COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
UNIVERSITY OF HAWAII AT MANOA

Department of Botany
3190 Maile Way
Honolulu, Hawaii 96822

(808) 956-3932

Clifford W. Smith, Unit Director

Technical Report 79

A TEST OF TWO HERBICIDES FOR USE ON BANANA POKA *(Passiflora mollissima)* (Kunth) L.H. Bailey IN HAWAII VOLCANOES NATIONAL PARK

Gregory L. Santos,
Linda W. Cuddihy, and Charles P. Stone

August 1991

UNIVERSITY OF HAWAII AT MANOA

NATIONAL PARK SERVICE Cooperative Agreement 8017-2-0001

Hawaii Field Research Center
Hawaii Volcanoes National Park
P.O. Box 52
Hawaii National Park, Hawaii 96718

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ABSTRACT

Banana poka (*Passiflora mollissima* (Kunth) L.H. Bailey), an ornamental vine introduced to Hawai'i from South America, has become a serious pest in rain forests of three of the Hawaiian Islands. In Hawaii Volcanoes National Park, banana poka has invaded much of 'Ōla'a Tract, where it damages native trees and displaces forest understory plants. Two herbicides in three different concentrations were tested for use against banana poka in 'Ōla'a Tract. Treatments were Garlon 3A (triclopyr) and Roundup (glyphosate), each undiluted and at 50% and 5% dilutions in water. Herbicides were applied to the cut surfaces of banana poka stems near the point of rooting. Water applied to cut-stem bases served as a control and a test of the effectiveness of cutting alone. Sample size for each treatment was 10 vines. All treatments, including the control, killed 100% of banana poka stumps. However, the aerial portions of the vines survived and rooted in 40% of the water control plants and 10% of vines treated with 5% Garlon 3A. In the other five treatments, all vines were killed. Ten common, widespread native plant species and many others of sporadic occurrence were monitored in plots surrounding treated banana poka. Three woody plant species, four ferns, and two herbs generally remained constant or increased in numbers over the year in plots of most treatments. Only one fern species (ho'io-kula or *Pneumatopteris sandwicensis*) showed a significant decline in numbers; this occurred in the undiluted Garlon 3A treatment. Several other native tree and shrub species of more limited occurrence showed losses over the year in the undiluted Garlon 3A, undiluted Roundup, and 50% Roundup treatments. The 5% dilution of Roundup is recommended as an effective cut-stump treatment for banana poka, with no observed negative impacts on surrounding native vegetation.

INTRODUCTION

Banana poka (*Passiflora mollissima* (Kunth) L.H. Bailey) is a large, climbing liana of the Passionflower Family (Passifloraceae), native to the Andean region of South America (Wagner *et al.* 1990). This robust, fast-growing vine has glossy, three-parted leaves, curling tendrils, and large, pendant, pink flowers. The fleshy fruit are oblong and yellow when ripe and are edible although rather insipid.

The species was introduced to North Kona, island of Hawai'i, before 1921, evidently as an ornamental or for its fruit (LaRosa 1984); since that time it has been spread to the islands of Kaua'i and Maui. In 1981, banana poka was found distributed over 500 km^2 (200 mi^2) on Hawai'i and Kaua'i (Warshauer *et al.* 1983). The Maui infestation, although still relatively small in area at 142 ha (350 a), has dramatically expanded in the last two decades (LaRosa, in press).

The three primary sites of banana poka invasion on the island of Hawai'i are in the North Kona district on the slopes of Hualālai and Mauna Loa, the windward slopes of Mauna Kea in the Laupāhoehoe area, and in 'Ōla'a Tract of Hawaii Volcanoes National Park (Warshauer *et al.* 1983; LaRosa, in press). The 'Ōla'a infestation is the youngest and most rapidly expanding banana poka population on the Island (LaRosa, in press). Planted in a nearby agricultural lot in the 1950s, the vine moved into the Tract and became established in openings and areas disturbed by feral pigs (*Sus scrofa*) and wind storms. Between 1971 and 1981, an 18-fold increase in the cover of banana poka occurred in 'Ōla'a (Warshauer *et al.* 1983), and in the late 1980s, the vine continued to expand its range and intensify in cover (S.J. Anderson, unpub. data).

Banana poka can be extremely disruptive to native forests; over time, the vine has changed both forest structure and species composition (Warshauer *et al.* 1983). The weight of the vine can cause mechanical damage to native tree species, and when branches break or trees topple, natural understory conditions are altered, with more light reaching the ground. Alternatively, a heavy cover of banana poka may reduce light available for photosynthesis and, when extreme, smother trees (Smith 1985; LaRosa, in press). In koa (*Acacia koa*) forests (a vegetation type represented in 'Ōla'a), banana poka competes with seedlings and saplings and may outgrow and smother them (Scowcroft and Nelson 1976). Seeds are spread by feral pigs (Warshauer *et al.* 1983) and kalij pheasants (*Lophura leucomelana*) (Lewin and Lewin 1984), making it very difficult to contain expansion of the pest.

Biological control research is in progress, and two potential control agents (*Cyanotricha necyria* and *Pyrausta perelegans*) have been discovered, screened, and released (Markin *et al.*, in press; C. Campbell, pers. comm. 1991). Research involving plant pathogens as potential biocontrol agents is also ongoing (Smith 1985). However, biocontrol may ultimately prove unsuccessful or effective only in part of the range of banana poka. If effective biocontrol agents are found, many years may be required for their propagation and establishment, and during this time banana poka may spread and intensify. Hawaii Volcanoes National Park requires immediate control methods to complement fencing and feral pig control efforts in the portion of 'Ōla'a Tract infested with banana poka. The current study was initiated to determine the feasibility of mechanical control of banana poka and to compare the efficacy of cutting alone with cutting and treating stem surfaces with two different herbicides. These two herbicides were selected for their relative safety and known effectiveness on other target alien plant species (see Appendix).

THE STUDY AREA

Hawaii Volcanoes National Park is infested by banana poka only in the 'Ōla'a Tract, composed of two parcels 3,770 ha (9,312 a) and 141 ha (348 a) in size. Ceded by the State to the National Park Service in the 1950s, ʻŌlaʻa Tract is not contiguous with the rest of the Park and is accessed from Wright Road in the village of Volcano. The part of ʻŌlaʻa selected for this test is the northwestern corner from 1,250 to 1,313 m (4,100-4,300 ft) elevation, an area (approximately 266 ha or 657 a) fenced in 1985 to exclude feral pigs (Fig. 1). This area was chosen because it is the most intact part of the Tract, is only lightly infested by banana poka, and will be a likely candidate for future alien plant control efforts.

ʻŌlaʻa contains the oldest rain forest in Hawaii Volcanoes National Park. The deep ash substrate of the Tract is at least 4,000 years old (Lockwood *et al.* 1988), much older than those of the more volcanically active Crater Rim and East Rift zones of Kīlauea. Climate in ʻŌlaʻa Tract is that of a montane rain forest: wet and cool. Mean annual precipitation falls between the 2,000 mm (79 in.) and 4,000 mm (157 in.) isohyets (Giambelluca *et al.* 1986). The mean temperature of the area is approximately 60 F (15.6 C) (Hawaii Division of Water and Land Development 1970).

Vegetation in the northwestern corner of ʻŌlaʻa Tract is a very open canopy ʻōhiʻa (*Metrosideros polymorpha*) forest with an understory of mixed native trees and a closed layer of tree ferns (*Cibotium* spp.). The most important native trees here are ʻōlapa (*Cheirodendron trigynum*), kawaʻu (*Ilex anomala*), kōlea-lau-nui (*Myrsine lessertiana*), olomea (*Perrottetia sandwicensis*), and pilo (*Coprosma ochracea*), but many other tree and shrub species also occur in the study site. Ground cover is dominated by native ferns, most notably hōʻiʻo (*Diplazium sandwichianum*), ʻakolea (*Athyrium microphyllum*), and hōʻiʻo-kula (*Pneumatopteris sandwicensis*). A number of other fern species, along with both native (*Peperomia* spp.) and nonnative herbs, are also components of the forest floor cover. Banana poka is currently the only seriously invasive alien plant in this section of ʻŌlaʻa Tract.

METHODS

In August 1987, 70 banana poka vines were selected from a population in the northwestern corner of the large tract of ʻŌlaʻa. Half of these were located on the interior fenceline of the northwestern ʻŌlaʻa pig exclosure. Twenty-four (34%) suitable plants were found either on a flagged trail in the southeastern corner of the exclosure near a cinder cone, or on a trail leading to pig snares in the northeastern corner of the fenced unit. The remainder (14%) were along two pig activity/weed monitoring transects, which crossed the central portion of the exclosure.

Sample size was ten plants per treatment. Vines were of good to excellent vigor and had a basal diameter of 0.5 cm (0.2 in.) or larger. All vines of suitable size and vigor encountered along the selected transects and fencelines were used except those with rare plants (see Higashino *et al.* 1988) growing within 1 m of the vine base. Data collected from each vine prior to treatment application included basal

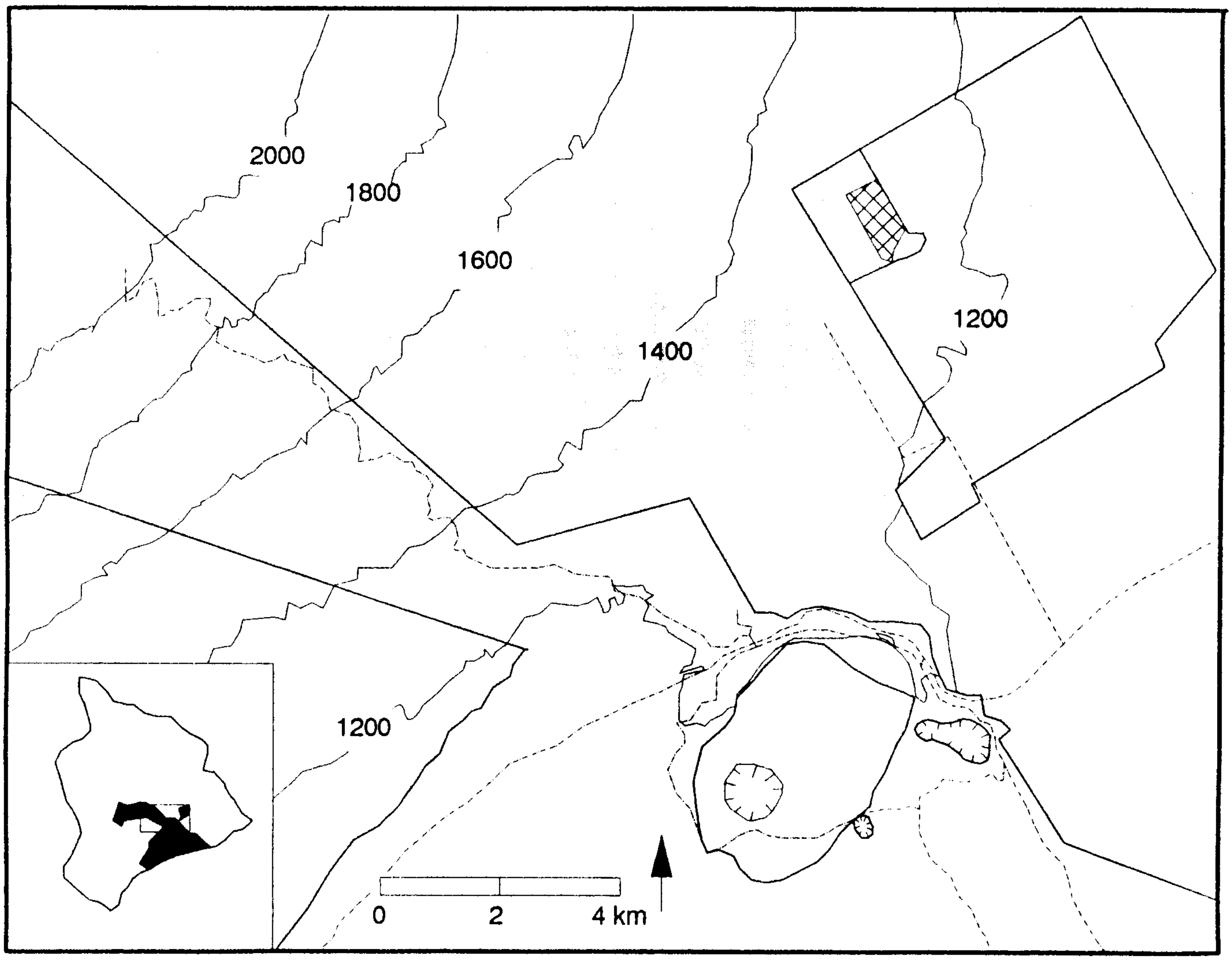

Figure 1. ‘Ōla‘a Tract and a portion of Hawaii Volcanoes National Park, with location of banana poka herbicide test indicated by cross-hatching.

diameter (cm), height class (<0.1, 0.1-0.5, 0.5-1, 1-1.5, 1.5-2, 2-3, 3-5, >5 m), vigor (excellent or good), and phenology.

Native Plants

Plots of 1 m radius were established around each stump to detect any treatment effects on surrounding native plants. Data collected on these species included identity, number of individuals per species stratified by height class, vigor (excellent, good, fair, poor, dead), and phenology. Native plant plots were monitored before treatment of banana poka and at 2, 6, and 12 months after treatment.

Forty-one different species of native plants were monitored for a year in these plots centered on treated banana poka. Native plants included more than a dozen tree or shrub species, an equal number of ferns, and several herbaceous plants. All but 10 of the native species occurred very sporadically in low numbers and were not found in plots of all (or even most) treatments. For the 10 species with adequate sample sizes, the change in number of individuals greater than 0.1 m in height was compared among treatments using the Kruskal-Wallis test, a non-parametric approximation of the chi-square test (Statistical Analysis Systems Institute 1985).

Application Procedure

Herbicides tested were Garlon 3A (triclopyr) and Roundup (glyphosate), each undiluted and at 50% and 5% v/v dilutions in water (0.18 and 0.018 kg a.e./l water, respectively). Stumps cut and treated with water served as both a control and as an assessment of mechanical treatment without herbicides. One of the seven treatments, chosen at random, was applied to the freshly cut stumps and severed aerial stems of 10 consecutive vines. When one treatment was completed a second treatment was selected, and the process was repeated until all treatments were applied.

The treatment protocol was to sever the vine as close to the ground as possible using pruning shears or a hand saw and then to apply the treatment to the entire stump surface with a hand-trigger spray bottle. Immediate application was essential to allow the negative pressure in the xylem to draw the herbicide into the stump (Hay 1956).

The stumps were monitored at 1, 3, 6, 9, and 12 months post treatment. Data collected for each stump included number of resprouts, height of the tallest resprout (cm), cambium condition (alive or dead) on both the stump and the severed aerial vine, and presence of vine rerooting. Stumps were considered dead when no live cambium or resprouts were found.

Seed Germination

A seed germination test was conducted to evaluate the potential longevity of banana poka seeds in the soil seed bank. Banana poka seeds were collected from ripe fruit on vines in ʻŌlaʻa Tract in September 1988. Pulp was removed from the seeds by rinsing in a colander. Half the seeds were air dried, divided into 50-seed samples, and stored at room temperature in plastic vials stoppered with clean cotton wool. The remaining seeds were separated into samples of 50 and placed in glass jars filled with a 50/50 mixture of sterilized potting mix and fine perlite. The mouths of the jars were covered with fine mesh screening, and the jars were buried on their sides to a depth of 10 inches in the soil of a closed canopy ʻōhiʻa forest near the Hawaii Volcanoes National Park Research Center.

Fifty fresh banana poka seeds were planted in fine vermiculite to a depth of the seed diameter; these were maintained in an open Park greenhouse with misting four times a day. Nine and 21 months after seed collection, 50 dried, stored seeds were planted in the same manner as fresh seeds. Seeds buried for 9 and 21 months were dug up, removed from bottles, recovered by sieving bottled soil, and planted in vermiculite. Pots were examined weekly and seedlings counted for six months.

RESULTS

All the treatments, including the water control, resulted in 100% kill of banana poka stumps by nine months post treatment (Table 1), but the aerial portions of vines were more difficult to kill. Only one stump, in the water control, resprouted during the test. This stump produced a single resprout by six months, which grew to a height of 5 cm before dying by nine months.

Root formation on the cut aerial portion of vines occurred in five of the treatments: Garlon 3A 5%, Garlon 3A 50%, Roundup 5%, Roundup 50%, and the water control. However, by 12 months roots had died on all but one vine in the Garlon 3A 5% treatment and four vines in the water control. Roots on the surviving vines had connected with the substrate and the vines appeared healthy.

Effects on Native Plants

Trees and Shrubs. The three most common native tree species in banana poka plots were pilo, ʻōhiʻa, and olomea; of these, only pilo was found in all treatments, occurring in 61% of all plots. Most of the counted pilo were in the height classes between 0.1 and 1 m, but young trees from 1-3 m tall and a few taller than 3 m were also present. Only Roundup 50% and the control plots showed any loss of pilo >0.1 m tall after a year of monitoring; all other treatments had small increases of pilo. The differences in pilo numbers among treatments were not significant when compared using the Kruskal-Wallis test (chi-sq = 7.26, p = 0.30) (Table 2).

Young ʻōhiʻa occurred in a few plots of all treatments except Garlon 3A 5%. Individuals were primarily in the lower height classes of 0.1-0.5 m and 0.5-1 m, although a few young trees 1-3 m tall were observed. No losses in ʻōhiʻa greater than 0.1 m tall occurred in any treatment over the year of monitoring, and differences among the six treatments were not significant (Kruskal-Wallis chi-sq = 7.20, p = 0.21). Even fewer olomea were found in study plots, and the species was absent from Roundup 5% and undiluted treatments. Where olomea did occur, they were primarily saplings and young trees 1-3 m tall. No losses of olomea were noted throughout the

Table 1. Effects of herbicide treatments on *Passiflora mollissima* in ‘Ōla‘a Tract, Hawaii Volcanoes National Park, 1986-1989.

Treatment	Time Since Treatment (mos)	Stumps Killed (n = 10)	No. Live Basal Resprouts	No. Stumps with Live Cambium	No. Live Aerial Vines	No. Vines Rerooting
5% Garlon 3A /Water	1	7	0	3	5	0
	3	10	0	0	4	0
	6	10	0	0	2	2
	9	10	0	0	1	1
	12	10	0	0	1	1
50% Garlon 3A /Water	1	10	0	0	7	0
	3	10	0	0	2	1
	6	10	0	0	1	0
	9	10	0	0	0	0
	12	10	0	0	0	0
Undiluted Garlon 3A	1	6	0	4	8	0
	3	10	0	0	1	0
	6	10	0	0	0	0
	9	10	0	0	0	0
	12	10	0	0	0	0
5% Roundup/ Water	1	7	0	3	0	0
	2	9	0	1	2	1
	6	10	0	0	1	0
	9	10	0	0	0	0
	12	10	0	0	0	0

Table 1, continued.

Treatment	Time Since Treatment (mos)	Stumps Killed (n = 10)	No. Live Basal Resprouts	No. Stumps with Live Cambium	No. Live Aerial Vines	No. Vines Rerooting
50% Roundup/ Water	1	10	0	0	9	0
	2	9	0	1	4	2
	6	10	0	0	0	0
	9	10	0	0	0	0
	12	10	0	0	0	0
Undiluted Roundup	1	8	0	2	4	0
	2	10	0	0	1	0
	6	10	0	0	0	0
	9	10	0	0	0	0
	12	10	0	0	0	0
Water Control	1	6	0	4	5	0
	2	10	0	0	9	5
	6	9	1	1	9	2
	9	10	0	0	4	4
	12	10	0	0	4	3

Table 2. A comparison of differences among treatments for change in number of individuals of 10 native plant species in *Passiflora mollissima* test plots, ʻŌlaʻa Tract, Hawaii Volcanoes National Park.

Species	Lifeform	No. Treatments Containing Species	N	Kruskal-Wallis Chi square	P
Athyrium microphyllum (ʻakolea)	fern	7	42	13.95	0.0303*
Cibotium glaucum (hapuʻu pulu)	fern	7	45	11.14	0.0840
Coprosma ochracea (pilo)	tree	7	43	7.26	0.2974
Diplazium sandwichianum (hōʻiʻo)	fern	7	48	3.16	0.7880
Metrosideros polymorpha + (ʻōhiʻa)	tree	6	16	7.20	0.2062
Peperomia spp. (ʻalaʻala wai nui)	herb	7	17	4.53	0.6048
Perrottetia sandwicensis + (olomea)	tree	5	14	2.00	0.7350
Pneumatopteris sandwicensis (hōʻiʻo kula)	fern	7	44	16.08	0.0133*
Sadleria pallida + (ʻamaʻu)	fern	6	14	0.90	0.0700
Uncinia uncinata	sedge	7	33	7.37	0.2881

* Significant at the 95% level.
\+ Not found in plots of all treatments.

year of the study, and differences among treatments were not significant (Kruskal-Wallis chi-sq = 2.00, p = 0.73).

Among the plants of more sporadic occurrence, a few losses were noted in the treatments of undiluted Garlon 3A and both undiluted and 50% Roundup. Individuals that disappeared over the year's time were primarily young shrubs and tree saplings, such as kawa'u, *Cyrtandra* sp., mamaki (*Pipturus albidus*), 'akala (*Rubus hawaiiensis*), and 'ōhelo (*Vaccinium calycinum*).

Ferns. The most abundant native plants in the 'Ōla'a study site were ferns; four different species were well represented in all treatments. Hō'i'o ferns increased in number over the year in all treatments except Roundup 50%, where the loss of one large individual was noted. Differences among treatments were not significant (Kruskal-Wallis chi-sq = 3.16, p = 0.79).

The tree fern hapu'u-pulu (*Cibotium glaucum*) was very common in the study area, with most treatments averaging one per plot. No losses in tree ferns were observed over the year of monitoring; instead, in most treatments modest increases were recorded. No significant differences among treatments were noted (Kruskal-Wallis chi-sq = 11.14, p = 0.08).

For the two other abundant fern species, differences among treatments were more pronounced. 'Akolea numbers increased in five treatments and remained the same in one (Roundup 5%) but decreased slightly in control plots. Probably due to fairly large increases in 'akolea in the three sets of Garlon 3A plots, a comparison of 'akolea numbers using the Kruskal-Wallis test indicated a significant difference among treatments (chi-sq = 13.95, p = 0.03). These differences cannot be attributed to negative impacts of herbicide treatments, as they are due to increases in young fern numbers over the year of monitoring. Hō'i'o-kula numbers showed the most variability among treatments of any of the ferns. Increases were observed in four treatments, ho'i'o-kula numbers remained constant in the control plots, and decreases were noted in the undiluted Roundup and Garlon 3A treatments. These differences among treatments were significant according to the Kruskal-Wallis test (chi-sq = 16.08, p = 0.01). The Wilcoxon rank sum test (which approximates a t-test) indicated that the decrease in ho'i'o-kula numbers in the undiluted Garlon 3A treatment was significant (when compared with the control (z = -2.14, p = 0.03), but the much smaller loss in the undiluted Roundup treatment was not significantly different from the control (z = 0.06, p = 0.95).

'Ama'u (*Sadleria pallida*) was much less abundant than the ferns discussed above. Numbers of 'ama'u increased or were constant throughout the year in all treatments except Garlon 3A 5%, when the loss of one individual was recorded. These differences were not significant when treatments were compared (Kruskal-Wallis chi-sq = 0.90, p = 0.07).

Other herbaceous plants. Two native herb species were found in plots of all seven treatments. The indigenous sedge *Uncinia uncinata* occurred in about half of all banana poka plots. Over the year of monitoring, *Uncinia* numbers increased in most treatments and decreased by only one individual each in the Roundup 50% and control treatments. These minor differences among treatments were not significant (Kruskal-Wallis chi-sq = 7.37, p = 0.29). ʻAlaʻala wai nui (primarily *Peperomia hypoleuca*) numbers changed very little over the year of the study, decreasing only in the undiluted Garlon 3A plots. No significance was attributed to these very small differences (Kruskal-Wallis chi-sq = 4.53, p = 0.60).

Seed Germination

Banana poka seeds buried in rain forest soil were not viable after nine months (or 21 months) in the ground. Split seed coats were all that remained of 50-seed samples buried in glass jars. By contrast, fresh seeds and air-dried seeds stored at room temperature showed high rates of germination.

The potential for rapid increase in banana poka density is very high. Seventy-eight percent of fresh banana poka seeds germinated within six months after planting in vermiculite under greenhouse conditions. Seeds stored for nine months had an even higher germination rate of 84% and germinated within two months of planting. After 21 months of storage, 72% of a 50-seed sample germinated within two months.

DISCUSSION

Banana poka appears to have little ability to resprout from cut stumps, and it may be unnecessary to apply herbicides to the cut stem base. Killing the aerial portion of the vines appears to be more difficult. The rerooting and survival of 4 of 10 control plants indicates that additional measures are necessary to completely kill vines in dense rain forest.

Several factors probably contributed to the survival of the vines. Frequent rainfall, cloud cover, and high relative humidity at the test site minimized vine desiccation and defoliation, facilitating recovery and root production. Adventitious rooting was observed on portions of banana poka vines touching the ground prior to treatment application. These auxiliary roots undoubtedly supplied the vine with water and nutrients after separation from the base. The most auspicious time to treat banana poka would be at the hottest hour of the day, preferably during a dry period.

Applying an herbicide to the cut surface of the aerial vine was very effective in killing the entire plant. All three Roundup treatments and both the undiluted and 50% Garlon 3A killed all vines treated. Costs of the two chemicals tested are similar; Roundup costs about 10% less than Garlon 3A. The least concentrated and safest of the effective chemical treatments was Roundup 5% in water; this is the recommended herbicide treatment for use on banana poka.

Based on the amount of herbicide used per stump ($\leq$2 ml) and the maximum density of banana poka (840 plants/ha) encountered in an experimental 25-ha (62-a) control block in ʻŌlaʻa Tract, the recommended herbicide treatment will easily fall within the rates allowed on the Roundup label. The recommended rate for most weeds species is 4,690-7,040 ml/ha (2-3 qt/a). The greatest quantity of Roundup (before dilution) used to date by Park Resources Management personnel to kill banana poka in ʻŌlaʻa was 84 ml/ha (1 oz/a) (J.T. Tunison, pers. comm. 1991).

No dramatic losses of native plants were observed during this test, and a significant change in the number of individuals was noted only for hoʻiʻo-kula in the undiluted Garlon 3A treatment. Other losses of individual plants were not significantly different from changes in control plots. Nonetheless, with two exceptions, all native plant losses (pilo, hōʻiʻo, hōʻiʻo-kula, *Uncinia*, and *Peperomia*) were observed in the treatments using 50% or undiluted Roundup and Garlon 3A. It appears that the 5% dilution of Roundup has no negative impact on nearby native plants when it is carefully applied to the cut surfaces of banana poka stems.

Although no mechanical method can be recommended as a reliable control for banana poka, non-herbicidal means may be useful in preventing rerooting of the vine. Removing a section of the vine so that no part touches the ground may be sufficient to achieve control, although this would not prevent adventitious rooting elsewhere along the vine. Following the vine and uprooting any rooted sections would be time consuming and difficult due to the serpentine growth habit of banana poka and the dense forest in which it is found. In a previous test of several herbicides and mechanical control, uprooting was tried as a control method, but only relatively small vines could be easily pulled out, and some resprouting was observed from roots or stems left in the soil (Hawaii Volcanoes National Park, Resources Management Division, unpub. data). In drier areas invaded by banana poka, herbicides may be unnecessary as the vines rapidly desiccate after being cut. Cutting banana poka appears to be effective without herbicides in open forests above 1,525 m (5,000 ft) elevation at Hakalau Forest National Wildlife Refuge on Mauna Kea (J. Jeffrey, pers. comm. 1991).

The seed viability study conducted at Hawaii Volcanoes National Park demonstrated that banana poka seeds buried in rain forest soils were not viable after nine months, even though dried, stored seeds collected at the same time had high germination rates for 21 months. This indicates that the soil seed bank will not be a persistent problem, once the input of seeds to the soil is curtailed by killing adult plants.

ACKNOWLEDGMENT

We wish to thank Michelle L. Fulton for drafting the map, and Danielle B. Stone for typing the manuscript and for help in editing.

APPENDIX*

Triclopyr

Chemical name: [(3,5,6-trichloro-2-pyridyl)oxy]acetic acid

Chemical formulation used: GARLON 3A (3 lb/gal) as triethylamine salt. Dow.

Herbicide use: Triclopyr is an auxin type selective herbicide for control of woody plants and broadleaf weeds. Most grasses are tolerant.

Mode of action: Triclopyr is readily absorbed by both foliage and roots and accumulates in meristematic tissue. The exact mechanism of action is unknown but appears to be similar to that of phenoxy herbicides.

Leaching: Triclopyr is not strongly adsorbed, with leaching potential dependent on soil organic matter content and pH. Some leaching may occur in light soils under high rainfall conditions.

Degradation: Rapid via microbial action and photodecomposition.

Toxicity: Triclopyr has a low order of toxicity to wildlife and fish. It is rapidly excreted and does not accumulate in blood or tissues. Technical triclopyr and GARLON 3A are not absorbed through the skin.

Information source: Dow Chemical.

Glyphosate

Chemical name: N-(phosphonomethyl)glycine

Chemical formulation used: ROUNDUP (4 lb a.e./gal) as the isopropylamine salt with in-can surfactant. Monsanto.

Herbicide use: Glyphosate is a broad-spectrum, nonselective herbicide effective on deep-rooted perennial species and on annual and biennial species of grasses, sedges, and broadleaf weeds.

Mode of action: Glyphosate is absorbed through the foliage and translocates throughout the plant. Root absorption is precluded by soil inactivation. The primary mode of action is through inhibition of the biosynthesis of aromatic amino acids.

Leaching: Strong soil adsorption results in very low leaching potential.

Degradation: Microbial degradation is the major route of decomposition, with negligible losses through photodecomposition.

Information source: Monsanto.

*Information derived from Humburg *et al.* 1989.

LITERATURE CITED

Giambelluca, T.W., M.A. Nullet, and T.A. Schroeder. 1986. *Rainfall atlas of Hawai'i.* Report R76, Water Resour. Res. Center with cooperation of Dept. Meteorology, Univ. Hawaii. State of Hawaii Dept. Land Nat. Resour. Div. Water and Land Devel. Honolulu.

Hawaii Division of Water and Land Development. 1970. *An inventory of basic water resources data, island of Hawaii.* Report R34, State of Hawaii Dept. Land Nat. Resour. Honolulu.

Hay, J.R. 1956. Translocation of herbicides in Marabu. I. Translocation of 2,4,5-trichlorophenoxyacetic acid following application to the bark or to cut surfaces of stumps. *Weeds* 4(3):218-226.

Higashino, P.K., L.W. Cuddihy, S.J. Anderson, and C.P. Stone. 1988. *Checklist of vascular plants of Hawaii Volcanoes National Park.* Tech. Rept. 64, Univ. Hawaii Coop. Natl. Park Resour. Stud. Unit. Univ. Hawaii, Honolulu. 82 pp.

Humburg, N.E., S.R. Colby, E.R. Hill, L.M. Kitchen, R.G. Lym, W.J. McAvoy, and R. Prasad. 1989. *Herbicide handbook of the Weed Science Society of America.* 6th ed. Champaign, Ill.: Weed Sci. Soc. Amer. 301 pp.

LaRosa, A.M. 1984. *The biology and ecology of* Passiflora mollissima *in Hawaii.* Tech. Rept. 50, Univ. Hawaii Coop. Natl. Park Resour. Stud. Unit. Univ. Hawaii, Honolulu. 168 pp.

LaRosa, A.M. In press. The status of banana poka in Hawai'i. In *Alien plant invasions in native ecosystems of Hawai'i: management and research*, ed. C.P. Stone, C.W. Smith, and J.T. Tunison. Univ. Hawaii Coop. Natl. Park Resour. Stud. Unit. Honolulu: Univ. Hawaii Press.

Lewin, V., and G. Lewin. 1984. The Kalij pheasant, a newly established game bird on the island of Hawaii. *Wilson Bull.* 96(4): 634-646.

Lockwood, J.P., P.W. Lipman, L.D. Petersen, and F.R. Warshauer. 1988. Generalized ages of surface lava flows of Mauna Loa Volcano, Hawaii. *U.S. Geolog. Survey Misc. Investigations Ser.* Map I-1908.

Markin, G.P., P.Y. Lai, and G. Y. Funasaki. In press. Status of biological control of weeds in Hawai'i and implications for managing native ecosystems. In *Alien plant invasions in native ecosystems of Hawai'i: management and research*, ed. C.P. Stone, C.W. Smith, and J.T. Tunison. Univ. Hawaii Coop. Natl. Park Resour. Stud. Unit. Honolulu: Univ. Hawaii Press.

Scowcroft, P.G., and R.E. Nelson. 1976. *Disturbance during logging stimulates regeneration of koa.* USDA Forest Service Res. Note PSW-306. Pac. SW Forest and Range Expt. Sta., Berkeley, Calif. 7pp.

Smith, C.W. 1985. Impacts of alien plants on Hawai'i's native biota. In *Hawai'i's terrestrial ecosystems: preservation and management*, ed. C.P. Stone and J.M. Scott, 180-250. Univ. Hawaii Coop. Natl. Park Resour. Stud. Unit. Honolulu: Univ. Hawaii Press.

Statistical Analysis Systems. 1985. *SAS procedures guide for personal computers*, version 6 edition. Gary, North Carolina: SAS Institute.

Wagner, W.L., D.R. Herbst, and S.H. Sohmer. 1990. *Manual of the flowering plants of Hawai'i*. Honolulu: Bishop Museum and Univ. Hawaii Presses.

Warshauer, F.R., J.D. Jacobi, A.M. LaRosa, J.M. Scott, and C.W. Smith. 1983. *The distribution, impact, and potential management of the introduced vine* Passiflora mollissima *(Passifloraceae) in Hawai'i.* Tech. Rept. 48, Univ. Hawaii Coop. Natl. Park Resour. Stud. Unit. Univ. Hawaii, Honolulu. 39 pp.