Photographic Estimation of Plant Size[1]

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Abstract. **A nondestructive photographic technique for measuring plant size is described. Photographs were taken of the sides and top of the plant with Kodak Direct Positive Panchromatic Film and photographic density was determined using a Beckman Model RB Analatrol resulting in a permanent measure of plant size. The results were highly correlated both to fresh and dry weight and provided a nondestructive alternative to weighing plants.**

It is frequently necessary to measure the size of plants at various stages of growth during the course of an experiment. Ideally, the same plants should be measured to eliminate the obvious problems involved with measuring different sets of plants. Height and diameter measurements are nondestructive means of describing plant size. However, neither method can take into account various foliage densities or irregular growth patterns as can destructive methods such as fresh or dry wt.

Photographs are an excellent record of plant size and form and thus a study was initiated to determine if the density of a positive photographic image on film might provide a suitable measure of plant size. We developed an alternative, nondestructive, photographic method of measuring plant size which is an improvement over height or diameter measurements that do not give reliable results on plants with irregular outlines.

Plants were photographed as shown in Fig. 1 with a 35 mm single lens reflex camera and a 50 mm lens using Kodak Direct Positive Panchromatic Film 5246. The background was a light color and uniformly lighted with four 500 watt photoflood bulbs. Plants were lighted with an electronic flash and the exposure was calculated from flash to subject distance, thus reducing shadows. The camera to subject distance (D) must remain constant for a roll of film and should be constant for the experiment.

Photographs are taken for the top and side of each plant as well as a blank for both the top and side views. The suggested sequence for photographs (Fig. 2) reduced the amounts of blanks necessary. Photographs were also taken of a standard size black card (Fig. 2) at the beginning, middle and end of each roll of film to reduce variation due to lighting and film development. Exposed film was then developed as a positive yielding a dark image on a light background.

Following development, the film density was read at a wave length of 600 nm and a slit width of 2 mm using a Beckman Model RB Analatrol equipped with a B-1 cam to read % transmittance. Area under the curve was calculated as counts using a disc integrator.

The average number of integrator counts which a standard size (250 cm^2 in this case) black card yielded was calculated and used as an internal check. Unusually dark or light rolls of film were then adjusted by multiplying the counts for the frame by an adjustment factor.

$$\text{Adj. factor} = \frac{\text{Average integrator counts for standardizing card for all rolls of film}}{\text{Actual integrator counts for standard card for this roll of film}}$$

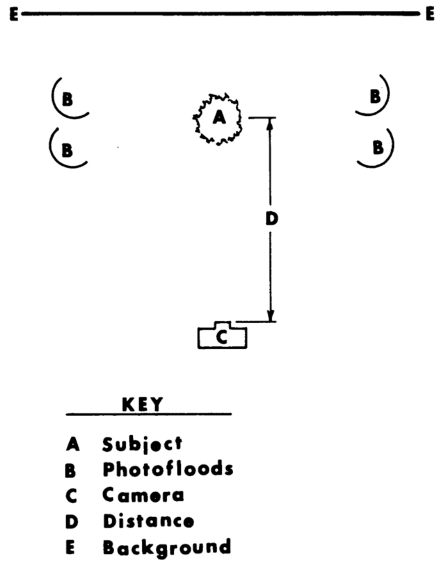

Fig. 1. Photographic set up showing relative position of components. Camera is fitted with electronic flash. D = 1.07 m for this experiment.

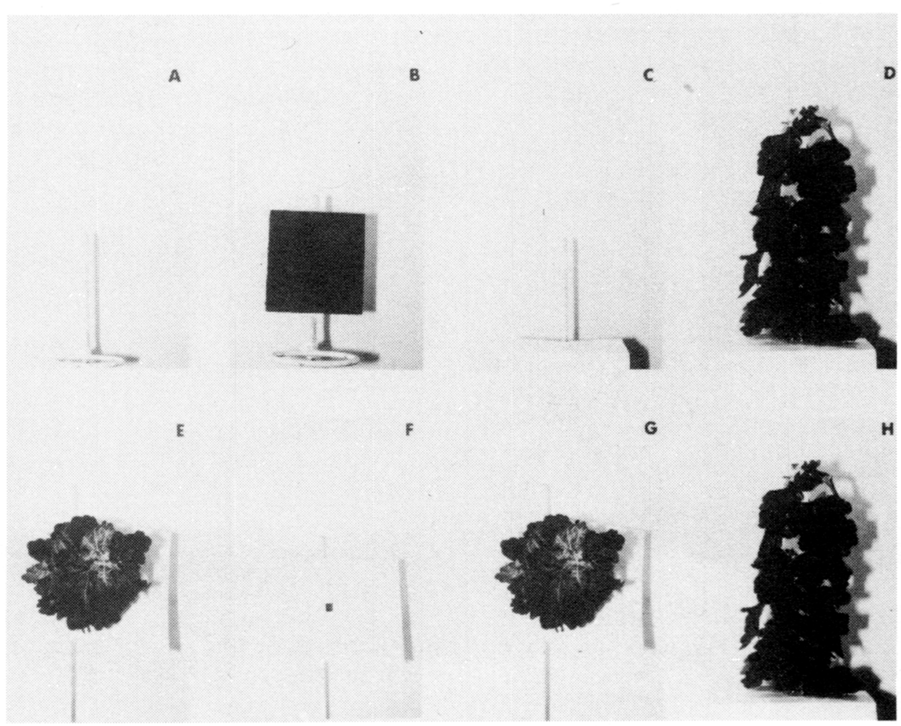

Fig. 2. Photography sequence (A) Standard card blank (B) Standard card (C) Blank for side of plant A (D) Side plant A (E) Top plant A (F) Top blank for plants A & B (G) Top plant B (H) Side plant B. All photographs above are positive images.

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Adjusted counts for both the top and side view of the plants were then calculated by subtracting the counts for the side or top blank from the counts obtained from the corresponding side or top view. Photographic volume was then calculated from the following formula:

$$\text{Photographic volume} = \pi \sqrt{\frac{\text{Adjusted top counts}}{\pi}} \times \text{Adjusted side counts}$$

The above formula is based on the assumption that the plants were cylindrical in shape. The resulting number is unitless.

To test the photographic technique *Chrysanthemum morifolium* (Ramat) cv. Bright Golden Anne cuttings were potted in 10 cm pots in a medium of peat and perlite 1:1 (v:v). The plants were grown under 9 hr nights to maintain vegetative growth. To obtain plants with a range in size, ten cuttings were drenched with ancymidol, at each of 5 levels: 0.00, 0.063, 0.125, 0.250, and 0.500 mg per 90 ml pot. The plants were harvested 19 and 26 days following growth regulator treatment. Plants were photographed and ht, diam, and fresh wt determined. Plants were dried for 3 days at 110°C, cooled, and weighed to obtain dry wt.

The experiment was set up as a completely random factorial design with 2 harvest dates, 5 chemical levels, and 5 replications per treatment. Analysis of variance was performed using photographic volume, fresh wt, dry wt, plant ht, plant diam, and a growth index (ht + diam/2) as indicators of plant size. Regression analysis was used to compare the effectiveness of photographic volume as a measure of plant size. Photographic volume was compared with fresh wt, dry wt, plant ht, plant diam, and a growth index.

A comparison of the methods used indicates that photographic volume is an excellent technique for measuring plant size. Correlation coefficients show that photographic volume is more highly correlated to fresh wt and dry wt than ht, diam, or growth index (Table 1).

Photographic volume can also be used to predict plant size (Fig. 3). The plot of the prediction equation and the data show an increase in deviation as plant size increases. This is due in part to distortion of image size caused by relatively short subject to camera distances and might be reduced by the use of a 135 mm lens rather than a 50 mm lens.

Table 1. Correlation coefficients of several indicators of plant size with fresh and dry wt.

Indicator	Correlation coefficient: Fresh wt	Dry wt
Photographic volume	0.912	0.901
Fresh wt	1.000	0.973
Dry wt	0.973	1.000
Plant ht	0.859	0.859
Plant diam	0.886	0.890
Growth index[z]	0.885	0.879

[z]Growth index = plant ht + plant diam/2.

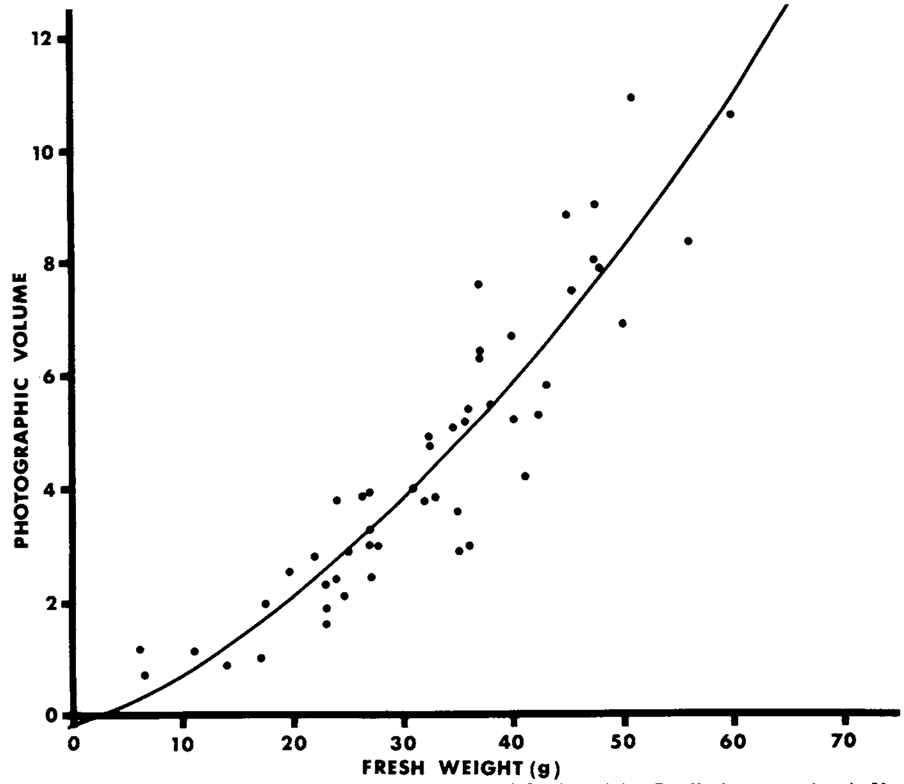

Fig. 3. The relationship of photographic volume and fresh weight. Prediction equation is $Y = 0.086\, z + 0.002\, z^2 - 0.279$; Correlation coefficient r = 0.912. A similar relationship exists for dry wt.

A comparison of the data for each type of plant growth index reveals that similar conclusions could be drawn about the effect of ancymidol on plant size using any of the measures of plant size (Table 2). Plant ht, diam, and growth index for chrysanthemum are excellent indicators of plant size because chrysanthemum has a regular outline. As a plant becomes more irregular in outline or shape the correlation of plant ht, diam, and growth index becomes poorer.

Preliminary studies with plants having irregular outlines i.e. *Picea, Juniperus* and *Cotoneaster* show that photographic volume is still highly correlated to fresh and dry wt. Correlation values of the earlier studies are not comparable because of modifications during technique development.

Photographic volume offers an excellent means of comparing plant size during growth. The technique is nondestructive and offers the advantage of providing a photographic record of each plant enabling the researcher to return and validate size, shape, and color at a later date. In addition, this technique might be modified to quantify necrosis using infra-red film or to quantify changes such as browning of peaches were a color change which can be recorded on black and white film occurs.

Table 2. A comparison of the effects of ancymidol levels and time on plant size as measured by six indicators of plant size.

Time after treatment (days)	Ancymidol (mg) per 10 cm pot	Photographic volume	Fresh wt	Dry wt	Growth index[z]	Plant ht	Plant diam
			g	g	cm	cm	cm
19	0.00	5.48	34.0	3.21	23.6	27.0	20.1
19	0.06	3.41	28.0	2.59	20.5	22.3	18.7
19	0.13	2.74	30.3	2.74	18.8	20.1	17.5
19	0.25	2.27	21.6	1.91	15.8	16.0	15.6
19	0.50	1.42	14.7	1.39	12.3	10.6	14.0
26	0.00	7.82	48.6	4.61	29.0	35.3	22.6
26	0.06	6.91	44.9	4.00	26.0	31.1	20.8
26	0.13	6.45	39.7	3.39	24.1	28.7	19.5
26	0.25	4.30	30.1	2.74	18.6	19.9	17.4
26	0.50	3.31	31.9	2.75	18.3	18.7	17.9
LSD 5%		1.79	8,0	0.67	3.0	4.3	2.2

[z]Growth index = plant ht + plant diam/2.