Tampa Bay National Estuary Program
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TAMPA BAY National Estuary Program

EXOTIC/INVASIVE SPECIES CONTROL MANUAL FOR MANGROVE FOREST AREAS

FINAL REPORT

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EXOTIC/INVASIVE SPECIES CONTROL MANUAL FOR MANGROVE FOREST AREAS

Submitted to
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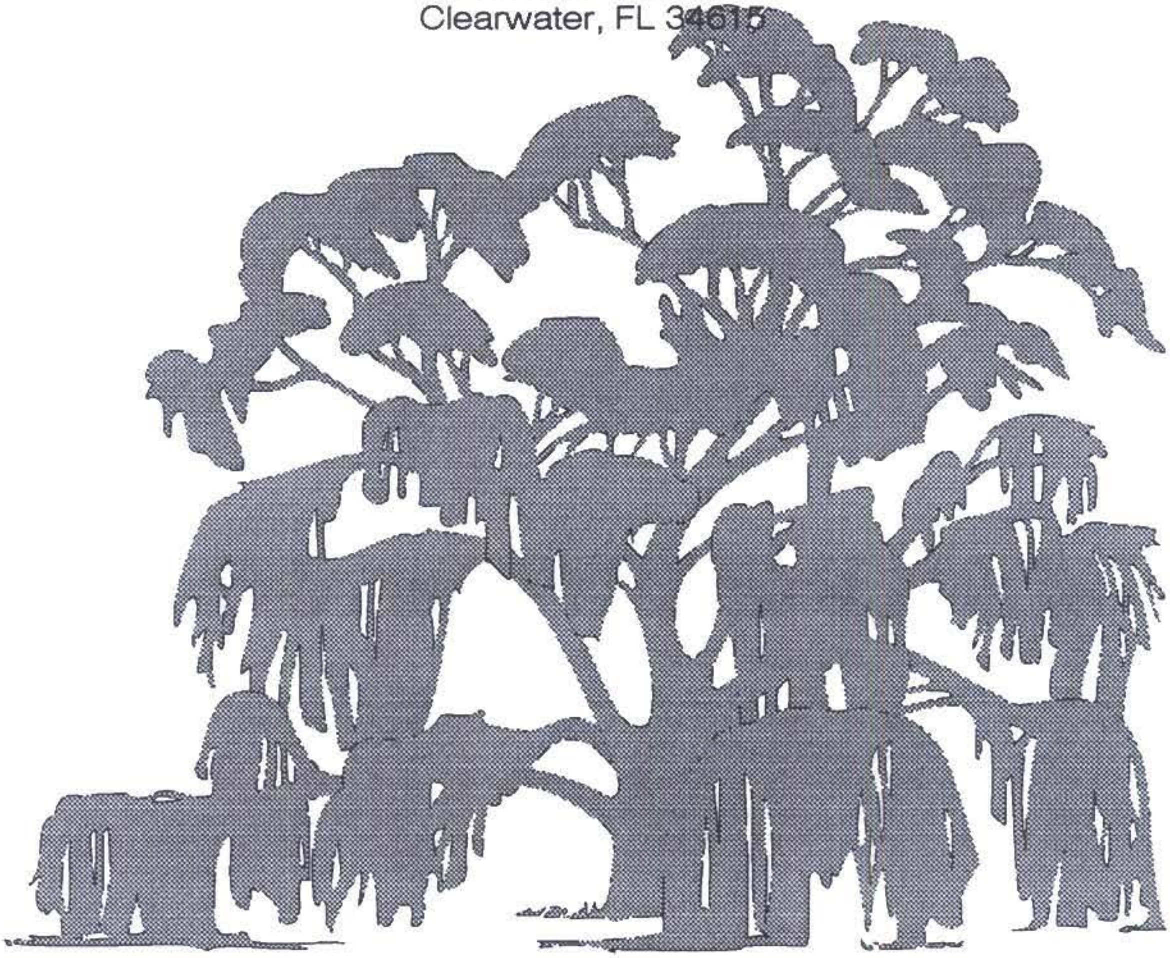

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EXOTIC/INVASIVE SPECIES CONTROL MANUAL FOR MANGROVE FOREST AREAS

INTRODUCTION

Problem

Exotic vegetation, especially Brazilian pepper (*Schinus terebinthifolius*), poses a great economic and environmental threat to the state of Florida. Brazilian pepper, which is native to Brazil and Paraguay, was introduced into the United States in the 1890s as an ornamental landscaping shrub. The common name of Florida holly is derived from the appearance of masses of bright red berries (produced by the female plants during the winter months between November and January) against the dark green evergreen foliage.

In Florida, Brazilian pepper is abundant in moist to transitional zones in both fresh and salt water habitats. Once present in these ecologically critical areas, it quickly dominates the more desirable native vegetation through rapid growth, shading and chemical inhibition. Brazilian pepper provides little habitat value, and in fact the berries that are produced are thought to have a narcotic or toxic effect upon the birds and wildlife which ingest them.

Solutions

At the present, several types of control are being developed or are in use. The control of peppers through the use of insects (biological control) is currently being researched. The use of equipment to physically remove (mechanical control) the peppers is time-consuming and expensive. However, physical removal is practical when employed concurrently with herbicide treatment on large tracts of land where peppers have formed a monoculture. If mechanical removal is the only method employed, regrowth of peppers occurs rapidly from the existing seed bank and viable vegetative fragments. Physical control is the use of fire to control peppers. This method is useful only for seedlings, not for mature trees because of the ability of large individuals to resprout. The use of herbicides (chemical control) is most common and cost-effective method employed to date for the control of Brazilian peppers.

DATA REVIEW AND FIELD TESTING

Existing Information

To investigate the most effective herbicide method of controlling peppers, three sources of information were queried. The first source of information was a bibliographic database search performed through a commercial database management company (STN International). Twenty-one databases, including BIOSIS and CAS (Chemical Abstracts), totaling 54,953,710 records from 1950 to the present, were queried using herbicide names (both trademark and chemical names) and Brazilian pepper (both common and scientific names) as keywords (Appendix A). From this, only four abstracts matched the search terms (keywords); two relating to Garlon 4 (triclopyr), one relating to Rodeo (glyphosate) and one relating to Velpar L (hexazinone).

Of these four, only one paper (Doren 1990) tested the effectiveness of herbicide control of Brazilian pepper. This study tested the effectiveness of triclopyr on age classes and matricide (treating only the female plants) in relation to labor hours using a 1:50 triclopyr:diesel (2 percent) solution. Young successional stands (less than 10 years old) required the lowest labor effort while old successional (10–20 years old) stands required the highest labor effort. Data regarding pepper mortality rates were not recorded.

The second source of information was to interview people who have had experience with controlling peppers through herbicide treatment. Seventeen people including representatives of the herbicide manufacturers, IFAS (Institute of Food and Agricultural Services) and state environmental agencies were interviewed for data and results using different herbicides and herbicide concentrations (Appendix A). The most common herbicide used by the applicators was triclopyr (Garlon 4) at a 1:10 triclopyr:diesel or mineral oil solution (10 percent). Although many applicators follow up on treatment effectiveness, no one has published results nor were they able to provide mortality rates of the mixtures used.

The third source of information regarding the effectiveness of herbicides in controlling peppers was to actually inspect sites that had been treated. Ten sites in central to south Florida were visited (Appendix A). Again, the most effective herbicide was the 1:10 triclopyr:diesel or mineral oil solution. At sites where 30-day and 90-day follow-up applications were performed after the original application, mortality rates of peppers exceeded approximately 90%.

Field Testing

Utilizing the information collected from the three sources, five treatment methods using the three most common and effective herbicides for controlling Brazilian peppers were determined (Table 1): glyphosate (Rodeo), triclopyr-triethylamine salt (Garlon 3A) and triclopyr-butoxyethyl ester (Garlon 4). A spray adjuvant (Cide-Kick II or Kinetic HV) which acts as a wetting agent, activator and penetrant to allow increased surface contact of the herbicide and allow the herbicide to penetrate the bark area or break down the waxy leaf cuticle was added to three of the solutions. This solution was mixed with a carrier (water or JLB oil) to provide the proper herbicide concentration and to assist with surface contact of the herbicide mixture. The remaining two treatment methods used 100% concentrations of herbicide.

To determine the effectiveness of each treatment, each was used at one of five 0.25-acre plots dominated by Brazilian peppers and also containing mangroves (*Avicennia germinans*, *Laguncularia racemosa* and/or *Rhizophora mangle*) (Table 2). The herbicide was applied to each plot one time and number of stems (measured at 1.5 ft above ground) treated, treatment time and applied herbicide quantity were recorded. This data allowed comparison of number of stems treated per hour and herbicide price per stem (Table 3). Also, using a $10.00 per hour average applicator wage rate, a herbicide and wage cost per stem was calculated (Table 3). This value is important in the determination of the most cost-effective method for treating peppers. Cost or expenditure of resources per unit area calculations were not practical due to the variation in vegetation size and plot density. Each plot was monitored at 30 and 60 days after initial treatment to determine mortality rates (Tables 4 and 5).

Table 1. Tank Mixture

Plot Number	Tank Mixture Concentration (%)	Chemical
1	2.5	Rodeo
	0.5	Garlon 3A
	1.0	Kinetic
	96.0	water
2	100.0	Garlon 3A
3	2.0	Garlon 3A
	1.0	Kinetic
	97.0	water
4	100.0	Rodeo
5	10.0	Garlon 4
	10.0	Cide-Kick II
	80.0	JLB oil

Table 2. Plot Description

Treatment Plot Number	Active Herbicide	Application Method	Herbicide Concentration (%)	Application Date
1	Rodeo	Foliar	2.5	6/14/95
2	Garlon 3A	Frill/Girdle	100.0	5/30/95
3	Garlon 3A	Foliar	2.0	6/15/95
4	Rodeo	Cut/Stump	100.0	5/31/95
5	Garlon 4	Basal/Bark	10.0	6/9/95

Table 3. Treatment Plot Results

Treatment Plot Number	Treatment Time (hours)	Number of Stems Treated	Herbicide Quantity (gallons)	Herbicide Price	Stems/Hour Treated	Herbicide Price/Stem	Herbicide and Wage Cost* per Stem
1	0.58	215	15.0	$ 52.08	370.7	$ 0.24	$0.27
2	3.78	581	1.75	117.08	153.7	0.20	0.27
3	0.60	230	10.0	19.88	383.3	0.09	0.11
4	4.25	898	0.375	37.31	211.3	0.04	0.09
5	0.83	871	5.0	68.18	1049.4	0.08	0.09

* $10.00/hr. wage rate

Table 4. 30-Day Post-Treatment Monitoring Results

Treatment Plot Number	Monitoring Date	Number of Misses	Number of Affected Mangroves	Number of Stems Resprouting	Percent Mortality
1	7/14/95	0	0	1	99.5
2	6/29/95	33	1	11	98.1
3	7/14/95	0	>50 (<6" tall)	4	98.3
4	6/29/95	31	0	9	99.0
5	7/14/95	3	0	0	100.0

Table 5. 60-Day Post-Treatment Monitoring Results

Treatment Plot Number	Monitoring Date	Number of Misses	Number of Affected Mangroves	Number of Stems Resprouting	Percent Mortality
1	8/15/95	0	0	38	82.3
2	8/15/95	33	1	11	98.1
3	8/15/95	0	0	84	63.5
4	8/15/95	31	0	43	95.2
5	8/24/95	3	0	0	100.0

RESULTS

Treatment 1: Foliar Application of Rodeo

The dominant herbicide in treatment 1 was glyphosate (Rodeo) and secondarily triclopyr (Garlon 3A). The tank mixture was 2.5% Rodeo, 0.5% Garlon 3A, 1% Kinetic and 96% water. The mixture was applied to the foliage of Brazilian peppers using a low volume sprayer (1.8 gallons per minute at 60 psi) until both the upper and under leaf surfaces were dripping. In treatment plot 1, 215 stems were treated, using 15.00 gallons of solution and requiring 0.58 labor hours. This results in 370.7 stems treated per hour (Table 3). The cost of the herbicide solution used at this plot was $52.08 resulting in a price per stem of $0.24. The herbicide and wage cost per stem was $0.27.

The 30-day post-treatment monitoring results (Table 4) indicate that all peppers within the plot were treated; no mangroves were affected by the herbicide and only one treated stem had resprouted. Mortality of peppers using this treatment was 99.5% at 30 days post-treatment. At 60-days post-treatment, the number of mangroves affected remained at zero, the number of resprouting peppers increased to 38, and mortality decreased to 82.3% (Table 5).

Treatment 2: Frill/Girdle Application of Garlon 3A

The herbicide in treatment 2 was 100% triclopyr (Garlon 3A). The herbicide was applied to the Brazilian peppers using the frill/girdle technique and a low volume backpack sprayer . This technique requires that cuts into the cambium be made completely around the circumference of the plant using a machete. Cuts should be angled downward into the cambium to aid in herbicide retention (multiple cuts are not required). Herbicide is applied to the cuts until wet.

In treatment plot 2, 581 stems were treated requiring 3.78 labor hours and using 1.75 gallons of solution (Table 3). This results in stems treated per hour of 153.7. The cost of the herbicide solution used at this plot was $117.08 resulting in a price per stem of $0.20. The herbicide and wage cost per stem was $0.27.

The 30-day post-treatment monitoring results indicate that all but 33 peppers within the plot were treated; one mangrove was affected by the herbicide, and 11 treated stems had resprouted (Table 4). Mortality of peppers was 98.1% at both 30 and 60 days post-treatment. At 60-days post-treatment, the number of mangroves affected remained at one and the number of resprouting peppers remained at 11 (Table 5).

Treatment 3: Foliar Application of Garlon 3A

The dominant herbicide in treatment 3 was triclopyr (Garlon 3A). The tank mixture was 2% Garlon 3A, 1% Kinetic and 97% water. The mixture was applied to the foliage of Brazilian peppers using a low volume sprayer until both the upper and under leaf surfaces were dripping. In treatment plot 3, 230 stems were treated requiring 0.6 labor hours and 10 gallons of solution (Table 3). Stems per hour treated with this method is 383.3. The cost of the herbicide solution used at this plot was $19.88 resulting in a cost per stem of $0.09. The herbicide and wage cost per stem was $0.11.

The 30-day post-treatment monitoring results indicate that all peppers within the plot were treated; more than 50 (<6" tall) mangroves were affected by the herbicide, and only four treated stems had resprouted (Table 4). The 30-day post-treatment mortality of peppers using this treatment was 98.3%. At the 60-day post-treatment monitoring inspection, it was observed that all of the mangroves previously affected had refoliated; the number of resprouting peppers increased to 84, and mortality had decreased to 63.5% (Table 5).

Treatment 4: Cut/Stump Application of Rodeo
The herbicide in treatment 4 was 100% glyphosate (Rodeo). The herbicide was applied to the Brazilian peppers using the cut/stump technique and a low volume backpack sprayer. This technique requires that each stem be severed using a machete or chainsaw. Herbicide is applied only to the cambium until wet.

In treatment plot 4, 898 stems were treated requiring 4.25 labor hours and 0.375 gallons of solution (Table 3). Stems per hour using this method is 211.3. The cost of the herbicide solution used at this plot was $37.31 resulting in a price per stem of $0.04. The herbicide and wage cost per stem was $0.09.

The 30-day post-treatment monitoring results indicate that all but 31 peppers within the plot were treated; no mangroves were affected by the herbicide, and nine treated stems had resprouted (Table 4). Mortality of peppers using this treatment was 99.0% at 30 days post-treatment and 95.2% at 60 days. At 60 days post-treatment, the number of mangroves affected remained at 0 and the number of resprouting peppers increased to 43 (Table 5).

Treatment 5: Basal Bark Application of Garlon 4
The herbicide in treatment 5 was triclopyr (Garlon 4). The tank mixture was 10% triclopyr (Garlon 4), 10% Cide-Kick II and 80% JLB oil. The mixture was applied to the Brazilian peppers using the basal bark technique and a low volume backpack sprayer. This method requires that the herbicide be applied directly to the bark from the ground up to approximately 15 inches from the ground, and completely encircling the stem.

In treatment plot 5, 871 stems were treated requiring 0.83 labor hours and using 5.0 gallons of solution (Table 3). This results in stems per hour treated of 1,049.4. The cost of the herbicide solution used at this plot was $68.18 resulting in a price per stem of $0.08. The herbicide and wage cost per stem was $0.09.

The 30-day post-treatment monitoring results indicate that all but 3 peppers within the plot were treated; no mangroves were affected by the herbicide, and no treated stems had resprouted (Table 4). Mortality of peppers at 30 days post-treatment was the highest of all plots at 100%.At 60 days post-treatment, the number of mangroves affected and resprouted peppers both remained at 0 and mortality remained at 100% (Table 5).

DISCUSSION

Application Considerations

Precipitation
All of the herbicides discussed in this manual are translocated into the pepper through direct contact with the plant. Therefore, heavy rainfall during or after treatment will severely reduce the herbicide effectiveness. Manufacturers of the herbicides used in this study recommend that the

herbicide must remain on the vegetation for two to six hours before a rain event. It has been the experience of herbicide applicators that a 6-hour contact time prior to rain is most acceptable. If rainfall occurs within six hours following application, repeated treatment may be necessary. Also, heavy rainfall after frill/girdle application, when a concentrated herbicide solution is used, could wash it into the soil and adversely affect non-target plants.

Application of herbicide during a drought period will reduce the effectiveness of the herbicide because stressed plants are less likely to absorb the herbicide. Thus, it is imperative that the local weather be considered prior to treatment.

Wind

Because these herbicides are non-selective, it is important to avoid spray drift into areas of non-target plants. If the spray is allowed to drift into non-target areas, desirable plants may be injured or killed. Also, foliar application during high wind conditions can result in poor herbicide coverage to the target plants. High winds should be avoided for foliar applications. Increased spray droplet size reduces the chance of herbicide drift. Therefore, match the nozzle size with the wind conditions.

Season

Seasonality affects herbicide efficiency in several ways. As the temperature drops, plant growth slows down, reducing the rate at which the herbicide is absorbed by the plant. During the wet season (summer in Florida), rain events will reduce the effectiveness of the herbicide or disallow application completely. Conversely, during the dry season peppers are under stress and the translocation of herbicide during this period is reduced.

Doren et al. (1991) studied the variation in herbicide effectiveness applied during different seasons in the Hole-in-the-Donut area in Everglades National Park (Dade County, Florida). During the months of March through May, the end of the dry season in south Florida, effectiveness of basal bark-applied Garlon 4 (2% and 4% solution with diesel) was low. This was apparently due to water stress that the peppers were under when stomata were frequently closed, reducing the translocation effectiveness of the herbicide. Herbicide effectiveness also decreased during the period of active flower production which results in decreased vegetative growth and lower metabolic activity.

During these two periods, Doren et al. observed increased resprouting of treated peppers and calculated the treatment effectiveness during these periods to be approximately 91%. During the months without the seasonal droughts or flower formation, treatment effectiveness was approximately 98%. Thus, awareness of the plants' physiological adaptations to seasonal changes is important to maximize herbicide treatment effectiveness.

Recommended Treatment Method

To determine the best treatment method, a number of parameters were considered—herbicide quantity used and its cost, number of stems treated (to determine a cost per unit effort), treatment time (time required to apply herbicide to the plants), percent mortality of treated peppers, number of affected mangroves, and regrowth of treated peppers. The two most important parameters are herbicide and wage cost (assuming a $10/hr wage rate) per stem and the percent mortality of the

Foliar herbicide application required the least amount of application time (Treatments 1 and 3). The Rodeo cut/stump method (Treatment 4) required the least amount of herbicide (0.375 gallons). This plot had the greatest number of treated stems (898) which resulted in the lowest herbicide price per stem ($0.04). The Rodeo cut/stump method and basal bark application of Garlon 4 (Treatments 4 and 5 respectively) had the lowest herbicide and wage costs per stem ($0.09). Thus, after initial treatment, these two methods were the most cost- and time-effective methods.

Table 4 shows the results of the 30-day post treatment monitoring episode. The Garlon 4 basal bark method had the highest mortality of peppers 30 days after treatment (100%). Also, no mangroves were affected by this application method. Because the basal bark application uses an easily controlled and relatively small amount of herbicide, opportunities for overspray are minimal in comparison to other treatments. Sixty days after the herbicide treatment, mortality of peppers treated with basal bark application of Garlon 4 remained at 100% while peppers at other plots had begun to resprout, decreasing the mortality rate. At 60-days post-treatment, no mangroves appeared to be adversely affected by this treatment method.

In conclusion, the data from this study suggests that a basal bark application of 10% Garlon 4, 10% Cide-Kick II, and 80% JLB oil to control Brazilian peppers in stands of mangroves is the most cost- and time-effective method resulting in the greatest mortality of peppers.

License/Permitting Requirements

Garlon 4 is a "specialty" herbicide, not a "restricted" herbicide, and therefore is treated under federal and state laws the same way as Roundup herbicide—that is, anyone can purchase and use it as long as the directions on the label are strictly followed. This is known as "the label is the law" policy. No special license or permit is required, but there are labeled restrictions, including a requirement that the herbicide not be applied such that any significant amount enters adjacent natural waters.

Garlon 4 is not readily available in small quantities on a dealer's shelf like Roundup. It can be purchased as a 9% solution premixed in a non-petroleum-based oil as Pathfinder II. Garlon 4 may also be bought as a pure herbicide ready to mix from Helena Chemical (813/722-3253) or Forestry Suppliers (800/543-4203). Only large quantities are available for purchase and are expensive ($100 per gallon). Smaller quantities may be available from Lewis Environmental Services, Inc. (813/889-9684).

Seasonal Application

Brazilian peppers produce red fruits with a single seed that does not need to pass through an animal's digestive system to germinate. Therefore, once the seeds are ripe (red) they can fall to the ground and germinate under the female tree, or remain viable and germinate later (up to nine months). Thus killing a female tree bearing ripe fruit, which is not killed by the herbicide, can produce hundreds of seedlings sprouting under the dead adult tree. Killing an adult female tree with unripe (green) fruit will not have the same result. Trees should be targeted for treatment during the three-month interval *before* fruit ripens—that is, August through October. This ensures that least possible remnant seedling production under adult female trees targeted for control.

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LITERATURE CITED

Doren, R.F. and L.D. Whiteaker. 1990. Comparison of economic feasibility of chemical control strategies on differing age and density classes of *Schinus terebinthifolius*. Natural Areas J. 10(1):28–34.

Doren, R.F., L.D.Whiteaker and R. Rochefort. 1991. Seasonal effects on herbicide basal bark treatment of *Schinus terebinthifolius*. Ch. 8, pp. 115–129 in Proceedings of the Symposium on Exotic Pest Plants, November 1988. National Park Service Tech. Rep. NPS/NREVER/NRTR-91/06. 387 pp.

APPENDIX

Table 1. Bibliographic databases searched for Exotic Vegetation Control Manual.

DATABASE	PRODUCER	NUMBER OF RECORDS	COVERAGE	CONTENT
BioBusiness/RN	BIOSIS	644,000	1985 to date	Business aspects of life sciences
BIOSIS Previews®/RN	BIOSIS	9.3 million	1969 to date	Biosciences
Chemical Abstracts	CAS	11.6 million	1967 to date	Biochemistry, chemistry, chemical engineering
CAB Abstracts	CAB INT'L	2.2 million	1973 to date	Agriculture
CApreviews®	CAS	100,000	current records	Current chemistry
Chemical Business Newsbase	Royal Society of Chemistry	324,000	1984 to date	Chemical business
Chemical Industry Notes	CAS	1 million	1974 to date	Chemical business
CJACS Plus	Am. Chem. Soc.	156,000	1982 to date	Chemical journals
Conference Papers Index	Cambridge Sci. Abstracts	1.4 million	1973 to date	Multidisciplinary conference papers
Food Science and Technology Abstracts	Int'l. Food Information Svc.	248,000	1969 to date	Food science
GENBANK	National Ctr. for Biotechnology Information	224,000	1982 to date	Nucleic acid sequences

(continued)

Table 1 continued.

DATABASE	PRODUCER	NUMBER OF RECORDS	COVERAGE	CONTENT
IFI Patent Database	IFI/Plenum Data Corporation	2.5 million	1950 to date	U.S. Patents
INVESTEXT	Thomson Financial Svcs.	4.3 million	1982 to date	Investment research reports
JP News	COMLINE Bus. Data Inc.	137,000	1986 to date	Japanese technology
Life Sciences Collection	Cambridge Sci. Abstracts	1.3 million	1978 to date	Life sciences
Natural Products Alert	Univ. of Illinois	113,000	1650 to date	Natural products
National Technical Information Service	Nat'l. Technical Information Svc.	1.6 million	1964 to date	Multidisciplinary
PHIC (Pharmaceutical Healthcare Industries News Database)	PJB Publications	1,710	current data	Pharmaceutical news
PHIN (Pharmaceutical Healthcare Industries News Database)	PJB Publications	206,000	1980 to date	Pharmaceutical news (archived material from PHIC)
Predicasts Overview of Markets & Technology	Information Access Co.	4.6 million	1978 to date	Sci-tech business information
SciSearch®	Institute for Sci. Information	13 million	1974 to date	Science and technology

Table 2. Results of the literature search from the STN database.

Keywords

Articles

Triclopyr and Brazilian pepper (Garlon 4)

Woodburn KB, Green WR, Westerdahl HE. 1993. Aquatic dissipation of triclopyr in Lake Seminole, Georgia. J. Agri. and Food Chem. 41(11):2172-2177.

Doren RF, Whiteaker LD. 1990. Comparison of economic feasibility of chemical control strategies on differing age and density classes of *Schinus terebinthifolius*. Nat. Areas J. 10(1):28-34.

Glyphosphate and Brazilian pepper (Rodeo)

Woodall SL. 1984. Herbicide tests for control of Brazilian pepper and melaleuca in Florida. Research Note, Southeastern Forest Experiment Station, USDA Forest Service, No. SE-314, 10 pp.

Hexazinone and Brazilian pepper (Velpar L)

Woodall SL. 1984. Herbicide tests for control of Brazilian pepper and melaleuca in Florida. Research Note, Southeastern Forest Experiment Station, USDA Forest Service, No. SE-314, 10 pp.

Table 3. People interviewed.

Diane Barile, Marine Resources Council
Allen Burdett, FDEP
Dr. Burkhalder, IFAS (Ft. Lauderdale)
Rod Burkhardt, TECO
Bo Burns, American Cyanamid Co.
Doug DeVries, Everglades National Park
Nick Ehringer, HCC
Amy Ferriter, SFWMD
Francois Laroche, SFWMD
John Mahagan, Monsanto Agricultural Co.
Pat Milam, Florida Natives Nursery
Eric Myers, Broward County DNRP
Tony Pernas, Big Cypress National Preserve
Cliff Smith, University of Hawaii
Vernon Vandiver, IFAS (Ft. Lauderdale)
Tom Wharton, DowElanco
Kim Zarillo, Conradina Native Plant Soc. (pres.), private consultant

Table 4. Site inspections.

Hillsborough County:	Cargill South Parcel Cargill Bayside Cockroach Bay HCC Environmental Studies Center
Hillsborough/Manatee County:	TECO Stewardship site
Broward County:	Pond Apple Slough Florida Wetlandsbank
Brevard County:	Samson's Island
Indian River County:	Ulumay Wildlife Refuge
Dade/Monroe County:	U.S. Highway 1 18-mile stretch