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Dikegulac-sodium Spray Enhances Uniform Regrowth of *Murraya paniculata* (L.) Jack Hedge

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Abstract. **An aqueous solution of dikegulac-sodium at 0, 2000, 4000, 6000, or 8000 mg a.i./liter was sprayed on a mature *Murraya paniculata* hedge as the first leaves expanded on newly developing lateral shoots after trimming. The lateral shoots from each 0.09-m^2 hedge surface elongated less and the coefficient of variation (CV) decreased as the growth regulator concentration increased. Application of dikegulac-sodium at 4000 mg a.i./liter to the most distal leaf on topped, single-leader seedlings inhibited the elongation of distal shoots while it enhanced proximal shoot growth. Dikegulac-sodium spray between 4000 and 6000 mg a.i./liter to the hedge decreased apical dominance among lateral shoots and enhanced uniform regrowth without causing visible damages. The CV reduction was attributed to the growth regulator-induced weakening of apical dominance. Chemical name used: sodium salt of 2,3:4,6-bis-*O*-(1-methylethylidene)-α-L-*xylo*-2-hexulofuranosonic acid (dikegulac-sodium).**

Murraya paniculata, commonly known as mock orange in Hawaii, is a 2- to 7-m-tall ornamental shrub in the subtropical Pacific area (Neal, 1965). Although the plant is often used for hedges, its high rate of growth requires frequent trimming, making it expensive to maintain. Growth regulator use after trimming may suppress hedge growth and reduce the frequency of trimming without noticeable damage.

Dikegulac-sodium (DS) is a foliage-applied growth regulator (Bocion et al., 1975). It readily translocates to the shoot apex (Arzee et al., 1977), kills dividing cells in meristematic zone (Zilkah and Gressel, 1977), and suppresses shoot growth and weakens apical dominance (Bocion and de Silva, 1976). While the growth regulator is mainly used for pinching potted ornamentals (Sanderson, 1977; Starman, 1991), it is also used for inhibiting the growth of woody ornamentals without inducing visible damage (Cohen, 1978; de Silva et al., 1976; Sachs et al., 1975). Weakening apical dominance, a strategy for hedge growth control, is particularly desirable because it makes hedges appear full and compact (Sachs and Hackett, 1972; Sachs et al., 1970).

When a *Murraya* hedge was sprayed with DS after trimming (Criley, 1980), treated hedge sections appeared retarded; however, randomly sampled lateral shoots were not statistically shorter than nontreated controls. The discrepancy could have occurred if the growth regulator differentially affected shoots of unequal size and development. While long shoots were more visible than short ones, random sampling did not allow selecting only long shoots. Although selectively sampling long, dominant shoots is common in the growth retardation studies on woody species, the degree of full and compact appearance cannot be measured by the selective sampling. An additional statistical method would be desirable for measuring the visual quality. Since the number of potential lateral shoots after trimming is predetermined at the time of spray, uniform elongation of all active lateral shoots gives an even and dense hedge. A good method of quantifying this is to use the coefficient of variation (CV) of randomly sampled shoot length.

The objectives of this research were to determine if DS sprays after trimming would suppress the elongation of *Murraya* lateral shoots and if they would enhance uniform regrowth of the hedge using CV as an indicator for the uniformity in the lateral shoot elongation.

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Materials and Methods

Hedge experiment. A mature *Murraya* hedge located on the Univ. of Hawaii campus, Honolulu, had been maintained 1.2 m high, 1 m wide, and 20 m long. It was composed of two rows of plants, 0.2 m apart and 0.2 m between plants within each row. A preliminary uniformity trial indicated no significant difference in lateral shoot regrowth among individual plants. The top and side surfaces were trimmed to 10 mm distal to the previous trimming, and 0.3 × 0.3-m plots were assigned on the edges of top surface separated by 0.1-m borders. An aqueous solution of DS at 0, 2000, 4000, 6000, or 8000 mg a.i./liter supplemented with a surfactant (0.1% X-77 by volume) was sprayed to runoff when the first leaves on newly elongating shoots fully expanded. A treatment set comprised the five spray concentrations randomized within neighboring plots. The treatment set was replicated on both edges of the top surface and in three hedge sections, providing six replications per treatment. The experiment was run twice: spraying the hedge on 6 May for warm- and on 24 Dec. for cool-season trials. A protective cover placed around the target plot during spraying minimized drift, and using different hedge sections in the two trials eliminated possible residual effects.

The length of newly developing lateral shoots was measured 8 weeks after spraying in two sampling methods: the longest lateral shoot emerged from the 0.3 × 0.3-m plot [longest shoot length (LSL)]; and nine lateral shoots located closest to the center of each of the 0.1 × 0.1-m subplots [nine shoots per plot, subsampled shoot length (SSL)]. While the LSL represented only the longest shoot segment, the SSL represented the entire population, assuming that lateral shoots emerged geographically at random. Shoot length was determined from its point of attachment on the older shoot to its tip. Shoots originating 30 mm below the trimming level or lower were not sampled to exclude shoots that started elongation before trimming. During the regrowth periods, air minima and maxima fluctuated in ranges of 19 to 21C and 23 to 29C, respectively, for warm- and 10 to 21C and 24 to 29C for cool-season trials.

The LSL and SSL were regressed on DS concentration, and the interaction with sampling methods was determined by the heterogeneity of slopes (Allen and Cady, 1982). The SSL was further grouped by size and the percent frequency distribution was graphically examined.

Seedling experiment. Six-month-old seedlings were transplanted to 1-liter plastic pots filled with a medium consisting of 1 perlite : 1 peat (v/v), 7.0 g/pot slow-release 14N–6.2P–11.6K fertilizer, and 1.0 g/pot minor elements (Micromax; Grace Sierra, Milpitas, Calif.), and placed under 60% plastic shade. Three months after transplanting, 16 seedlings were selected for single-stem form and uniform size. Stems were pruned at 0.5 m above the medium and extra leaves were removed, leaving five distal leaves on the pruned stem. The top leaf of each seedling was dipped in a DS solution of 0 or 4000 mg a.i./liter for 3 sec and washed with water 8 h later. Both treatments were replicated eight times.

The lateral shoot length, recorded 5 weeks after treatment, was regressed on the position number, 1 for the most distal to 5 for the most proximal, and the interaction with the treatments was determined by the heterogeneity of slopes. The SAS GLM procedure (SAS Institute, 1990) was used for the statistical computation for these experiments.

Results and Discussion

Hedge experiment. DS reduced lateral shoot elongation, expressed as LSL or SSL, in straight-line responses in the warm-season trial (warm season, Fig. 1). A significant difference was expected between means for the two sampling methods (sampling, Table 1) because of different populations each method represented. However, the interaction (concentration × sampling) also was significant, indicating the presence of two differing slopes: the negative slope for the LSL was twice as large as the slope for the SSL. In the cool-season trial, the slope of decline for the LSL was significantly larger than for the SSL again. Both regression coefficients for slopes for the cool season were larger than those for the same sampling method for warm season.

As with other shrubs that showed multiple flushes (Sachs, 1969), the *Murraya* LSL showed two flushes in 18 weeks after trimming in warm season. DS treatments were still effective at the 18th week as DS at 2000 to 8000 mg a.i./liter limited the shoot length to 78% to 59% of the 0-mg DS control's 176 mm. Yellowing of young expanding leaves (Sachs et al., 1975) also was observed in our 8000-mg treatment in both seasons; however, affected leaves gained their normal green at maturity. Abnormal symptoms were absent on plants treated with 6000 mg DS or less.

The frequency distribution of the SSL (Fig. 2) indicated the longest shoot group (>199 mm) in 0 mg DS was eliminated by any DS treatment in both seasons. In the warm season, the percentage of the shortest shoots (0 to 49 mm) increased with the growth regulator concentration, up to 6000 mg·liter^{-1}, while the number of longer shoots (100 to 199 mm) decreased (warm season, Fig. 2). The negative slope of the SSL in the warm season in Fig. 1 reflected this change in size distribution. In the cool season, the percentage of the shortest shoots (0 to 49 mm) decreased while that of medium-sized shoots (50 to 99 mm) increased (cool season, Fig. 2). These changes resulted in a slightly positive slope for the SSL in cool season in Fig. 1. The variation of the SSL decreased as DS concentration increased: CV decreased from 56% for 0 mg to 43% for 8000 mg DS in the warm and from 75% to 59% in the cool season. Therefore, although DS spray did not universally inhibit lateral shoot elongation, as the SSL in the cool season slightly increased, it suppressed the occurrence of long lateral shoots (LSL) and enhanced uniform regrowth in the SSL both seasons.

Seedling experiment. Lateral shoot elongation (Fig. 3) was greatest for the most distal (position 1) shoots, and it decreased for the lower shoots in straight-line responses for 0 or 4000 mg DS. While mean shoot lengths were not significantly different (treatment, Table 2), the slope for the 4000-mg DS was significantly less steep (position × treatment) than for the 0-mg DS. Consequently, two regression lines intersected each other near position 3. As with the hedge experiment, CV for the 0-mg DS (51%) was reduced by the 4000-mg DS (42%).

The negative slope for the 0-mg DS treatment demonstrated the presence of apical dominance (Martin, 1987; Phillips, 1975) among developing lateral shoots in *Murraya* seed-

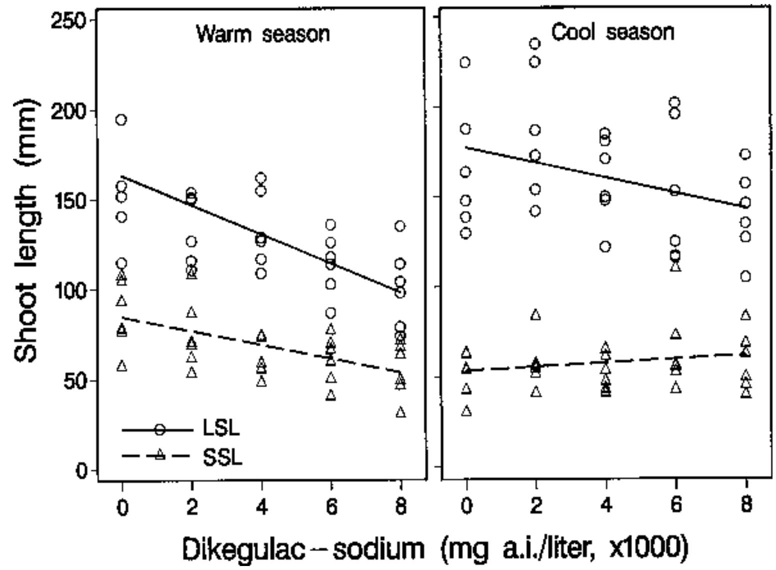

Fig. 1. Lateral shoot elongation on a *Murraya paniculata* hedge treated with dikegulac-sodium (DS) at 0, 2000, 4000, 6000, or 8000 mg a.i./liter on 6 May (warm season) or 24 Dec. (cool season) as the first leaves on newly developing lateral shoots expanded after trimming. Lateral shoots were sampled 8 weeks later in two sampling methods: the longest shoot emerged from each 0.09-m^2 plot (LSL) and the mean of nine subsampled shoots (SSL). LSL warm season (mm) = 163 – 0.00814 × DS; SSL warm season = 85 – 0.00428 × DS; LSL cool season = 179 – 0.00424 × DS; SSL cool season = 54.6 + 0.00104 × DS.

Table 1. Analyses of variance for regressing *Murraya paniculata* hedge regrowth on two sampling methods and dikegulac-sodium concentration. Dikegulac-sodium at 0, 2000, 4000, 6000, or 8000 mg a.i./liter was sprayed on 6 May (warm season) or 24 Dec. (cool season) as the first leaves on newly developing lateral shoots expanded after trimming. The length of the longest shoot and the mean of nine subsampled shoots emerging from 0.09-m^2 plot were recorded 8 weeks after treatment.

		Warm season			Cool season		
Source	df	SS[z]	F	*P* > F[y]	SS	F	*P* > F
Sampling	1	56,884	103.20	<0.01	158,746	244.71	<0.01
Concentration (concn)	1	17,293	31.37	<0.01	1,229	1.89	0.17
Sampling × concn	1	2,197	3.99	0.05	3,350	5.16	0.02
Residual	56	30,868			36,328		

[z]Sequential sum of squares.
[y]Probability of obtaining an F this large or larger by chance alone.

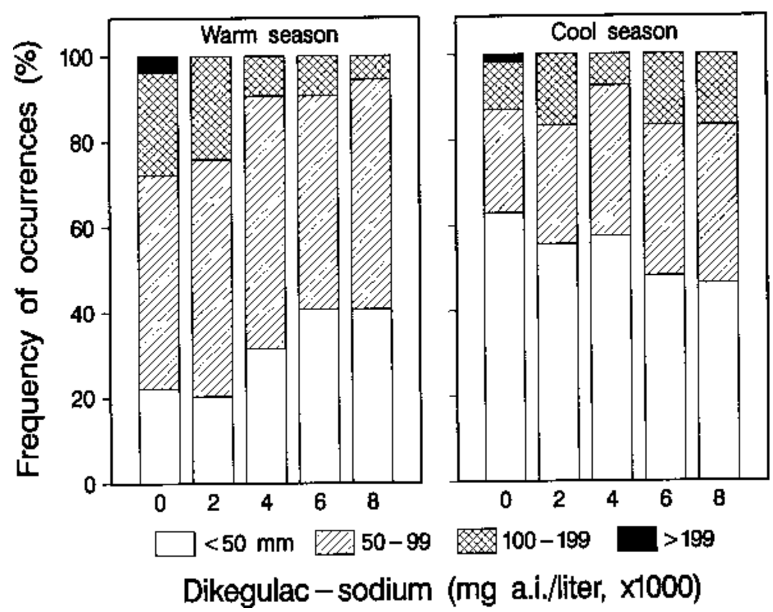

Fig. 2. Frequency distribution of *Murraya paniculata* lateral shoot length. Dikegulac-sodium at 0, 2000, 4000, 6000, or 8000 mg a.i./liter was sprayed on 6 May (warm season) or 24 Dec. (cool season) as the first leaves on newly developing lateral shoots expanded after trimming. Shoots were randomly subsampled 8 weeks later. Each bar represents 54 shoots.

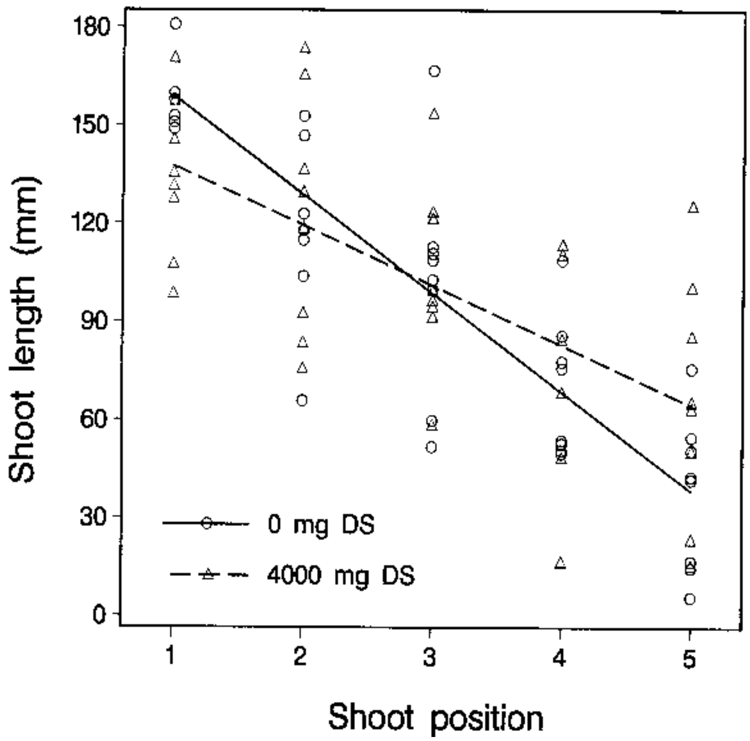

Fig. 3. Lateral shoot elongation of *Murraya paniculata* seedlings. Seedlings were pruned 0.5 m above the medium to retain five distal leaves, and the most distal leaves were treated with 0 or 4000 mg a.i. dikegulac-sodium (DS)/liter. The length of newly extending lateral shoot, measured 5 weeks later, was regressed on the shoot position, 1 for the most distal to 5 for the most proximal, and the growth regulator treatment. Shoot length (mm) = 188 – 30 × position, 0 mg DS; shoot length = 155 – 18 × position, 4000 mg DS.

Table 2. Analysis of variance for regressing lateral shoot elongation of *Murraya paniculata* seedlings on growth regulator treatments and the shoot position. Seedlings were pruned 0.5 m above the medium, lower leaves were removed to retain five distal leaves, and the positions were numbered: 1 for the most distal to 5 for the most proximal leaves. The position 1 leaves were treated with dikegulac-sodium, 0 or 4000 mg a.i./liter, and the length of newly elongating lateral shoots was measured 5 weeks after treatment.

Source	df	SS[z]	F	$P > F$[y]
Treatment	1	206	0.25	0.62
Position	1	92605	113.84	<0.01
Treatment × position	1	5564	6.84	0.01
Residual	74[x]	60198		

[z]Sequential sum of squares.
[y]Probability of obtaining an F this large or larger by chance alone.
[x]Degrees of freedom for residual reflects two missing data.

lings. Since DS absorbed by leaves could be translocated to actively growing apical meristems in lateral shoots, it was possible that the growth regulator affected the growth of the fast-growing distal shoots more than slow-growing proximal shoots, resulting in growth enhancement of lower shoots. In our experiment, the extension reduction of position 1 and 2 shoots was offset by increases of comparable magnitudes in position 4 and 5 shoots, indicating the growth regulator redirected the growth among lateral shoots.

If shoots at position 1 or 2 in the seedling experiment represented the LSL in the hedge experiment and all five shoots represented the SSL, the effects of DS on *Murraya* are in agreement in both experiments: the growth suppression of long dominant shoots, the enhancement of elongation in short suppressed shoots, and CV reduction. It is likely the negative slopes of the LSL in the hedge experiment were due to suppression of dominant shoot extension, and the trend of less steep slopes for the SSL than for the LSL was due to weakened apical dominance, thus enhancing the extension of suppressed shoots. The difference in the SSL response between two seasons indicates seasonal differences in shoot development (Sachs, 1969).

Sampling shoots as the LSL and SSL in the hedge experiment and measuring shoot length in relation to shoot position in the seedling experiment enabled us to characterize the apical dominance in *Murraya* hedge regrowth. A DS foliar spray between 4000 and 6000 mg a.i./liter suppressed dominant shoots and enhanced uniform regrowth without causing marked chlorosis or shoot distortion. Characterization of *Murraya* seasonality and flush growth patterns are needed to determine if the growth regulator spray would result in economic savings.

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