growing small orchard grafts in a year of normal tip moth activity (Table 7) indicates Systox is too costly for practical consideration. The other alternatives are roughly equivalent with granular Di-Syston being the most economical. The practical advantages gained by the liquid formulations of Furadan or Di-Syston over a granular application are due to three considerations: (1) the liquid formulation would allow smaller incremental investments in the early portion of the control program and later applications could be applied or deleted depending on insect activity, (2) the cost of application (not including chemical cost) would be less with a liquid formulation applied through the trickle system when compared with a soil incorporation granular application, (3) the trickle application would be immediately available to the plant, whereas the granular application would depend on a soaking rain for good root uptake.

Table 7.--Annual Chemical Cost of Controlling Tip Moth on 1,000 Trees (Basal Diameter 1-1¼ Inches) in an Orchard with Trickle Irrigation

Chemical	Rate Application Pounds Active Ingredient/Tree	No. of Applications	$ Cost/Pound Active Ingredient	1981 Annual Chemical Cost ($)
Liquid Furadan	0.005	4	$11.00	$ 220
Liquid Di-Syston	0.015	4	6.06	362
Liquid Systox	0.030	4	11.90	1,428
Granular Furadan	0.013	2	9.50	247
Granular Di-Syston	0.019	2	7.33	139

CONCLUSIONS

Although the liquid formulations of Furadan and Di-Syston are currently not specifically registered for this type of application, these chemicals hold much promise for improving the techniques of controlling tip moth in young seed orchards that have trickle irrigation systems. Lower rates per application (compared to soil-incorporated granular applications) are desirable and convenient when utilizing this technique. A reduction in the total amount of insecticide applied annually is also possible with this new technique. Successful metering of Furadan through a trickle irrigation system was demonstrated, with no residuals remaining in the piping. Chemical application rates per tree vary significantly when applied through the trickle system but remain within the range of generally utilized granular rates. International Paper Company is continuing its evaluation of these techniques for the control of various orchard insects.

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