RESULTS OF TGR SURVEY[1]

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Abstract. The Empire State Electric Energy Research Corporation (ESEERCO) contracted with ACRT, Inc. Environmental Specialist to research the status and efficacy of Tree Growth Regulators (TGR's) and their applicability for the electrical utility industry. The project included the preparation of an annotated bibliography, a TGR practitioner survey for usage data and unpublished reports, a synopsis of the bibliography, and an information dissemination/storyboard session for ESEERCO members and TGR scientists. The user survey had 160 respondents and their responses are tabulated and discussed. Various TGR application methods—trunk injection, bark banding, trunk implant, soil application—are discussed and evaluated. This presentation summarizes the user information and the pertinent results of the storyboard session.

Résumé. L'Empire State Electric Energy Research Corporation (ESEERCO) prenait un contrat avec l'ACRT, Inc. Environmental Specialist pour déterminer les qualités et l'efficacité des régulateurs de croissance (TGR) et leur applicabilité pour l'industrie de service électrique. Le projet incluait la préparation d'une bibliographie annotée, d'une étude d'une praticien des régulateurs de croissance pour des données d'usage et des rapports non publiés, d'un précis pour la bibliographie et d'une session d'information de dissémination d'un tableau historique, et ce, pour les membres de l'ESEERCO et les scientifiques des régulateurs de croissance. Cette présentation fait le sommaire de l'information d'usage et des résultats pertinents à la session du tableau historique. L'étude d'usage comportait 160 répondants et leurs réponses sont compilées et discutées. Des méthodes variables d'application de régulateurs de croissance--injection dans le tronc, bandage sur l'écorce, implantation dans le tronc, application sur le sol--sont discutées et évaluées.

Empire State Electric Energy Research Corporation (ESEERCO) contracted with ACRT, Inc. Environmental Specialist to research Tree Growth Regulator (TGR) literature and for preparation of an annotated bibliography. A computer search of over ten million records for published technical information on all aspects of tree growth regulators was conducted by David A. Breedlove and Drs. William R. Chaney and Harvey A. Holt, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana.

Another phase of that project was a mail and telephone search conducted by ACRT for field usage data and unpublished TGR information. ACRT sent out approximately 1,200 survey units to all people known to be, or suspected of being, TGR users or researchers.

A literature synopsis of the TGR annotated bibliography was prepared by ACRT to summarize key information.

The final project task was a storyboard, an information discussion session conducted with all key international scientists and major users. As a result of that meeting, a recommended research, development, and demonstration project was prepared for ESEERCO members.

TGR Background

The concept of tree growth regulator usage is in the advanced research—early field development stages insofar as their involvement as a routine standard line clearance maintenance practice within the utility industry. PGR's have been recognized and experimented with by plant physiologists since the early 1940's. The horticulturist and orchardist, because of economic crop advantages from their usage, took the developmental lead in TGR woody plant use. The earlier plant growth regulators were hormonal in nature—dikegulac (Atrinal), maleic hydrazide (Slow Grow)—or altered the normal growth process—the morphactins Maintain A and CF125 (Chlorflurenol).

The newer class of compounds are anti-gibberellic or antihormonal in nature. Cell division (i.e. growth) still occurs, but the cells do not realize their growth potential. The anti-gibberellic nature of the compound suppresses the cell maturation process and the leaf stacking/internodal elongation suppression phenomenon results. Paclobutrazol (Clipper), flurprimidol (Cutless), and uniconazole (Prunit) are the three principal regulators in this class of compounds.

TGR Manufacture Status

Clipper is the most extensively used TGR. Monsanto had been distributing that product in the utility line clearance market under license from Imperial Chemical Industries (ICI), Great Britain. Monsanto has decided to stop marketing Clipper. Two other TGR manufacturers have indicated an

1. Presented at the annual conference of the International Society of Arboriculture in Toronto, Ontario in August 1990.

interest in future Clipper marketing. According to Monsanto, the Clipper already formulated will continue to be available until current supplies are exhausted.

Cutless, a product of Eli Lily Company (Elanco) is the next most commonly used TGR. Dow Chemical and Elanco are in the process of merging their plant science research and marketing groups at a new facility under construction in Indianapolis. Cutless has a new product manager from the former Dow organization. Dow has an excellent herbicide utility marketing force which will now have Cutless to sell. However, there is lost Cutless initiative during the consolidation and reorganization period.

Valent is an affiliation of Chevron Chemical Sumitoma Chemical, Japan to market Prunit. Indications are Chevron and Sumitoma are evaluating the current TGR marketing potential.

Clipper has the most comprehensive EPA registration and has had the widest and most extensive utility usage. The decision of Monsanto to exit the market has adversely affected utilities perception to TGR potential. There is considerable confusion as to who will offer what TGR product in the future. However, apparently there will be TGR's in the future.

TGR User Survey

There were a total of 160 responses to ACRT's survey questionnaire. Considering there are 218 investor-owned utilities in the U.S., this represents a significant part of the utility industry.

Eighty-one respondents are currently using TGR's. Another 36 were not using them at present for various reasons or had ceased their usage because of bad experiences. The remaining 18 respondents were undecided as to TGR benefit or were awaiting more definite positive results.

A 2:1 predominance of TGR users (108-57) determined rate strictly by trunk diameter and did not consider the size of the crown, timing of the application in relation to pruning cycle, season of the application in relation to pruning cycle, season of application, prior presence of deadwood in the crown, prior trunk injury, rate/severity of ultimate pruning. All of these factors have a direct relationship on uptake of material, concentration at any specific location, and the degree and timing of escapes/sucker proliferation.

Forty-three percent of the respondents had not tested the products sufficiently to pass judgement. While over one-third of the respondents were satisfied with results, 18 percent were dissatisfied with the results.

Only ten percent of the respondents indicate public complaints about TGR treated tree appearance. The survey attempted to focus on the source of the problem(s) in areas where TGR's are not being used at present or where past usage has been curtailed. The perceived problems have been, in descending order of importance: weeping, non-uniform distribution throughout the crown, branch escape, trunk discoloration, change in leaf size, bark splitting, blow outs, excessive suckering after treatment, death of grass adjacent to the tree, localized swelling, and tree mortality. The number of complaints on any issue ranged from a high of 92 to a low of 3.

The terms bark splitting and blowouts were quasi, multifacet terms that were subject to the individual respondents judgement. Both terms are significant symptomatic expressions that have several potential causes. Each will be defined further for descriptive purposes.

Blow out can be one of the causal agents of bark splitting. Three different types of "blow out" are possible. The most significant is related to the angle of injection and ultimate depth of the tangential opening. The volume of the injected TGR plus its solvent carrier under pressure creates considerable disruptive force within the wood surrounding the injection head. If the angle is small, less than 30 degrees, or the end of the hole is too close to the vascular cambium, the TGR solution can cause a physical eruption or bubble of separation between the cambium and sapwood and, if severe enough, also result in a bark rupture. This inadvertent wound becomes quite significant from an appearance and compartmentalization of decay in tree (CODIT) standpoint. Blow outs of this

Table 1. Comparison of crew background making the actual application

Contract Crews	49
Chemical Company Representatives	25
In-House Crews	20
Specialized Crews	13
Standard Tree Trim Crews	10

Note: 74 respondents also stated that the application crews had undergone some form of special training prior to start up.

nature are also associated with prior defects such as wounds, slime fluxes, and frost cracks that are not evident at the time of injector head placement. But the result, cambial death, is the same.

The second blow out situation is a result of improper injector head setting or placement and results in TGR and carrier forcibly being ejected into the environment and possibly on to the applicator. This then could qualify as a pesticide spill incident and chemical trespass. Cambial tissue immediately adjacent to the injection hole may be damaged by carrier contact.

The final blow out circumstance involves premature withdrawal of the injector head before all the material has been expelled into the tree. The material under pressure that has not yet been taken up may "bleed" back to the outside of the hole as the head is removed. This may result in cambial dieback adjacent to the hole and in trunk discoloration. This is not to be confused with weeping that can occur for a long period after injector head removal.

Bark splitting is the end result of cambial dieback resulting in a trunk canker. In this case, there is a bark rupture in a vertical plane up and down from the point of injection or blow out. There has also been speculation that the injection hole itself becomes a focal point (locus) for frost cracks or fulcrum point for future frost cracks if the injection hole has been plugged.

Tree Population Treated by Size Class

Due to the fact that the size of any individual woody plant growing beneath an overhead conductor is influenced by its age and environment, an attempt was made to determine what type and relative size of specimen were being treated. That is summarized in Table 4.

The respondents tested trees in multiple categories as seen by the total number of responses. The reported TGR results were not broken out by size class or category. The majority of the later ongoing tests involved street trees generally ranging between 10 inches and 30 inches DBH.

Tree Injection

Considerable concerns were expressed about the perceived negative aspects of injection. Discussion centered upon the improvements that have been made and incorporated into what is a more standard injection technique as opposed to earlier employed procedures:

- Lower pressures are now being employed than were used formerly. Standard pressures are now in the area of 60 to 75 psi as opposed to the 90 to 110 psi or higher as was common in the past. This aids in preventing mechanical damage and blow out.
- In addition to lower pressure, smaller dosages are being used. Label rates have been refined so that one-third to one-tenth as much material is now introduced per injection site as opposed to earlier injection work. This also reduces mechanical damage and blow out chances while minimizing the chances of overregulation of tree growth.
- The actual injection mechanics have been modified considerably. Initially, the injection hole

Table 2. Specific problems resulting from TGR injection introduction

Tree Growth Regulator	*Clipper*	*Cutless*	*Prunit*	*CF125*	*Atrinal*	*Slow Grow*
Users/Respondents	68	35	24	8	11	6
Problem			*Percent user complaint*			
Blowout	34	29	25	13	27	17
Weeping	62	54	67	50	55	83
Bark splitting	19	29	29	50	64	67
Trunk discoloration	43	40	50	75	73	83
Excessive suckering after treatment	13	11	17	50	45	83
Grass death adjacent to tree	9	9	21	38	27	50
Non-uniform distribution throughout the crown	57	37	42	63	64	83
Localized swelling	3	3	4	25	0	0
Branch escape	47	40	54	63	73	67
Change in leaf size	41	29	46	50	55	67
Tree mortality death	4	0	0	0	0	0

Note. Percentages do not add up to 100 percent due to multiple responses. For example, 34 percent of those using Clipper complained of weeping. Twenty-nine percent of Cutless users complained of blow out while 54 percent complained of weeping. Conversely 83 percent of Slow Grow users complained of weeping.

was higher up on the stem. Placement between knee and waist level was fairly common. At present, the injection site is as low as possible to the ground in the buttress region. This lower placement minimizes the impact of any bleeding or seepage that may occur.

- The drill bit for making the hole itself was initially a wood auger type bit. The resultant hole was quite often sloppy and injection head seating was a problem increasing the chance of blow out and blow by seepage. At present, brad point drill bits and step drill bits are used providing more uniform holes and secure head seating.
- The angle of injection has changed. It was formerly 30° from perpendicular to the outside bark surface. It is now recommended to be 45° or 60° from perpendicular to bark. This orientation allows better vascular (sapwood) TGR interception and minimizes cambial damage.
- It is now recognized that plugging the holes did not stop leakage or bleeding and was purely a cosmetic function to ease public objection to the open hole. At present, hole plugging is not practiced except upon specific request or direction.

As an adjunct to reduced TGR dosage, there is a reduction in carrier volume. This volume reduction also reduces mechanical damage, blow back chances and lessens the chance of cambial injury by contact.

There is also a trend in changing the alcohol carrier from methanol to isopropanol. This carrier shift results in a change from the EPA mandated skull and crossbones labeled product to one carrying a caution label. There is no noticeable alteration in product efficacy, but there is a large change in public perception, applicator acceptance, and reduction in liability.

With the newer injection technique, it is reported that treated trees will hold for three years of growth at low rates while with higher TGR rates, five to six years of retardation is not an unrealistic expectation.

There were also negative concerns about trunk injection. Tree injection is a labor intensive operation. Specialized training is required to acquire the necessary application skills and knowledge. These drawbacks are not major but have a definite impact in TGR application, cost considerations, and the resultant economic justification.

The majority of the often reported and generally perceived problems are attributable to the older injection techniques and rates. They may not be as significant or problematical under the present procedures, concentration, and rates. However, they are still points of concern, and they have greatly prejudiced potential TGR users against trunk injection and even against TGR's. Among those problems are weeping, bleeding, bark splits, various branch and positional escapes, and the apparent lack of uniform results among workers and product efficacy. Most of the perceived problems are a result of poor technique both from prior technology and workers doing application.

The new application procedures should minimize the problems in future work. Unfortunately, those problems attributable to human error will not be as easy to correct and will continue to be a problem until a better educated and skilled work force are available.

Another drawback to injection is the expensive equipment necessary to do the job. The various injectors are expensive to purchase initially and to maintain in good working order. If only a small

Table 3. Summary of predisposing factors

Potential agents of predisposition affecting product efficacy	*Number of respondents noting or questioning possible correlation with efficacy*
Prior Tree Health/Vigor Status	26
Size of Crown	20
Timing of Application within Pruning Cycle	20
Deadwood in Crown	19
Season of TGR Application	19
Prior Trunk Injury	14
Rate/Degree of Pruning	14
Other Non-Defined Factors	10
Age of the Tree	8
Presence of Slime Flux	5
Pruning Technique	5
Presence of Girdling Roots	1
Nearby Soil Disturbances	1

Note. Not all respondents answered this questions while others gave multiples responses.

Table 4. Test population demographics

Description of tree being tested	*Number of respondents performing such tests*
Greenhouse study	4
Juvenile trees, under 9" dbh	58
Mature trees, over 9" dbh	62
Plantation trees	34
Forest grown trees	37
Street trees, under 24" dbh	122
Street trees, over 24" dbh	106

number of trees are being treated, this is a high capital cost item to consider. As the number of treated trees increases, the per tree equipment costs are reduced. Trunk injection is also seasonal in nature dependant on the plant's growing season. In the more temperate north, the injection season runs from March through October and leaves an approximate four month period of inactivity. More southern utilities will get an extended season. As long as the tree is actively functioning, injection uptake seems to proceed within a reasonable period of time. When the tree is dormant, the injection time becomes too long to be cost justifiable.

Other concerns with trunk injection are not as easy to rationalize. There is always the uncertainty as to what will be encountered under the outer bark layers. Structural defect is often masked and can adversely impact efficacy. A portion of the TGR error rate, often implicated by injection, can be explained or blamed on that aspect.

Special concerns are raised about the final resultant size of the injection wound and about multiple columns of defect. There are real concerns about the potential for girdling the tree as a result of multiple applications. At present, no data exist to substantiate or refute this hypothesis as repetitive applications are not yet common.

Recommendations Based upon Discussion

Tree growth regulators are not the sole solution to the line clearance vegetation management problem. Rather, they are a tool that needs to be further refined for inclusion and integration into the vegetation management program conducted by each utility.

Not every tree would benefit from nor lends itself to TGR application. Only those trees that are fast growing or quickly capable of re-intercepting the plane of the conductors in a short time are prime candidates. The consensus opinion was that a two or three year (or ideally longer) extension of the normal trim cycle could pay for the TGR application and make it cost justifiable. Trim cycles, presently three years or shorter, would benefit the most. Trim cycles of five years or longer would probably not be TGR cost justified. It will be necessary to evaluate historic circuit/grid trim cost data and compare it with TGR cost and future trimming cost to see if there will be a cost justification for use. Records presently exist for chemical cost, labor rates, equipment costs and overhead. The largest variable that became evident between utilities, was the difference in contractor rates between systems and localities and it was quite significant.

No one application method is, or will be, best in all situations. Any one method can be universally employed, but it may not be cost justified or publicly accepted. Rather, the systems and trees should be subdivided into two, three, or four subcategories qualified by land use or spatial limitations and the TGR application method of choice be tailored to each.

The question of future product choice and availability was raised. ESEERCO wants to be sure that any TGR researched will be commercially available and registered with the EPA five years in the future when the project is completed. Serious concerns were raised about the future of Clipper (Monsanto/ICI) and Prunit (Chevron/Valent/Sumitoma). Maintain was put aside as having problems, and will not be considered further. It would appear that Cutless (Dow-Elanco) was the product being most actively researched and marketed at present and with the most potential for future marketability. Consensus was that Cutless should be the primary product of further study with one or both of the others depending on their status and commercially availability in the near and more distant future.

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