Using digital image analysis to estimate flower numbers of Cootamundra wattle (*Acacia baileyana* F.Muell.) and hence determine seed production and weed potential

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Summary

***Acacia baileyana* F.Muell. (Cootamundra wattle), a native plant of Australia, is a widely planted ornamental tree that produces attractive displays of yellow inflorescences. Outside its endemic range in Australia and in South Africa it has escaped from cultivation to become a weed. In this study, a non-destructive, digital photographic image method was investigated as a technique for estimating total flower numbers from 10 trees of *A. baileyana*. This would give a better understanding of the flower and seed characteristics and therefore, the weed potential of this species. Flower numbers per tree were estimated by obtaining density of flowers in four destructive samples per tree, and scaling up with canopy volume. Numbers ranged from 1.25 million to over 13 million. A relationship was established between density of flowers and proportion of yellow flower colour in photographic digital images, using multiple linear regression on log-transformed data (R^2 = 0.40, P = 0.052). This was used to predict number of flowers per plant, although further work could be done to better establish the relationship between proportion yellow and density of flowers. Predicted flower numbers were similar to the estimated, ranging from 1.5 to 16.3 million. The total number of pods and seeds per tree were estimated from branch counts and scaled up from the estimated number of flowers. Average pod set for the 10 trees was 0.12%, and average seeds per pod was 4.0. Nevertheless, because of the large number of flowers, the average seed production was over 19,500. This is a very large reproductive output, partly explaining the weed status of this species.**

Introduction

Acacia baileyana F.Muell. (Cootamundra wattle) has a restricted natural distribution in New South Wales, Australia, but has been planted as a garden tree for over 100 years and is now cultivated for cut stems (Horlock *et al.* 2000). The plant has escaped from cultivation to become an aggressive environmental weed in Australia (Mulvaney 1991) and South Africa (Ross 1975, Milton and Moll 1982). One of the attributes of a weed is the production of a high number of viable seeds (Adair 1995) and the success of *A. baileyana* in South Africa as a weed has been attributed to its large seed production (Milton and Moll 1982).

Most acacias produce large numbers of flowers but only a small proportion develop into fruit (New 1984). Information on flowering is very useful to predict the extent of fruit set. Most studies on *Acacia* have reported flower and pod production from only a subset of branches (Grant *et al.* 1994, Kenrick and Knox 1989, Pietersen and Cairns 1988), inflorescences (Sedgley *et al.* 1992, Morrison and Myerscough 1989), or racemes (Kenrick *et al.* 1987). For example, in a study on Australian weeds in South Africa pod set was determined from branch counts, with the total number of seeds estimated by weighing all the pods on the trees (*A. saligna* and *A. cyclops;* Milton and Hall 1981). Some authors have determined total pod production by counting a proportion of the tree and extrapolating (Tybirk 1989 and 1993), but very few investigators have endeavoured to count total flower numbers on trees. Baranelli *et al.* (1995) estimated the total number of inflorescences for trees of *A. caven* by counting the number of inflorescences in a quarter of the crown and scaling up for the whole tree. Morrison and Myerscough (1989) counted the total number of inflorescences per plant, and the number of flowers per inflorescence for *A. suaveolens*. This was feasible because there were fewer than 88 inflorescences per plant.

In this study, a non-destructive, digital photographic image method was investigated as a technique for estimating total flower numbers of *A. baileyana* trees, to better understand the flower and seed characteristics and therefore, the weed potential of the species. A digital method was chosen because the silvery blue-green foliage contrasts to racemes of bright yellow inflorescences and the six metres maximum height of the trees meant easy access for photographs. Flower, pod and seed numbers, pod set and seeds per pod were determined from counts on branches. Using the total estimated number of flowers determined from digital image analysis and the flower and seed counts from the branches, total seed production per tree was estimated.

Digital photographic image analysis has been used previously to estimate leaf area (Baker *et al.* 1996, Bignami and Rossini 1996), plant dimensions (Bignami and Rossini 1996), and canopy volume (Bignami and Rossini 1996, Miller and Lightner 1987, Sydnor *et al.* 1975). The benefit of a photographic method for determining plant characteristics, such as flower number, is that it is non-destructive and thus allows post-flowering events, such as fruit-set, to be quantified. Repeated measurements may also be done without affecting plant growth and production, and several parameters can be calculated from the one image.

Materials and methods

Tree selection

The study was conducted in the water catchment area of the Millbrook Reservoir, near Adelaide, South Australia, where *A. baileyana* has invaded the natural bush. Ten solitary trees (i.e. non-overlapping canopies) with dense flowering canopies were selected when the trees were at peak flowering. Flowering trees of different size were chosen to obtain a range of canopy volumes.

Digital images

The ten trees were photographed from four approximately equidistant points around the perimeter of each canopy. Photographs were taken using an EOS Canon 500 camera, with an EF 35-80 mm zoom lens, and Kodak, 35 mm 400 ASA print film. A metre rule was included in each photograph as a scale. To obtain a digital image, each photograph (10.2 × 15.2 cm) was scanned using a Hewlett Packard ScanJet IIcx/T colour scanner to produce an image of size 700 × 500 pixels. The brightness and contrast for each image was standardized visually to account for trees photographed under different light conditions.

A schematic diagram indicating the sequence of measurements made from the digital images is shown in Figure 1. This figure also shows the sequence for analysis of the destructive samples (see below).

Proportion yellow flowers (PY)

Each of the four images per tree was analysed digitally for surface area (SA) of vegetation and area of yellow flowers

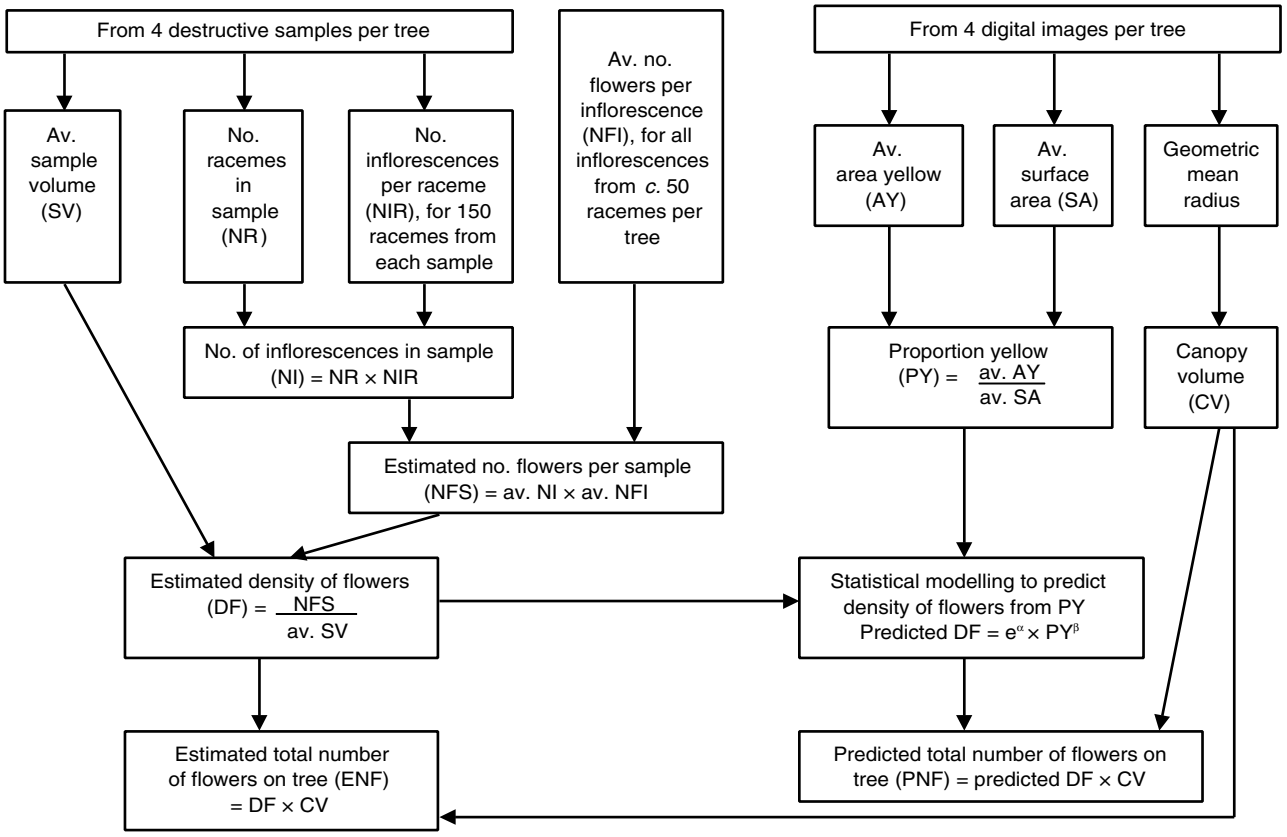

Figure 1. A flow diagram of the digital image analysis and destructive sampling techniques used to estimate and predict total number of flowers on trees.

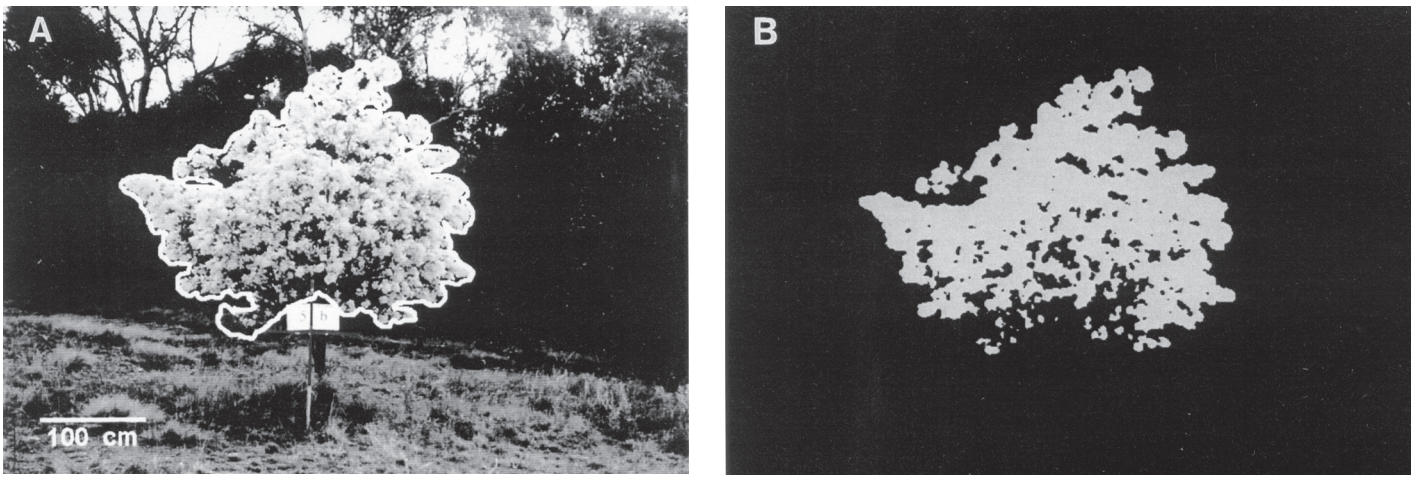

Figure 2. Digital image analysis of area of yellow flowers and canopy area in *Acacia baileyana*. A: An outline of the tree canopy is drawn to exclude neighbouring trees. B: Resulting area of flowers.

(AY), by the computer image analysis program *Video Pro* (Leading Edge, Australia) (Figure 2). Inflorescences at flowering and bud stage were yellow, while dying inflorescences were dark-yellow. From the four images analysed for each tree, average SA and AY were calculated. Proportion yellow (PY) for the tree was determined by PY = average AY / average SA.

Canopy volume

For each of the four images from each tree, the radius of a circle of area equal to the image canopy SA was calculated. The geometric mean of the four radii was calculated ($r = (r_1 r_2 r_3 r_4)^{1/4}$), and the volume of the tree canopy was estimated as the volume of a sphere of radius r, namely $4/3\pi r^3$. Geometric mean was chosen because mathematical analysis gave a volume closer to the true volume for ellipsoidal canopies. Arithmetic means of four radii would give similar but slightly higher values for radii and hence volume.

Flower counts

A destructive sample was taken on four sides of each tree at the same time as photography to estimate number of flowers. A 1 × 0.5 m quadrat was positioned at the mid point of each side of the canopy and all inflorescences within this quadrant from the edge of the canopy to the centre of the tree were harvested. The distance from the edge of the canopy to the centre of the tree was measured to calculate the volume of the box-shaped sample.

Ten to 25 flowers are clustered together into flower heads (inflorescences) arranged as balls (Simmons 1988). The inflorescences are arranged in dense racemes (Elliot and Jones 1984). All the racemes in each of the four destructive samples per tree were counted. To determine the mean number of inflorescences per raceme, 150

racemes were selected haphazardly from each sample and the number of inflorescences on each counted. The average number of flowers per inflorescence was estimated separately for each tree, based on all inflorescences collected from an average of five racemes (range 3–19) at 9 to 15 sites per tree, totalling about 50 (range 48–94) racemes per tree. The total number of inflorescences sampled per tree ranged from 398 to 1027. For each tree, an unweighted mean number of flowers per inflorescence was calculated from all the inflorescences. The average number of flowers per sample was estimated by multiplying the average number of inflorescences per sample by average number of flowers per inflorescence.

For each tree, the estimated average number of flowers from the four destructive samples was divided by the average volume of the four samples to give an estimate of the density of flowers for the tree per cubic metre. The total number of flowers per tree was then estimated by multiplying the estimated flower density by the estimated canopy volume.

Total pod and seed production

Six branches per tree were tagged, and the number of inflorescences was counted *in situ*. Net bags were placed over the branches in November to collect any dropped pods. In January the pods were collected and counted, and opened to record the number of seeds. Percentage pod set was determined for the 10 trees by dividing the number of pods by the number of flowers for each of the six branches. The number of flowers per branch was estimated by multiplying the number of inflorescences by the number of flowers per inflorescence. Average percentage pod set per tree was calculated by averaging the individual pod set for each branch. Average seeds per pod for each tree was calculated by averaging the individual seeds per pod for each branch.

To estimate the total number of pods per tree, the total estimated flower number was multiplied by the number of pods from the branch counts, divided by the number of flowers from the branches. To estimate the total number of seeds per tree, the total estimated flower number was multiplied by the number of seeds from the branch counts, divided by the number of flowers from the branches.

Relationship between density of flowers and proportion of yellow

The number of flowers will be positively related to both tree canopy size and density of flowers. To obtain a relationship to predict the density of flowers from digital images, the flower density from samples was related to proportion yellow (PY). The following model was assumed initially:

$$\text{number of flowers} = \text{constant} \times PY^{\beta} \times \text{size}^{\delta}$$

where the number of flowers is proportional to some power of PY and to some measure of size of the canopy. Size measurements that could be used are radius, surface area, or volume; the power δ will adjust according to the best units of measurement.

Number of flowers in this model can be replaced by the density of flowers in the canopy (estimated from the destructive samples) multiplied by the volume of the canopy, giving:

$$\text{density} \times \text{volume} = \text{constant} \times PY^{\beta} \times \text{size}^{\delta}$$

Since volume is a function of size, the equation can be simplified to:

$$\text{density} = \text{constant} \times PY^{\beta} \times \text{size}^{\gamma}$$

with a different constant and size now having a different power. This was logarithmically transformed to stabilize the variance of flower density, as larger densities tend to have larger variance. Multiple linear regression of the logarithm of density of flowers on the logarithm of the proportion yellow and the logarithm of a size measure provided estimates of the parameters α, β and γ. Hence, predicted density = $e^{\alpha} \times PY^{\beta} \times \text{size}^{\gamma}$, substituting regression estimates for parameters α, β and γ. Multiple linear regression was undertaken using GenStat (Harding *et al.* 2000).

Predicted total flower number

The fitted model enabled prediction of density of flowers based only on information from the digital images, namely PY and size. The total number of flowers on a tree could then be predicted as the product of the predicted density and the estimated canopy volume. Therefore, predicted total number of flowers per tree = predicted density × canopy volume.

Standard error

Standard errors of PY, canopy radius, canopy volume, predicted total number of flowers, average number of flowers per sample, density of flowers, and estimated total number of flowers were calculated using the delta method for variances of derived variables (Kotz *et al.* 1988). Variance of the average number of flowers per inflorescence was estimated as the 'between sites' mean square, from an analysis of variance, allowing for site effects, divided by the number of inflorescences. Standard error was obtained as the square root of the variance. Standard errors for all other means in Tables 1, 2 and 3 were estimated as the square root of the sample variance divided by n = 4.

Table 1. *Acacia baileyana* flower data (means ± standard errors) derived from destructive sampling.

Tree	Destructive sample volume in m^3 (n=4)	No. racemes $\times 10^3$ per destructive sample (n=4)	No. inflorescences per raceme (n=4 means, each from 150 racemes)	No. flowers per inflorescence (n=*c.*50)	Density of flowers $\times 10^5$ (flower no. per m^3) (n=4)	Estimated total no. flowers $\times 10^6$ per tree (ENF)
1	1.17 ± 0.07	2.74 ± 1.12	10.1 ± 0.45	12.3 ± 0.37	2.80 ± 1.06	2.48 ± 1.04
2	1.08 ± 0.07	2.32 ± 0.48	9.1 ± 0.58	12.0 ± 0.31	2.42 ± 0.45	2.41 ± 0.52
3	1.94 ± 0.27	2.90 ± 0.93	11.1 ± 1.35	13.5 ± 0.41	2.25 ± 0.92	13.17 ± 5.89
4	1.36 ± 0.08	1.31 ± 0.27	9.5 ± 1.52	13.9 ± 0.67	1.38 ± 0.49	3.09 ± 1.12
5	0.92 ± 0.07	2.13 ± 0.32	10.5 ± 0.78	14.2 ± 0.45	3.46 ± 0.51	2.96 ± 0.53
6	1.17 ± 0.09	2.24 ± 0.35	14.8 ± 1.14	16.2 ± 0.44	4.63 ± 0.73	8.07 ± 1.46
7	1.26 ± 0.03	1.65 ± 0.41	12.4 ± 1.01	16.7 ± 0.26	2.87 ± 0.80	3.37 ± 1.11
8	1.71 ± 0.15	1.85 ± 0.23	10.7 ± 0.46	13.8 ± 0.75	1.60 ± 0.17	13.14 ± 2.07
9	0.88 ± 0.07	0.86 ± 0.12	8.5 ± 0.19	15.0 ± 0.28	1.24 ± 0.21	1.25 ± 0.26
10	1.66 ± 0.05	1.00 ± 0.29	14.2 ± 1.67	14.5 ± 0.64	1.34 ± 0.46	5.49 ± 1.91
P-values			0.002[x]	<0.001[y]		
Mean	1.3	1.90	11.1	14.2	2.24	5.5

[x] indicates a significant difference in number of inflorescences per raceme between trees.
[y] indicates a significant difference in number of flowers per inflorescence between trees.

Table 2. *Acacia baileyana* canopy data (means ± standard errors) and predicted number of flowers determined by digital image analysis.

Tree	Canopy surface area (SA) m^2 (n=4)	Canopy radius m (n=4)	Canopy volume (CV) m^3	Area of yellow flowers (AY) m^2 (n=4)	Proportion yellow (PY)	Predicted total no. of flowers × 10^6 per tree (PNF)
1	5.3 ± 0.56	1.3 ± 0.08	8.9 ± 1.57	2.0 ± 0.39	0.38 ± 0.04	1.48 ± 0.95
2	5.7 ± 0.40	1.3 ± 0.05	10.0 ± 1.08	3.7 ± 0.33	0.65 ± 0.02	3.38 ± 1.40
3	18.6 ± 2.31	2.4 ± 0.15	58.5 ± 10.79	8.1 ± 1.13	0.43 ± 0.05	11.70 ± 6.78
4	9.6 ± 0.51	1.7 ± 0.05	22.3 ± 1.74	3.6 ± 0.26	0.37 ± 0.02	3.63 ± 2.26
5	5.1 ± 0.32	1.3 ± 0.04	8.5 ± 0.86	3.3 ± 0.45	0.65 ± 0.05	2.88 ± 1.22
6	8.2 ± 0.49	1.6 ± 0.05	17.5 ±1.57	4.5 ± 0.54	0.54 ± 0.04	4.72 ± 2.15
7	6.4 ± 0.73	1.4 ± 0.08	11.7 ± 2.04	3.1 ± 0.70	0.49 ± 0.06	2.75 ± 1.45
8	23.0 ± 1.78	2.7 ± 0.10	82.0 ± 9.58	9.9 ± 0.88	0.43 ± 0.03	16.26 ± 9.03
9	5.7 ± 0.48	1.3 ± 0.05	10.1 ± 1.22	2.5 ± 0.37	0.44 ± 0.05	2.08 ± 1.15
10	14.4 ± 0.32	2.1 ± 0.02	41.1 ± 1.34	5.3 ± 0.38	0.37 ± 0.02	6.60 ± 4.12
P-value					<0.001[x]	
Mean	10.2	1.7	27.1	4.6	0.48	5.6

[x] indicates a significant difference in PY between trees.

Table 3. Total pod and seed numbers estimated for 10 *Acacia baileyana* trees, scaled from pod and seed numbers per branch, with total flower counts and number of flowers per branch as the reference. Means per branch were derived from six branch samples.

Tree	Mean per branch						From estimated number of flowers	
	No. inflorescences	No. flowers	No. pods	No. seeds	% pod set ± SE (n=6)	Seeds per pod ± SE (n)	Estimated no. pods per tree	Estimated no. seeds per tree
1	877	10789	9	38	0.08 ± 0.02	4.4 ± 1.0 (6)	2259	8616
2	601	7216	6	34	0.08 ± 0.04	5.7 ± 1.0 (3)	2007	11373
3	1100	14843	9	41	0.07 ± 0.03	3.3 ± 1.2 (4)	8135	36387
4	537	7469	19	61	0.23 ± 0.06	2.9 ± 0.7 (5)	8002	25111
5	575	8165	6	17	0.08 ± 0.04	2.6 ± 0.3 (4)	2292	6274
6	727	11783	8	29	0.07 ± 0.05	2.9 ± 1.1 (5)	5595	19868
7	654	10913	17	52	0.16 ± 0.06	3.6 ± 0.5 (5)	5297	16148
8	787	10863	0	na	0	na	0	na
9	727	10898	42	269	0.36 ± 0.05	6.0 ± 0.7 (6)	4778	30953
10	631	9145	8	36	0.09 ± 0.02	4.2 ± 0.5 (6)	4801	21306
P-values					< 0.001[y]	= 0.051[z]		
Mean	4329	61250	75	384	0.12	4.0	4317	19559

[y] indicates a significant difference in % pod set between trees.
[z] indicates a significant difference in seeds per pod between trees.

Differences between trees

Tests were performed for differences between trees for five variables: PY, average number of inflorescences per raceme, average number of flowers per inflorescence, pod set, and seeds per pod. In each case, a random effects analysis of variance was performed, testing whether the variance between trees was significantly different from zero. Variance components were also included, where relevant, for samples or sites within trees, racemes within sites, and inflorescences within racemes. These analyses were performed using the statistical package GenStat (Harding *et al.* 2000).

Results

Density of flowers (DF) per m^3 estimated from the destructive samples ranged between 124 064 and 462 578 per m^3 (Table 1). There was a large within-tree variation in flower density, as shown by the large standard errors. The estimated total flower number per tree ranged from 1.25 million to over 13 million, with an average of 5.5 million. The number of racemes in the destructive samples varied by more than 3-fold between trees, but the SE was large between samples within individual trees. The number of inflorescences per raceme varied significantly between trees, with an average of 11.1 (P=0.002). The mean number of flowers per inflorescence also varied significantly between trees, ranging from 12.0 to 16.7, with an mean of 14.2 (P<0.001, Table 1).

Canopy surface area ranged from 5.1 to 23 m^2 for the 10 trees, while the tree radius ranged from 1.3 to 2.7 m (Table 2). There was approximately a 10-fold difference between the trees in canopy volume (range 8.5–82 m^3), and a 5-fold difference in area of yellow flowers (range 2.0–9.9 m^2). There was significant variability in proportion yellow (PY) per tree (P<0.001), from 0.37 to 0.65 (Table 2).

There was significant variability in average percentage pod set between the 10 trees (P<0.001), ranging from zero to 0.36%, with an average of 0.12% (Table 3). However, pod set analysis should be interpreted with caution, as the data did not exhibit constant variance. The average seeds per pod for each tree was significantly different between the 10 trees (range 2.6–6.0, P=0.051), with an overall average for all the trees of 4.0. For total estimated

number of pods per tree, there was a four-fold difference between the nine trees that produced pods, and for the total estimated seed numbers, there was nearly a six-fold difference. The range in total pod numbers for the 10 trees was zero to 8135 (average 4317). For the trees that had successful pod formation, the range in seed numbers was from 6274 to 36 387 (average 19 559).

From the multiple linear regression to predict ln DF, neither ln PY (P=0.127) nor ln size (P=0.682) were significant. Due to the high P-value for ln size, ln size was removed from the model, giving the simplified model:

ln DF = 13.302 + 1.310 ln PY
SE = 0.45 0.57
P = <0.001 0.052

The regression for ln density on ln PY, gave an R^2=0.40 (Figure 3), and P=0.052.

Therefore, predicted density of flowers
= $e^{13.302} \times PY^{1.310}$
= $598\,440 \times PY^{1.310}$

and predicted total number of flowers
= predicted density of flowers × canopy volume
= $598\,440 \times PY^{1.310}$ × canopy volume

Using this equation the calculated predicted number of flowers was found to be similar to the number estimated by destructive sampling (Table 1 and 2, and Figure 4). Predicted number of flowers ranged from 1.5 to 16.3 million, with an average of 5.6 million (Table 2).

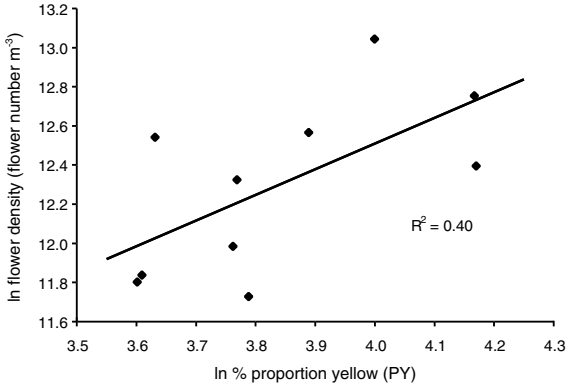

Figure 3. Estimated density of flowers from destructive sampling against proportion of yellow (PY) in photographic images, with fitted regression line, ln density = 13.302 + 1.310 ln PY.

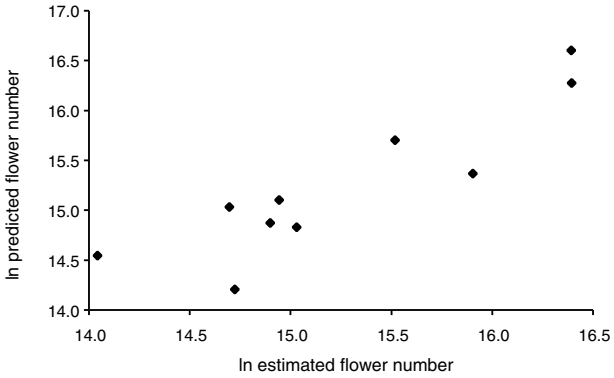

Figure 4. Relationship between predictions of flower numbers from digital image analysis and estimated flower numbers from destructive sampling.

Discussion

Digital image analysis provided a non-destructive method to predict flower numbers of *A. baileyana*. Although the regression equation had an R^2 of only 0.40 and a P-value of 0.052, the image analysis technique shows potential, avoiding the need for costly and time-consuming destructive sampling. No direct comparison was made between the estimated number of flowers from destructive sampling and variables derived from digital images, as both depend on canopy volume. Instead, a relationship was derived between the components of these variables excluding canopy volume, namely estimated flower density (from destructive samples) and estimated proportion yellow (from digital images). This relationship was then used to determine predicted flower numbers. The predicted (from image digital analysis) and estimated (from destructive sampling) flower numbers were similar for the 10 trees, as shown by the means and standard errors.

One potential limitation in a model such as this is the calculation of canopy volume, as it is a vital component in the estimation of flower number. In this study, the canopy volume was assumed to be that of a sphere with a radius equal to an average radius calculated from surface areas from the photographs. Several methods have previously been used to determine canopy volume of plants. Sydnor *et al.* (1975) used photographic methods to determine the canopy volume of *Chrysanthemum morifolium*, assuming that the plants were cylindrical in shape. Bignami and Rossini (1996) determined canopy volume of young hazelnut plants, using image analysis methods, assuming volume of an inverted cone. In this latter study, plant size parameters (height, width, canopy cross-sectional area and volume) were correctly predicted by image processing. Miller and Lightner (1987) determined canopy volume of apple trees using digital image analysis and a mathematical formula that correlated volume with trunk circumference and cross-sectional area. In the current study, a sphere was used to calculate canopy volume, as it is exact for spherical canopies and likely to be reasonable for many ellipsoidal-shaped canopies. This method is a better estimate than measurements based on height and width, which do not take into account the irregular boundaries of the canopies (Sydnor *et al.* 1975). However, confirming the accuracy of the canopy volume determined in this present study would be difficult due to the large size of the trees.

Other limitations of the technique include the sampling method for trees and destructive samples, and the relatively subjective procedures involved with the digital image analysis. Increasing the number of trees assessed would allow better evaluation or confirmation of the regression model, and may allow inclusion of other explanatory variables such as canopy size. It should also provide more precise estimates of the parameters α, β and γ and hence predicted flower density. There will always be variability between trees, although the model may be improved by allocating different sized trees into categories. Predicted flower density could also be improved by improving the estimated flower density and proportion yellow (PY) measurements. To improve flower density estimates without total destructive sampling, sample number or sample size could be increased. In the current study, 5% of the tree canopy was subsampled for flower density. This could be increased to 10%.

For proportion yellow, the use of digital image analysis requires consideration of how factors such as light conditions, interference with neighbouring trees, and image collection procedure affect accuracy. Changing the brightness and contrast of the image before scanning and changing the threshold for the yellow flower detection in the video programme can alter the area of yellow. These subjective procedures must be carefully monitored, and ideally, the same operator should do all the digital image analysis. In this study, care was taken to prevent errors. Dense tree canopies must also be chosen for this technique, as flowers on the far side of the tree may be inadvertently included in the calculation of PY in sparse canopies. The dense canopy trees may therefore, give an over estimation of the number of flowers in the population. More photographs may also give a better representation of PY for the tree. In addition, solitary trees are needed to obtain the four photographs, which prevents the random choice of plants. To study trees in groups, the image would need digital manipulation to remove unwanted trees from the background.

The average pod set for *A. baileyana* was 0.12% in this study, and ranged from

zero to 0.36%. Low percentage pod set is common in acacias, ranging from 0.01 to 0.60% (Milton and Hall 1981, Tybirk 1989, Moncur *et al.* 1991, Grant *et al.* 1994, Tybirk 1993). In this study, low pod set may have been due to limited movement of pollinators between trees, since the 10 trees chosen for the study were solitary (to permit photography for digital analysis). In addition, pollination and fertilization failure could occur if ineffective self-pollination is common as *A. baileyana* is highly self-incompatible (Morgan *et al.* 2002). Pod and seed production may also be limited by adverse environmental conditions.

The *A. baileyana* trees studied produced an average of 5.5 million flowers that resulted in an average of 19 559 seeds per tree. Maximum seed production was over 36 000 per tree. This is a very large reproductive output, confirming the weed potential of this species. Other species of *Acacia* that have become weeds show a similar reproductive output. For example, *A. saligna* and *A. cyclops*, Australian acacias that are weeds in south-western Cape Province of South Africa, can produce over 48 000 seeds per tree (Milton and Hall 1981). In comparison, *A. nilotica,* a South African species, that is a major weed in the Mitchell grasslands of Queensland (Mackey 1997), can produce three million flowers per tree, with seed production per tree reaching over 30 000 in South Africa (Tybirk 1989) and as much as 175 000 in Queensland (Carter *et al.* 1989). *Acacia baileyana* and *A. nilotica* have similar pod set, although *A. baileyana* had an average of 4.0 seeds per pod, compared to 10.8 for *A. nilotica* (Tybirk, 1989), accounting for the lower reproductive output. This average seeds per pod of 4.0 (maximum 6.0) was lower than that previously recorded for *A. baileyana* (7.6 with a maximum of 12; Kenrick and Knox 1982).

Digital image analysis was useful in determining total numbers of flowers of *A. baileyana*. Despite the low pod set the reproductive output is still high, due to the high flower numbers. The extent to which *A. baileyana* is a major weed problem will depend on the number of seeds that germinate and grow. However with such a large seed set, even a low rate of germination and survival could allow this species to spread rapidly.

Acknowledgments

Thanks to SA Water for access to the trees, Alex Sas and Carey Adams for help with the field work, Dr. Neville Robinson, and Dr. Ray Correll for statistical advice, and Michelle Lorimer for statistical analysis. A. M. was supported by an Australian Postgraduate Award, a Rural Industries Research and Development Corporation Scholarship, a Noel and Vivian Lothian Scholarship and a Aileen and Bert Kollosche Scholarship.

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