CSIRO PUBLISHING
www.publish.csiro.au/journals/ajea *Australian Journal of Experimental Agriculture,* 2004, **44**, 75–81

Evaluation of a hand-held burner for the control of woody weeds by flaming

J. S. Vitelli[A,B,C] *and B. A. Madigan*[A]

[A]Queensland Department of Natural Resources and Mines, Tropical Weeds Research Centre, PO Box 187, Charters Towers, Qld 4820, Australia.
[B]CRC for Australian Wheat Management, PMB 1, Waite Campus, Glen Osmond, SA 5064, Australia.
[C]Author for correspondence; e-mail: joseph.vitelli@nrm.qld.gov.au

Abstract. A hand-held burner (Atarus Ranger) was evaluated as a method for controlling woody weeds by flaming in sensitive or riparian areas where traditional methods, such as chemical or mechanical control, have limited usefulness. The equipment was trialled on 3 North Queensland weed species: bellyache bush (*Jatropha gossypiifolia*), parkinsonia (*Parkinsonia aculeata*) and rubber vine (*Cryptostegia grandiflora*), at 5 different heat durations (0, 10, 30, 60 and 120 s) and on 3 plant size classes based on basal diameter (15–25, >25–50 and >50 mm).

No significant difference in percentage mortality was recorded between a 10 s treatment and longer heat treatments for bellyache bush and parkinsonia plants, or between a 60 s treatment and longer heat treatments for rubber vine. A 10 s treatment killed 92% of the treated bellyache bush plants and 83% of the parkinsonia plants, while a 60 s treatment killed 76% of the treated rubber vine plants (values are the means of all size classes combined).

Flaming was least effective on rubber vine, which had the thickest bark, but was highly effective on bellyache bush, which had the highest bark moisture content. Weeds with a low capacity for root suckering, thin bark, high bark moisture content and low bark density appear the best candidates for flaming. Flaming is an effective technique for the control of woody weeds with efficacy varying among species. Individual plants are targeted, and the technique is accepted by organic farming groups.

Additional keywords: bellyache bush, parkinsonia, rubber vine.

Introduction

Flame cultivation (or flaming — a method of dehydrating target vegetation) as a technique for weed control in crops has been in use since 1852 (Vester 1988). In more recent times, hand-held burners have been used for selective flaming of young annual and perennial weeds (Parish *et al.* 1997). A hot flame is passed over the seedling, and the intensity of heat and time of exposure are adjusted to rapidly raise the temperature of the moisture in the plant without combustion of the plant itself. The expansion of the liquid in the plant cells causes the cell walls to rupture, leading to plant death (Vester 1988; Parish *et al.* 1997; http://www.gameco.com.au/catalogue/fw/Default).

Selective flaming over entire plants is not feasible for large or mature woody weeds, but using a hand-held burner to heat a woody weed at the base of its stem may provide control. Localised heat, applied around the entire circumference of the base of a woody plant by a hand-held burner, may be effective in destroying the vascular cambium. Previous studies on the effect of fire in forests have shown that injuries to the trunks of individual trees that are sufficient to kill the cambium layer reduce growth and kill the shoot (Hare 1961). The exotic weed *Prosopis pallida* is readily killed by fire, even if damage is only slight (Campbell and Setter 2002). Simulated fires on 11 species native to the central hardwood region of eastern United States found that increased thickness of basal bark led to decreases in the maximum cambial temperature recorded (Hengst and Dawson 1994). The cambium layer is normally destroyed when the cambium exceeds a temperature of 60°C (Hare 1961; Fahnestock and Hare 1964), although the effect of fire or heat on plant mortality is species-specific (Dyer *et al.* 1997).

Flaming of woody weeds may be useful in areas where chemical and mechanical control is inappropriate or ineffective, or where broad-acre use of fire is not the preferred control option. Flaming could also be used during wet weather or when target plants are growing in wet areas. Additionally, thermal weed control (including flaming) is permissible under many organic agriculture standards, including those of the International Federation of Organic Agriculture Movement (http://www.ifoam.org/standard/ basics.html).

The objectives of this study were 3-fold: to determine the maximum plant stem surface temperature during and after application of the hand-held burner; the burner's effectiveness and cost of application as a control method for 3 woody weed species [*Jatropha gossypiifolia* (bellyache bush), an erect

 10.1071/EA02096 0816-1089/04/010075

shrub or small tree (2–5 m); *Cryptostegia grandiflora* (rubber vine), a free-standing (up to 2 m) or climbing (up to 30 m) woody vine; and *Parkinsonia aculeata* (parkinsonia), an erect shrub or small tree (rarely to 10 m)]; and to determine whether efficacy of the burner is related to the bark and stem properties of the three woody weeds studied.

Materials and methods

Experimental design

The experiment was a 3 by 5 by 3 factorial replicated 4 times using a split-split-plot design. Factor A is the 3 weed species (*Jatropha gossypiifolia* L., *Parkinsonia aculeata* L. and *Cryptostegia grandiflora* R.Br.) assigned to the mainplots, factor B is the 5 heat durations (0, 10, 30, 60 and 120 s) assigned to the subplots, and factor C is the 3 basal diameter size classes (15–25, >25–50, >50 mm) assigned to the sub-subplots. Each treatment contained 10 plants.

Four properties near Charters Towers (20.09°S, 146.24°E) in Queensland, Australia, each containing a mixed infestation of bellyache bush, parkinsonia and rubber vine were chosen as field sites for the experiment (Table 1). Each property constituted a replicate. At each site, a total of 450 plants were selected, measured and tagged.

Flame and temperature equipment

The heat-source was the Atarus Ranger (Origin Energy, Adelaide, SA, Australia). The Atarus Ranger is a hand-held appliance with twin high-efficiency LPG burners, and can be used with a single burner or with the addition of a booster burner. Two burners were used during all heat treatments in this experiment. In this mode the burner outlet recorded temperatures of 1200°C. The tip of the Atarus Ranger was placed on the stem of the plant 5 cm above ground level for half the time of treatment, then the tip position was moved 180° around the stem (to the opposite side) for the remaining half of flaming time. This technique of positioning the tip of the flamer at 2 opposite points on the plant base allowed the entire circumference of the stem to be treated with heat. An infrared thermometer (Cole-Parmer Infrared Thermometer model 39800-33, Cole-Parmer Instrument Company, Vernon Hills, Illinois, USA) was used to record the temperature of the treated section of the stem before flaming, during heat application and 15 s after the heat source was removed.

Flaming versus basal bark control

A basal bark treatment was applied to allow comparison of cost and efficacy of flaming with a known chemical method. At each site, an additional 10 plants of each size class for each species were selected, measured and tagged. The basal bark treatment used triclopyr/picloram (Access) at 2.0/4.0 g a.i./L diesel. Access is a registered herbicide for the control of *C. grandiflora* and *P. aculeata* (http://www.dowagro.com/au/Pages/Labels&MSDS_PDF/LabelsPdf/AccessLabel.PDF). The herbicide–diesel mix was applied using an 8 L hand-carried pneumatic sprayer with variable cone nozzle and an operating pressure of 70 kPa.

Evaluating plant injury

Plant damage was assessed at 14, 40, 75, 200 and 365 days after treatment using a rating scale of 1 (healthy) to 10 (dead — no live tissue in main stem and taproot of plant). Plant mortality at the final assessment (365 DAT) is presented here.

Bark properties

In order to gain information on the possible influences of bark properties on the efficacy of the Atarus Ranger, the relationships between bark thickness and basal stem diameter, bark density and bark moisture content were determined for all 3 species. Ten sections, 15 mm thick, of plant stems from the 3 basal diameter size classes were cut 5 cm above ground level. Means of bark thickness, stem diameter, bark moisture content and density of bark were obtained for these sections. Bark thickness and stem diameter were measured using the OPTIMAS 6.1 digital image analysis system (Optimas Corporation, Bothell, Washington). Bark volume was determined by the cubic volume (area of base by height) method. Moisture content was calculated by obtaining an initial fresh weight, drying bark sections at 80°C for 48 h and then reweighing. The moisture content was expressed as percentage of oven dry bark weight and calculated as:

$$\frac{M_1 - M_2}{M_2} \cdot 100,$$

where M_1 is bark fresh weight and M_2 is bark dry weight. The bark density (g/cm^3) was determined on an oven-dried weight to volume ratio, as follows:

$$\frac{\text{Oven-dry weight of bark (g)}}{\text{Volume of bark (cm}^3\text{)}}.$$

Statistical analyses

An analysis of variance was performed on bark surface temperatures during and after heat applications, plant mortality, bark thickness, bark moisture content and bark density. Where the *F*-test was significant ($P<0.05$) the mean differences were determined using Fisher's Protected Least Significant Difference (l.s.d.) test. Plant mortality and bark moisture content were arcsin-transformed before analysis and back-transformed prior to presentation. The relationship between bark thickness and stem diameter were analysed using linear regression. All analyses were performed using Systat 9 Statistical Program (SPSS Inc., Chicago, Illinois).

Results

Plant surface temperature during and 15 s post-treatment

Plant stem surface temperature averaged 36°C for all species before treatment. The application of heat to the base

Table 1. Site description and conditions during basal bark treatment and flaming treatment for bellyache bush, parkinsonia, and rubber vine near Charters Towers during November 2001

	Property 1	Property 2	Property 3	Property 4
Location	20.05197°S, 146.21223°E	19.91667°S, 146.20°E	20.04830°S, 146.21223°E	19.82721°S, 146.06694°E
Soil type	Black earth	Cracking grey clay	Sandy loam	Cracking grey clay
Soil moisture	1.8–2.8%	2.0–2.7%	2.5–2.9%	1.4–2.8%
Weather conditions				
Air temperature (°C)	32–40	32–40	31–40	34–40
Relative humidity (%)	23–70	30–70	34–80	32–85
Wind speed (m/s)	0–3.5	1–4	1–4	1–5

of plants using the Atarus Ranger significantly increased plant surface temperatures with increasing heat duration, both during application (Fig. 1), and after application (Fig. 2). Maximum temperatures for all 3 species exceeded 820°C following 120 s exposure (Fig. 1). Temperatures had dropped by 67–82% by 15 s after the treatment.

There were significant positive relationships between plant surface temperature and heat duration (Fig. 1) with significant ($P<0.0005$) differences between species. Bellyache bush recorded the highest temperatures followed by rubber vine and then parkinsonia, irrespective of size class. The greatest differences occurred at the lower heat durations.

For the 15 s post-application temperatures, a significant plant species by heat duration by size class interaction ($P = 0.006$) was identified. The treatment contributing the most to this interaction was the 15–25 mm bellyache bush size class (Fig. 2). These plants were scorched and were burning through at the base during treatment application. Temperatures of up to 204°C were recorded. The other 2 bellyache bush size classes recorded the lowest stem surface temperatures (<130°C). The hottest post-application temperatures were recorded for rubber vine, particularly the largest size class reaching 285°C for the 120 s treatment (Fig. 2).

Plant observations during heat applications

The bark and the stems of bellyache bush blistered during application of direct heat, and some of the small diameter plants burnt through at the base and fell either during application or shortly after. In many cases the detached burnt-off-stems that were lying on the ground retained and produced leaves up to 6 months following treatment. No adventitious roots developed on these plants despite them lying on the ground during the wet season. The bark on the stems of rubber vine plants was heated sufficiently during longer application times (120 s) to be glowing red. The waxy cuticle on the stem surface of parkinsonia plants appeared to change following the application of heat, resulting in a 2–3 cm shiny, translucent waxy cuticle band above and below the point of heat application for the 10 and 30 s treatments. The bark of parkinsonia plants exposed to longer heat treatments was scorched at the site of treatment application.

Plant mortality

Plant mortality resulting from flaming ranged between 22.5 and 100%, with significant ($P<0.001$) interactions occurring between plant species and heat duration (Fig. 3) and between plant species and size classes (Fig. 4).

Bellyache bush and parkinsonia required less heating than rubber vine before maximum mortality occurred. No

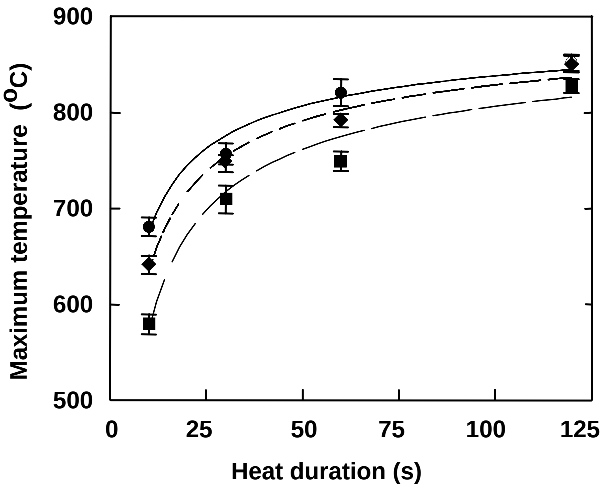

Figure 1. Average maximum temperature recorded on the plant surface during treatment application for bellyache bush (●), parkinsonia (■) and rubber vine (◆). The Atarus Ranger was applied for 10, 30, 60 or 120 s duration at 5 cm above the base of each plant. Vertical bars represent the standard error of the mean. The equations of the lines are:

bellyache bush: $y = 913.1 - 755.7/x^{(0.5)}$ ($R^2 = 0.43$),
parkinsonia: $y = 903.6 - 1041.7/x^{(0.5)}$ ($R^2 = 0.60$),
rubber vine: $y = 918.1 - 892.9/x^{(0.5)}$ ($R^2 = 0.65$).

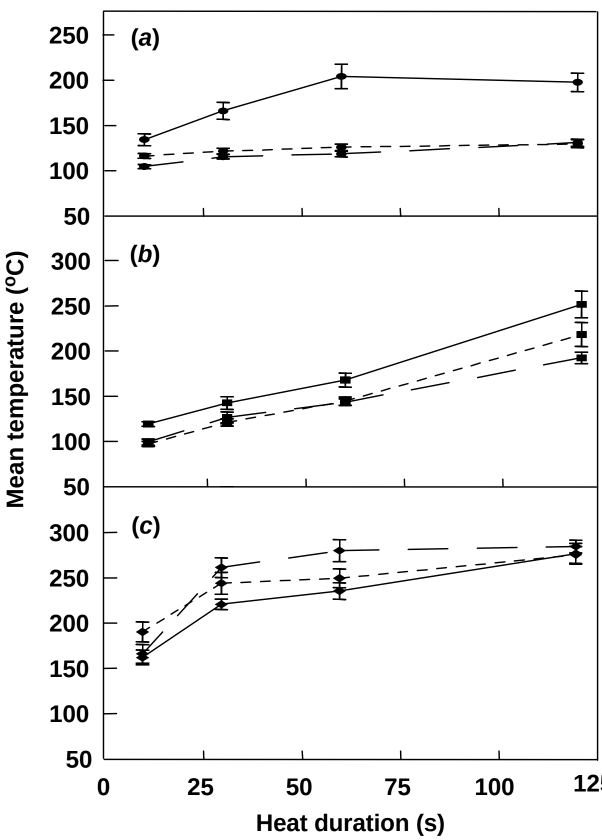

Figure 2. Average maximum temperature recorded on the plant surface 15 s post-treatment application for (*a*) bellyache bush, (*b*) parkinsonia and (*c*) rubber vine at each size class [15–25 (——), >25–50 (---), and >50 mm (– – –) basal diameter]. The Atarus Ranger was applied for 10, 30, 60 or 120 s duration at 5 cm above the base of each plant. Vertical bars represent the standard error of the mean.

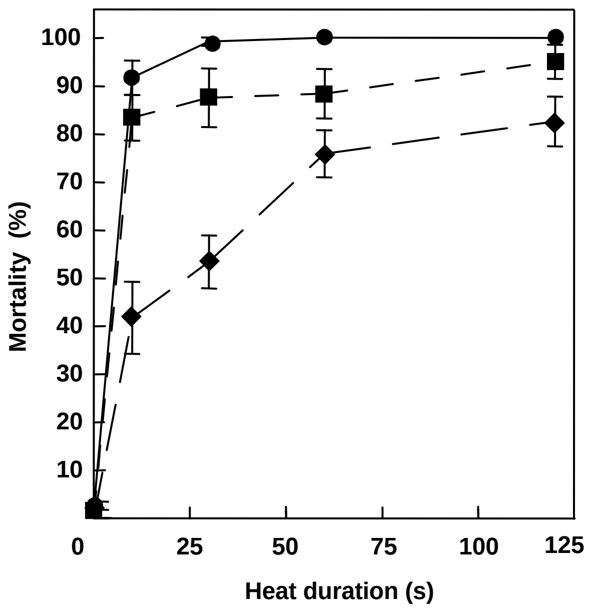

Figure 3. Average plant mortality recorded for bellyache bush (●), parkinsonia (■) and rubber vine (◆) meaned over size classes (15–25, >25–50 and >50 mm basal diameter). Flaming was applied for 10, 30, 60 or 120 s duration at 5 cm above the base of each plant. Vertical bars represent the standard error of the mean.

significant (*P*>0.05) difference in percentage mortality was recorded between a 10 s treatment and longer heat treatments for bellyache bush and parkinsonia plants or between a 60 s treatment and longer heat treatments for rubber vine (Fig. 3).

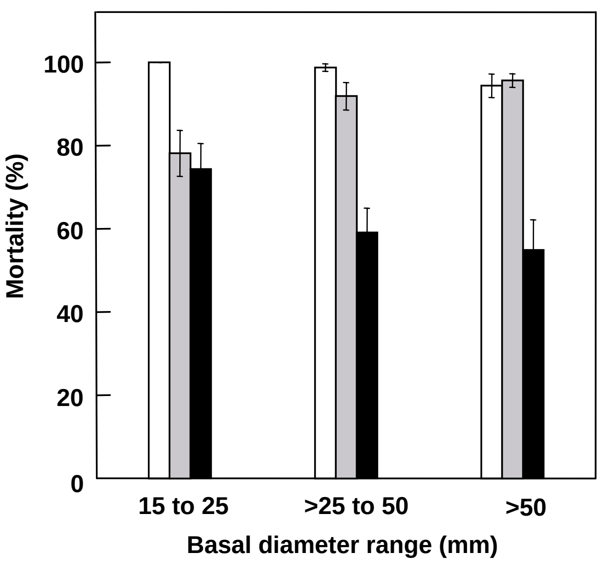

Figure 4. Average plant mortality recorded for bellyache bush (open bars), parkinsonia (shaded bars) and rubber vine (solid bars) across 3 size classes (15–25, >25–50 and >50 mm basal diameter) irrespective of heat duration. Flaming was applied for 10, 30, 60 or 120 s duration at 5 cm above the base of each plant. Vertical bars represent the standard error of the mean.

A 10 s treatment killed 92% of the treated bellyache bush plants, 83% of the parkinsonia plants, and a 60 s treatment killed 76% of the treated rubber vine plants (values are means of all size classes combined).

Size class significantly influenced mortality of parkinsonia and rubber vine plant, but not of bellyache bush. Parkinsonia plants with basal diameters less than 25 mm were more difficult to kill (78% mortality) than larger sized parkinsonia plants (94% mortality) irrespective of the heat treatment applied to them (Fig. 4). The reverse was observed for rubber vine plants. As plant basal diameter increased (15 to >50 mm) plant mortality decreased (74 to 54% mortality).

Mortality for the basal bark (chemical) treatment was 100% for all size classes for parkinsonia, 100% for <25 mm and >25–50 mm size classes in both rubber vine and bellyache bush, and 97.5% for >50 mm size classes in rubber vine and bellyache bush.

At the end of the assessment period, there was no noticeable difference in seedlings or grasses around the bases of all treated plants compared with untreated plants.

Bark characteristics

For all species, a positive linear relationship between bark thickness and stem diameter was observed (Fig. 5). The equations for the 3 species all differed significantly

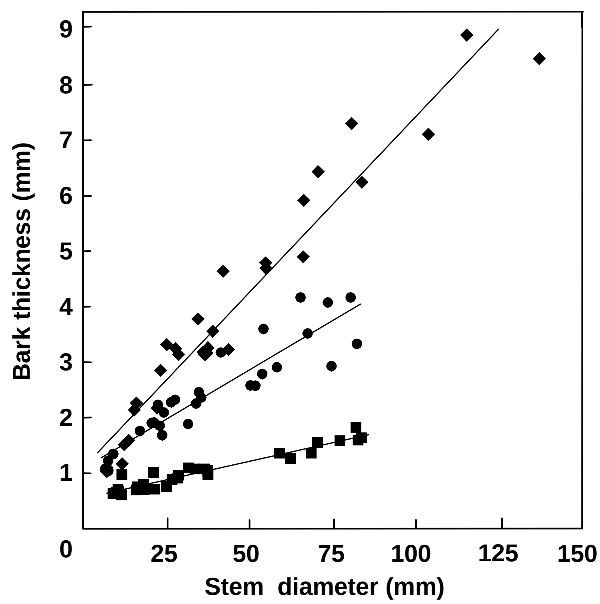

Figure 5. Comparison of basal stem diameter and bark thickness for parkinsonia (■), bellyache bush (●) and rubber vine (◆) plants across all size classes tested (15–25, >25–50 and >50 mm basal diameter). Data are based on 15 mm thick stem sections cut 5 cm above ground level. The equations of the lines are:

bellyache bush: $y = 1.069 + 0.036x$ ($R^2 = 0.85$),

parkinsonia: $y = 0.550 + 0.013x$ ($R^2 = 0.93$),

rubber vine: $y = 1.078 + 0.063x$ ($R^2 = 0.94$).

(*P*<0.0005). Rubber vine had the thickest bark followed by bellyache bush and then parkinsonia.

Bark moisture content was significantly (*P*<0.0005) different between species. Bellyache bush recorded the highest bark moisture content (76%), followed by rubber vine (53%) and parkinsonia (43%). No significant differences were recorded between size classes. Bark density was also significantly (*P*<0.0005) different for the 3 species, with parkinsonia (0.48 g/cm^3) greater than rubber vine (0.34 g/cm^3) greater than bellyache bush (0.20 g/cm^3).

Cost of Atarus Ranger compared with basal bark treatment

The cost per plant of using the Atarus Ranger ranged from 7.5 cents for a 10 s treatment to 90 cents for a 120 s treatment (Table 2). The cost per plant of a basal bark treatment varied from 4.6 cents for bellyache bush plants with a basal diameter of 15–25 mm, to 12.1 cents for rubber vine plants >50 mm basal diameter. These costs include the time to apply the treatment to the plant, plus cost of LPG gas or herbicide mixture used. They do not include cost of equipment, mixing time, time to fill gas bottles, or time between treating individual plants. Table 2 compares the cost of basal bark treatments for the different size classes and species with the cost of flaming at 10 s for bellyache bush and parkinsonia and 60 s for rubber vine. Mean percentage mortality rates are also shown for the treatments listed. Under normal operating of the hand-held burner, 4 standard 5 L gas cylinders lasted about 6 h in the field (time includes flaming of individual plants, time between treating plants and exchanging of gas cylinders in the field).

Discussion

Flaming effectiveness

This study established that flaming of individual woody weeds can be an effective technique for isolated weed infestations, although the degree of control varied between species. Effectiveness was highest for bellyache bush, followed by parkinsonia and rubber vine, respectively. The importance of calibrating heat applications for individual plant species was also evident from this study. Maximum mortality for both bellyache bush and parkinsonia occurred after 10 s of treatment, but rubber vine needed at least 60 s. Another difference between plant species was the response of different size classes. Irrespective of heat treatment, plant mortality decreased with increase in size class for bellyache bush and rubber vine, but increased for parkinsonia.

Bark characteristics

In woody plants, externally applied heat is received on the bark surface, and then conducted through the bark to reach the cambium. The heat received at the cambial layer depends both on the amount and duration of heat at the bark surface, and on the characteristics of the bark (Spalt and Reifsnyder 1962; Fahnestock and Hare 1964). Characteristics, such as bark thickness, moisture content, and density are the main factors contributing to fire resistance according to studies on fire tolerance of plants (Hare 1961; Spalt and Reifsnyder 1962; Whelan 1995).

Bark thickness increased as the stem diameter increased for the 3 species tested, and as bark thickness increases, the time needed to raise the temperature of the cambium

Table 2. Mortality and cost per plant for basal bark treatment and flaming treatment for bellyache bush, parkinsonia, and rubber vine

Treatment	Basal diameter size class (mm)	Cost per plant (cents)	Mortality (%)
	Bellyache bush		
Basal bark[A]	15–25	4.6	100
	>25–50	5.5	100
	>50	9.2	97.5
Atarus Ranger	All size classes for 10 s	7.5	91.7
	Parkinsonia		
Basal bark[A]	15–25	6.5	100
	>25–50	7.3	100
	>50	9.7	100
Atarus Ranger	All size classes for 10 s	7.5	83.3
	Rubber vine		
Basal bark[A]	15–25	5.6	100
	>25–50	7.5	100
	>50	12.1	97.5
Atarus Ranger	All size classes for 60 s	45.0	75.8

[A]Basal bark costs are based on average volume herbicide mixture used per plant plus labour required to treat each plant (May 2003 prices: access, \$55.50/L; diesel \$0.70/L; labour, \$16/h).

[B]Atarus Ranger costs are based on LPG used per plant plus labour per plant (May 2003 prices: LPG, \$8.25/2.5 kg).

increases, though the exact relationship differs among species (Hare 1965*a*; Whelan 1995). Thermal conductivity within the bark is influenced by moisture content, and measurement of moisture content helps determine how quickly internal tissues reach the lethal temperature of 60°C (Stickel 1941; Spalt and Reifsnyder 1962; Hare 1965*b*). In a study by Gill and Ashton (1968) on fire tolerance in eucalypts, the lethal temperature for the cambium was assumed to be similar for all species. This study assumed that the lethal temperature for the cambium is similar for bellyache bush, parkinsonia and rubber vine plants.

The type of heat received at the bark surface was the same in all cases, only the duration of heat varied per treatment. Temperature of the bark surface increased with duration of flaming in all plant species irrespective of plant size, though the maximum mean temperature recorded differed among species for each heat duration (120 s treatment ranged from 830 to 850°C). Stem surface temperatures dropped up to 82% 15 s post-heat application (temperatures ranging from 105 to 279°C 15 s post-application). The absorption of heat from a constant source varies with species and the flammability of the bark can contribute to this variation, with flammability influenced by moisture content, density and the initial temperature of the bark (Gill and Ashton 1968). The visual effects of heat on the bark surface varied for the 3 species, with some smaller bellyache bush plants burnt through the base, parkinsonia plants scorched, and the bark on some rubber vine plants glowed red under the longer heat treatments.

Even though bellyache bush had relatively thick bark, the porous nature and higher water content of the bark appeared to reduce fire resistance in this species. Rubber vine's thicker bark, lower moisture content and higher bark density probably contributed to its greater resistance to the heat treatment. Parkinsonia had the densest bark and the lowest bark moisture content, but also the thinnest bark layer. In cases of longer heat treatments, the bark of parkinsonia plants was scorched through at the base of the plant.

Cost considerations

A 10 s heat treatment on bellyache bush plants gave an average plant mortality of 92% at a cost of 7.5 cents per plant regardless of size class. The basal bark treatment gave a 99% mean mortality at an average cost of 6.4 cents per plant. Based on these results, flaming 1000 bellyache bush plants would cost $11 more than basal barking, and would result in a slightly lower percentage kill.

A 10 s heat treatment cost the same amount per plant (7.5 cents) for parkinsonia as for bellyache bush, but resulted in a mean plant mortality of 83.3%, while the basal bark treatment gave 100% mortality at an average cost of 7.8 cents per plant. Flaming 1000 parkinsonia plants would cost $3 less than using a basal bark treatment, but be only 83.3% effective. Longer heat treatments for parkinsonia did not improve the mortality percentage significantly, but escalated the cost.

The 60 s heat treatment for rubber vine plants gave 75.8% mean plant mortality at a cost of 45 cents per plant, compared with a 91.7% mean plant mortality at an average cost of 8.4 cents per plant using the basal bark technique. Treating 1000 of these plants by flaming would cost $366 more than by basal barking, with a much lower plant kill. Increasing the heat duration to 120 s increased mean mortality to 82.6%, but doubled the cost of the 60 s treatment.

Higher mortality rates could be achieved with a second flaming for reshooting plants, but this would add to the overall cost. The basal bark treatment had no instances of reshooting in any of the species trialled. Cavanagh and Weyrick (1978) also noted that reshooting was common with hardwoods after a flaming technique, whereas the use of herbicides usually limited reshooting.

Conclusion

In summary, flaming can be an environmentally friendly and effective technique for control of woody weeds, and should be considered as a viable alternative method of control for small weed infestations or for situations where other control methods are unsuitable. Individual plants can be burnt without using grass as a fuel source. In this study flaming and spraying had similar costs and effectiveness for bellyache bush and parkinsonia control, but flaming was more costly and less effective for rubber vine. Thermal weed control is also permissible under many organic agriculture standards, including those of the International Federation of Organic Agriculture Movement (http://www.ifoam.org/standard/basics.html). With care not to start a wildfire, other vegetation in the area will be unaffected by flaming.

Though this study did not compare the effectiveness of the Atarus Ranger at different times of the year, Cavanagh and Weyrick (1978) suggest the technique can be used year round. Flaming can be carried out in rain (http://tncweeds.ucdavis.edu/esadocs/documnts/ailaalt.html) or in wet areas, however, for safety reasons it would not be used in areas where there is a dry fuel load (Cavanagh and Weyrick 1978). In contrast, some herbicide control methods are effective only in certain seasons (Vitelli 2000).

Practical considerations of the weight of the equipment, availability of LPG gas and the duration of the gas cylinder in the field also need to be considered. The Atarus Ranger is comparable in weight and ease of use to a woody weed brushcutter. Operators planning to control weeds in the field by flaming would require a minimum of 4 standard 5 L gas cylinders per day. Flaming would not be practical for controlling dense weed infestations.

The efficacy and costs of flaming depend on the bark characteristics of the woody weed species to be controlled. Weeds that have thin bark, high moisture content, low bark density, and tend not to reshoot after fire damage, would make good candidates for flaming. Laboratory studies of bark characteristics can help predict fire damage for different tree species (Hare 1961). Field studies, measuring the temperature of the cambium of living trees during varying intensities and duration of externally applied heat, have also been made to help ascertain the role of prescribed burning in silviculture management (Kayll 1963). Similar studies for woody weed species could also predict the efficacy of flaming as a control method.

Acknowledgments

The authors acknowledge Origin Energy for supply of the burner and the Tropical Weeds Research Centre staff (Rodney Stevenson and Kyle Risdale) for technical support. Preparation of the paper was aided by comments from Drs J. C. Scanlan and S. D. Campbell and Marie Vitelli.

References

Campbell SD, Setter CL (2002) Mortality of *Prosopis pallida* (mesquite) following burning. *Australian Journal of Experimental Agriculture* **42**, 581–586.

Cavanagh JB, Weyrick RR (1978) Weed burner for controlling undesirable trees and shrubs. *Journal of Forestry* **76**, 472–473.

Dyer R, Craig A, Grice AC (1997) Fire in northern pastoral lands. In 'Fire in the management of northern Australian pastoral lands'. (Eds AC Grice, SM Slatter) pp. 24–40. Tropical Grassland Society of Australia Occasional Publication No. 8, Townsville, Queensland.

Fahnestock GR, Hare RC (1964) Heating of tree trunks in surface fires. *Journal of Forestry* **62**, 799–805.

Gill AM, Ashton DH (1968) The role of bark type in relative tolerance to fire of three central Victorian eucalypts. *Australian Journal of Botany* **16**, 491–498.

Hare RC (1961) 'Heat effects on living plants.' United States Department of Agriculture Southern Forest Experiment Station Occasional Paper 183, North Carolina.

Hare RC (1965*a*) Bark surface and cambium temperatures in simulated forest fires. *Journal of Forestry* **62**, 437–440.

Hare RC (1965*b*) Contribution of bark to fire resistance of southern trees. *Journal of Forestry* **63**, 248–251.

Hengst G, Dawson JO (1994) Bark properties and fire resistance of selected tree species from the central hardwood region of North America. *Canadian Journal of Forest Research* **24**, 688–696.

Kayll AJ (1963) 'A technique for studying the fire tolerance of living tree trunks.' Canadian Department of Forestry Publication No. 1012, Ottawa, Ontario.

Parish RL, Porter WC, Vidrine PR (1997) Flame cultivation as a complement to mechanical and herbicidal control of weeds. *Journal of Vegetable Crop Production* **3**, 65–83.

Spalt KW, Reifsnyder WE (1962) 'Bark characteristics and fire resistance: a literature survey.' United States Department of Agriculture Southern Forest Experiment Station, Forest Service Occasional Paper No. 193, Connecticut.

Stickel PW (1941) 'On the relation between bark character and resistance to fire.' United States Department of Agriculture Northeastern Forest Experiment Station 1, Technical Note No. 39, Connecticut.

Vester J (1988) Flame cultivation for weed control — 2 years' results. In 'Proceedings of a meeting of the EC Experts' Group, Weed control in vegetable production'. pp. 153–167. (Stuttgart, Germany)

Vitelli JS (2000) Options for effective weed management. *Tropical Grasslands* **32**, 280–294.

Whelan RJ (1995) 'The ecology of fire.' (Cambridge University Press: Cambridge, UK)

Received 21 May 2002, accepted 5 June 2003