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ETHREL STIMULATION OF INFLORESCENCE SAP FLOW IN TAPPED COCONUT (*COCOS NUCIFERA*) PALMS

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SUMMARY

The effect of Ethrel on the yield and sugar content of coconut (*Cocos nucifera*) inflorescence sap and sustainability of productivity was investigated on forty-year-old tall coconut palms (var. typica) at Bandirippuwa Estate, Lunuwila, Sri Lanka. Ethrel was applied at a concentration of 2.5% and the volume and sugar content of the sap were measured. Application of Ethrel consistently increased the yield per day, yield per spadix, yield per palm per annum and sugar content in the sap for a period of four years. The removal of carbon, nitrogen, phosphorus, potassium and magnesium with the sap was greater from Ethrel-treated than from untreated palms, and this was attributed mainly to the enhanced sap yields and sugar concentrations.

INTRODUCTION

In coconut (*Cocos nucifera*), fully extended, but unopened tender spadices (inflorescences) just prior to splitting of the spathes and the emergence of spikelets, are artificially stimulated (tapped) to obtain sap, locally known as 'mee-ra' or fresh toddy. The freshly collected sap which contains 12–18% sugar, mainly in the form of sucrose, can be used as a beverage or converted to various products such as alcoholic drinks (arrack), sugar, treacle, jaggery and vinegar (Nathanael, 1966; Pethiyagoda, 1978). A healthy coconut palm (var. typica) yields about 200–220 l of fresh toddy per annum. Tapping coconut palms for toddy is far more profitable to coconut growers than is nut harvesting. The process of tapping (mechanical wounding) causes a climacteric, leading to the release of growth hormones (Taiz and Zeiger, 1991). Externally applied hormone could be expected, therefore, to stimulate sap flow. Preliminary trials (not reported here) indicated substantial responses to several stimulants. Of these, ethylene (Ethrel: 2-chloroethylphosphonic acid) appeared to be the most promising.

Ethrel, an ethylene-releasing synthetic chemical (Warner and Leopold, 1969), has been used in many agricultural applications, taking advantage of its numerous effects on plant growth and development. It is readily absorbed by the plant and releases ethylene slowly by a chemical reaction that allows the hormone to exert its effects. Ethrel is used routinely for regulating many physiological processes such as the latex flow of tapped rubber (*Hevea brasiliensis*) trees (Waidyanatha and Angammana, 1981), production of oleo-gum resin in *Commiphora wightii* (Bhatt *et al*., 1989), oil yield in *Cymbopogon martinii* (Srivastava *et al*., 1998), flower and fruit development (Farmahan

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and Dhiman, 1998), fruit ripening (Pal, 1998), hydration of pectic network (Batisse *et al*., 1998), simultaneous stimulation of longitudinal growth and lateral expansion of oat mesocotyls (Nishizawa and Suge, 1995) and reducing callose (a polysaccharide formed of β-D–glucopyranose residues linked together by β-1–3–glycosidic linkage) formation in *Phaseolus vulgaris* (Scott *et al*., 1967; Abeles and Forrence, 1970).

No information has been reported to date, however, on the effect of Ethrel on coconut toddy tapping. This study investigated the effect of Ethrel on the sugar content and yield of coconut inflorescence sap and their sustainability.

MATERIALS AND METHODS

Selection of palms

Tall coconut palms (var. typica) of uniform size were selected at Bandirippuwa Estate, Lunuwila, situated in the northwest of Sri Lanka (lat. 7°20′ N, long. 79°53′ E). This area receives an annual rainfall of 1900–2000 mm distributed mainly in the months of April–July and October–January. The palms were 40 years old and were subjected to uniform agronomic and cultural practices. The experiment began in November 1997, and was terminated four years later in November 2001. The design was a completely randomized single-tree plot with 16 replicates per treatment.

Tapping procedure and data collection

The traditional tapping technique, evolved over centuries, was modified as described by Nathanael (1966) for use in this study. All spadices of the selected palms were tapped for toddy. A thin slice of each spadix was pared transversely twice per day, morning (07.00–09.00 h) and evening (16.00–18.00 h), and the collected fresh toddy yield of each palm was measured. Samples for sugar analysis were collected from each palm at three-monthly intervals. The fresh sap, collected into 1.5 ml Eppendorf tubes immediately after slicing, was stored at –20 °C until analysis.

Application of Ethrel (stimulant)

In order to identify the best approach, a preliminary investigation was undertaken with different concentrations of Ethrel and application methods. As a result, a small piece of cotton wool soaked in a 3 ml solution of commercially available Ethrel (ethephon), at a concentration of 2.5%, was placed at the axis of the tapping spadix (at the base of the outer bract). One application was made on each spadix on the first day of slicing. Untreated palms were used as the control.

Estimation of sugar content in the sap

The collected sap was diluted 100 times, purified using a sep-pak cartridge and analysed for sugars (sucrose and total) using a high performance liquid chromatography (HPLC) system (Waters, USA) with a sugar-pak column.

Estimation of the removal of carbon and major nutrients (as toddy)

Sucrose being the most predominant carbon (C) source (12–18%) in the sap (Pethiyagoda, 1978), the total sucrose removed was considered as the total carbon

Table 1. Effect of application of Ethrel (E) on the yield of fresh sap during four years. The numbers of spadices produced and tapped (control and Ethrel-treated) were 15, 18, 18 and 12 in years 1–4 respectively. The number of tapping days per year was 365.

	Yield of sap											
	Year 1 November 1997–October 1998			Year 2 November 1998–October 1999			Year 3 November 1999–October 2000			Year 4 November 2000–December 2001		
Treatment	ml d^{-1}	l $spadix^{-1}$	l $palm^{-1}$ a^{-1}	ml d^{-1}	l $spadix^{-1}$	l $palm^{-1}$ a^{-1}	ml d^{-1}	l $spadix^{-1}$	l $palm^{-1}$ a^{-1}	ml d^{-1}	l $spadix^{-1}$	l $palm^{-1}$ a^{-1}
2.5% E	833	20.8	304	898	18.0	328	707	14.1	258	657	19.7	240
Control	634	15.9	231	626	12.5	229	619	12.4	226	504	15.1	184
s.e.	105	1.86	26.0	118	1.67	20.0	120	1.7	20.4	108	1.8	9.2
Increase (%)		31			44			13			30	

Table 2. Effect of application of Ethrel (E) on sugar content (g 100 ml^{-1}) in fresh sap during four years.

	Year of tapping							
	Year 1 November 1997–October 1998		Year 2 November 1998–October 1999		Year 3 November 1999–October 2002		Year 4 November 2000–December 2001	
Treatment	Sucrose	Total sugars	Sucrose	Total sugars	Sucrose	Total sugars	Sucrose	Total sugars
2.5% E	14.3	16.9	13.7	16.2	14.3	16.8	15.0	17.8
Control	12.4	14.0	12.4	14.2	12.4	14.1	12.0	12.6
s.e.	0.32	0.41	0.36	0.39	0.31	0.44	0.34	0.40

Table 3. Effect of application of Ethrel (E) on concentration of N, P, K and Mg (ppm) in fresh sap (pooled values).

Treatment	N	P	K	Mg
2.5% E	0.047	0.015	0.216	0.004
Control	0.044	0.015	0.203	0.004
s.e.	.004	.0009	.0008	.0002

removed by the sap. Nitrogen (N), phosphorous (P), potassium (K) and magnesium (Mg) concentrations of the sap of control and Ethrel-treated palms were measured using an Atomic Absorption Spectrophotometer (GBC, Australia) at intervals of six months throughout the period of the experiment. Based on these results, the annual removal per palm of C, N, P, K and Mg by the sap was also calculated.

The data were analysed using the SAS statistical package, with one-way ANOVA.

RESULTS

Application of Ethrel at the axis of the tapping spadix increased the yield of fresh toddy per day, per spadix and per palm per annum throughout the four years of the experiment. The increase was not statistically significant in the third year, however, possibly due to the high variation in yields among the palms (CV = 51%). The stimulatory effect was less in the third year compared with that of the first, second and fourth years (Table 1). Ethrel application increased the sucrose and total sugar contents in the sap consistently over four years (Table 2), the total mean increase being 17%.

Concentrations of N, P, K and Mg were similar at each sampling date, and there were no differences between the Ethrel-treated and untreated plants (Table 3).

The annual removal of C, N, P, K and Mg was higher from Ethrel-treated palms than from the control palms in all years. While an untreated coconut palm removed 13–14 kg of carbon as sap, an Ethrel treated palm removed 16–20 kg per palm annually. This was due to higher sap volume (Table 1) and higher concentrations of sugars (Table 2) whereas the increased removal of other nutrients was entirely due to the increased volume of sap removed annually (Table 1). The relative order of nutrient removal by the sap was K > N > P > Mg (Table 4).

Table 4. Effect of application of Ethrel (E) on the removal of carbon (kg palm^{-1} a^{-1}) and major nutrients, N, P, K and Mg (g palm^{-1} a^{-1}) by the sap during the past three years. Calculations are based on the total volume of sap collected during each year.

Element	Treatment	Year 1 November 1997–October 1998	Year 2 November 1998–October 1999	Year 3 November 1999–October 2000	Year 4 November 2000–December 2001
C	2.5% E	18.2	18.8	15.5	15.1
	control	12.0	11.9	11.8	9.3
s.e.		1.46	1.15	1.12	1.18
N	2.5% E	143.0	154.8	121.8	113.3
	control	102.6	101.7	100.3	81.7
s.e.		11.90	9.40	9.14	8.98
P	2.5% E	46.8	50.5	39.7	37.0
	control	35.1	34.8	34.4	27.9
s.e.		3.89	3.11	2.99	2.94
K	2.5% E	658	710	558	519
	control	468	464	458	373
s.e.		5.66	43.34	41.74	40.98
Mg	2.5% E	12.2	13.1	10.3	9.6
	control	8.8	8.7	8.6	6.9
s.e.		1.01	0.81	0.77	0.76

DISCUSSION

Application of 2.5% Ethrel at the axis of the tapping spadix increased the sap yield, total sugar content and concentration in the sap throughout the four-year experiment, with the stimulatory response being lower in the third year than in the other three. The reason for reduced stimulation in the third year is not clear. The level of stimulation did not have a correlation with either rainfall or number of rainy days. The rate of sap flow soon after tapping was markedly higher in Ethrel-treated palms than in untreated palms (data not shown) suggesting that an impediment to sap flow following tapping developed more slowly in Ethrel-treated palms.

Callose appears almost instantly in various parts of plants that are subject to mechanical stress (Taiz and Zeiger, 1991). In the process of tapping, when the spadix is sliced (damaged), the sugar-rich phloem sap surges toward the cut end and callose may be formed on the sieve plate pores, helping to seal the sieve element and to prevent further loss of sap. In the present study, Ethrel possibly inhibited callose formation, thereby increasing the duration of sap flow and also the total flow rate. Application of Ethrel has been shown to promote the synthesis of β-1–3–glucanase, an important enzyme in degradation of sieve-tube callose, in leaves and stems of *Phaseolus vulgaris* (Abeles and Forrence, 1970; Clark and Villemez, 1972; Jaffe *et al*., 1985). This may suggest that Ethrel increased the activity of β-1–3–glucanase in coconut inflorescence tissues, thus enhancing the sap flow by dissolving the callose. Further, the increased sugar content of the sap of Ethrel treated palms may possibly be due to the breakdown of callose (polysaccharide) into sugars, mainly sucrose.

There was a greater removal of C (sugars) and other nutrients from Ethrel-stimulated palms than from the control palms. This raises the question of whether or not such a

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loss could have a debilitative effect on stimulated palms in the long term. It has been estimated that a productive coconut palm, in yielding 75 nuts per annum, removes 23 kg C, 467 g N, 97 g P, 896 g K and 127 g Mg (Ranasinghe, 2000). The amounts of nutrients removed by the sap in Ethrel-treated palms were substantially less than the amounts removed in nuts in a nut-producing palm. Furthermore, none of the Ethrel-treated palms showed any visible symptoms of vigour loss even after being tapped for four consecutive years. This suggests that additional extraction of sap through stimulation should not have any long-term debilitating effects on the palms if adequate nutrients are provided through fertilization. Studies have commenced to determine the mode of action of Ethrel in stimulation of toddy yield and sugar content.

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