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An Investigation of Yield and Quality of Coconut Inflorescence Sap in Different Coconut (*Cocos nucifera* L.) Genotypes under West Coast of India

R. Sudha[1*], V. Niral[1], K. Samsudeen[1] and K. B. Hebbar[2]

[1]Division of Crop improvement, [2]Division of Physiology and Post harvest Technology, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala, India

**Corresponding author*

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A B S T R A C T

Identification of potentially valuable genetic stocks and development of unique trait specific varieties is the need of the hour to cope up with the changing demand of global market. Coconut inflorescence sap is a potential product that has many health benefitting properties. The present study was conducted with nine coconut genotypes *viz*., Gangapani Tall, Gonthembili Tall, Nigerian Tall, Jamaica Tall, Hazari Tall, Niuquewen Tall, West Coast Tall, East Coast Tall and Navasi Tall to find out the suitable coconut genotype for inflorescence sap production. The study revealed that the genotype Nigerian Tall produced highest average sap yield per palm (1.7 L/day), sap yield per inflorescence (79.45 L/inflorescence) and annual sap yield (622.33 L/palm). Duration of sap flow/inflorescence was maximum in Navasi Tall (51.75 days) and days taken to start the sap flow was minimum in Gangapani Tall (15.55 days) followed by Nigerian Tall (15.92 days). Biochemical parameters revealed that the West Coast Tall recorded highest total sugar (13.4 g/100ml), amino acid (73.75 mg/100ml) and protein content (609.1 mg/100ml) compared to other genotypes. Certain morphological parameters also recorded in the palms which are influencing the sap production. Correlation analysis showed that number of leaves, stem girth, length and median circumference of the inflorescence positively correlated with sap production whereas length of petiole and single internode showed negative correlation with sap yield.

Introduction

Coconut (*Cocos nucifera* L.) is an important economic crop in the tropics. The coconut palm is a multipurpose perennial crop and cultivated in 93 countries in an area of 12 million hectares. In India, annual production of coconut is 21,384 million nuts and contributes nation's GDP about 34,100 crore rupees (Press Information Bureau, 2019). Coconut is mainly used for copra (70%) and culinary purpose (30%). Only 2% of the nuts are used as tender nuts. However, high cost of cultivation and low price for the primary coconut produces such as nut, copra, and oil makes the popularity of coconut cultivation is on the declining trend. Hence, there is an urgent need to make coconut industry profitable through product diversification. Value addition and product diversification

remain the most viable but least explored areas as the coconut is concerned. The farmers who depend exclusively on coconut cultivation are mostly under employed for want of coconut based processing at the farm-household and community levels. Cost effective and labour intensive activities assume importance in such a situation. Production of coconut inflorescence sap, a healthy drink obtained by tapping the unopened inflorescence is highly profitable and viable option for the coconut growers.

Coconut inflorescence sap is the sweet phloem sap tapped from the immature inflorescence of coconut. It is a delicious nutritional health drink and a rich source of natural sugars, protein, minerals, antioxidants, vitamins and utilized by the plant for the growth and development of nuts. It contains considerable amounts of iron, phosphorus and ascorbic acid. The most significant characteristic of the product is its low Glycemic Index (GI is 35). The global demand for low GI sugar are on the increasing trend and hence inflorescence sap and its products viz., coconut palm sugar, palm syrup, palm jaggery which are having high domestic and international demand owing to their high nutritional values. The immature inflorescence which is about to burst open is the stage at which the tapping is done. The yield of coconut inflorescence sap is highly variable. It differs with palm variety, vigour and season. In general, coconut genotypes play an important role in coconut inflorescence sap production. It is reported that a good healthy tall palm may yield up to 2 liter neera per day. At a sugar content of about 15-20%, this would give a sugar yield of 300-400g per palm per day. Studies have revealed that coconut varieties differ with respect to sap yield and quality (Samsudeen *et al.,* 2013; Konan *et al.,* 2014; Joseph *et al.,* 2018). Hence, it is important to identify coconut genotypes having superior sap characteristics for commercial utilization of coconut inflorescence sap. However fewer reports only available regarding studies on coconut inflorescence sap yield, its biochemical properties, morphological traits which are influencing the sap yield in different coconut varieties. Hence**,** the present study was carried out to investigate the coconut genotypes suitable for high yield and superior quality of coconut inflorescence sap and to study the morphological traits which are influencing the sap yield.

Materials and Methods

Plant material

The study has been carried out at Central Plantation Crops Research Institute (CPCRI), Kasaragod during 2018-2019 and 2019-2020 on 50 years old coconut palms of nine genotypes *viz*., Jamaica Tall, NiuQuewen Tall, Gangapani Tall, Gonthembili Tall, Navasi Tall, Nigerian Tall, Hazari Tall, West Coast Tall and East Coast Tall that are being maintained in the National Gene Bank for coconut at CPCRI, Kasaragod, Kerala, India (Table 1). Three palms of each variety were used for the study.

Collection of inflorescence sap

Fully emerged (6-8 weeks from the first emergence of bunch on the leaf axil) unopened inflorescences or bunches were selected for tapping. The bunch was tied at many places to prevent burst opening of the inflorescence. The first cut was made on the same day of tying or within next four days (Fig. 5). After the first cut, every day the cut surface was sliced twice by cutting edge again and the bunch is gently beaten thrice a day to stimulate flow of sap. After started the consistent flow of sap, the sap was collected in CPCRI developed coco sap chiller (Hebbar *et al.,* 2015). Slicing the cut edge and tapping

were repeated every day till the end of sap flow (Fig. 6 and 7). The sap was collected twice a day, morning (7:30AM to 10:00AM) and evening (3:30PM to 6:00PM), and measured. To prevent any break in continuity of sap collection, about three weeks prior to the predicted time of cessation of tapping on a spathe the next younger spathe in the crown is gradually prepared for tapping. Hence the tapping continued without a break for a period of one year. The study was undertaken for twelve months.

Traits under study

Morphological parameters *viz*., stem girth (m), number of leaves, length of the inflorescence (cm), median circumference of the inflorescence (cm), length of the petiole (m) and internodal length (cm) were recorded in all the genotypes. The stem girth at one meter above collar region was measured and expressed in centimeters. The number of leaves at crown per palm were counted and recorded. Petiole length was measured for three leaves per palm and mean value was arrived and expressed in metre. Length between two leaf scars on the stem was measured and expressed in centimetre. The length of inflorescence was measured from the base of the stalk to the inflorescence tip and expressed in centimetre. The median circumference of the inflorescence was measured at middle portion of inflorescence and expressed in cm. After selecting the suitable bunch for tapping, the days between initiation of the tapping process and commencement of flow of sap was recorded. The days for sap flow starting to till it stops were recorded in each bunch and hence the duration of the tapping in each bunch was calculated. The sap was collected and sap volume was measured in each harvesting. Sap samples were collected in polycarbonate bottles for biochemical analysis and samples were immediately analysed for biochemical contents such as total sugar, reducing sugar, protein (Lowry *et al.,* 1951; Somogyi, 1952; Dubois *et al.,* 1956) and amino acid (Yao *et al.,* 2006). The total soluble solid (TSS) content of the fresh coconut inflorescence sap was measured using the hand refractometer (ATAGO, ATC-1E). The pH of the coconut sap was measured using a digital pH meter (inoLab WTW digital pH meter) immediately as soon as samples were collected and this was done in triplicate.

Statistical analysis

Data were analyzed statistically by applying the technique of analysis of variance (ANOVA) as described by Gomez and Gomez (1984). Correlation study of different sap production parameters was done by the method of Pearson.

Results and Discussion

Sap yield

In all the genotypes, the sap flow was slow initially for 10 to 15 days, peaks around 20 days and continues in the same pattern for next 25 to 30 days. After that the flow slows down and stops in another 10 to 15 days. Similar trend was observed in a study by Rajagopal *et al.,* (1989) and Samsudeen *et al.,* (2013) on sap production. Initially, tip of the inflorescence only sliced hence only the spikelets that appear in the tip part of the inflorescence undergo the bleeding, and involves for the flow of the sap. After that the sap exudation increases as more as large number of spikelets are involved. During the maximum sap yielding stage, the whole spikelets are involved in the exudation (Sambou *et al.,* 2002).

In the present study, the mean sap yield of different genotypes varied from 0.96 to 1.7 L per day per inflorescence. Highest sap yield

of 1.7 L per day per inflorescence was recorded by Nigerian Tall followed by Gangapani Tall (1.35 L) (Table 2). The mean sap yield per inflorescence ranged from 8.87 to 79.45 L. Highest sap yield per inflorescence was observed with Nigerian Tall and the lowest was in East Coast Tall (Fig. 1). Similar trend was observed in annual sap production per palm. Highest annual sap production of 622.32 L was noticed in Nigerian Tall followed by Gangapani Tall (490.925 L). The differences in the sap production in different genotypes can be attributed to the genetic potential of the genotype. The sap flow is attained by injuring fibro vascular tissues of the tip of the spathe and the high sugar concentration in the sap indicate that it is drawn from stored resources and is in excess of currently synthesised sugars (Dalibard, 1999). Hence the yield of sap depends on potential of the genotypes on its nutrient uptake, transport, assimilation, storage, remobilization and synthesis of storage compounds. Browning and Symons (1961), Maravilla (1975) and Maravilla and Magat (1993) highlighted several factors such as age of palms, climate, phenotypic yield group and mineral nutrition of palms are the reasons for differences in inflorescence sap yield of coconut palms. In the present study, difference in genotype in terms of vegetative and floral characteristics of the coconut palms is the specific factor significantly contributes to the differences in yield of the coconut inflorescence sap. Since significant differences in the number of leaves on the crown and inflorescence length and circumference were observed and these parameters may contributed to the differences in sap yield of coconut genotypes (Table 3). Secretaria *et al.,* (2002) emphasized that the palms which have more number of living fronds on the crown have the tendency to have more sap yield, because every living frond of bearing palms has a natural capacity to support a spathe which can be used for tapping. He also reported that floral structure especially the length of the inflorescence is a good indicator for higher sap since longer spathe implies longer spikelets and flowers which are contained inside the spathe and could be the source of sap from the spathe.

Nathanael (1966) and Ranasinghe (1997) opined that the coconut varieties, environment and management factors have a substantial influence on sap yields. Rethinam *et al.,* (2002) also reported variations in sap yield of different genotypes viz., Laccadive Ordinary Tall, Andaman Ordinary Tall, Laccadive Micro Tall and West Coast Tall. Similar results were reported by Jeganathan (1974), Konan *et al.,* (2013), Samsudeen *et al.,* (2013), Jnanadevan (2013) and Joseph *et al.,* (2018) in different coconut varieties.

Table.1 Details of coconut genotypes used in this study

Genotypes	Region	Country
Gangapani Tall	South Asia	India (Andhra Pradesh)
Gonthembili Tall	South Asia	Sri Lanka
Nigerian Tall	Indo -Atlantic	Africa
Jamaica Tall	Indo -Atlantic	Jamaica
Hazari Tall	South Asia	India (West Bengal)
NiuQuewen Tall	Pacific Ocean Islands	New Caledonia
East Coast Tall	South Asia	India (Tamil Nadu)
West Coast Tall	South Asia	India (Kerala)
Navasi Tall	South Asia	India (West Bengal)

Table.2 Sap yield, duration of sap production and days taken for commencement of sap flow, TSS and pH of inflorescence sap of different coconut genotypes

Genotypes	Average sap yield (L/day)	Duration of tapping per inflorescence (days)	Days taken for commencement of sap flow (days)	TSS (°Brix)	pH
Gangapani Tall	1.34	45.95	15.55	16.37	6.6
Gonthembili Tall	0.93	47.65	17.15	16.73	6.6
Nigerian Tall	1.71	46.6	15.92	15.37	7.2
Jamaica Tall	1.09	41.28	18.92	15.10	6.8
Hazari Tall	0.93	39.43	17.56	16.02	7.0
NiuQuewen Tall	1.06	36.58	15.79	16.27	6.5
East Coast Tall	0.28	31.75	23.25	16.00	6.8
West Coast Tall	0.98	33.9	16.48	16.93	6.7
Navasi Tall	1.15	51.75	17.00	16.50	6.7
CD (0.05%)	0.35	9.17	1.78	0.13	NS

Table.3 Morphological traits of different coconut genotypes

Genotypes	Stem girth (m)	Number of leaves	Length of the petiole	Internodal length (cm)	Length of the inflorescence (cm)	Median circumference of the inflorescence (cm)
Gangapani Tall	0.93	31.0	1.09	8.8	74.5	21.0
Gonthembili Tall	1.00	29.0	1.14	8.0	77.6	21.7
Nigerian Tall	1.26	36.0	0.98	8.0	69.3	21.0
Jamaica Tall	1.23	32.5	1.04	7.5	75.0	19.0
Hazari Tall	1.06	26.0	1.17	8.0	76.0	20.0
NiuQuewen Tall	0.87	26.0	1.05	9.5	77.0	21.0
East Coast Tall	1.00	23.0	1.04	10.0	71.5	21.0
West Coast Tall	1.01	27.5	1.04	10.0	69.0	21.0
Navasi Tall	1.13	29.5	1.03	7.9	79.0	20.5
CD (0.05%)	NS	1.83	NS	0.18	1.84	1.53

Table.4 Correlation analysis of average yield of inflorescence sap with sap production parameters

	No. of leaves	Petiole length	Internodal length	Stem girth	Length of the inflorescence	Median circumference of the inflorescence	Sap yield
No. of leaves	1.0000						
Petiole length	-0.4217	1.0000					
Internodal length	-0.6351	-0.1440	1.0000				
Stem girth	0.6808*	-0.4319	-0.6611	1.0000			
Length of the inflorescence	-0.1597	0.4698	-0.4741	-0.2252	1.0000		
Median circumference of the inflorescence	0.5532	0.0143	-0.2427	0.0679	-0.0377	1.0000	
Sap yield	0.7622*	-0.3561	-0.5100	0.3984	0.1057	0.4379	1.0000

* significant at 5% level

Fig.1 Total sap yield per inflorescence in different coconut genotypes

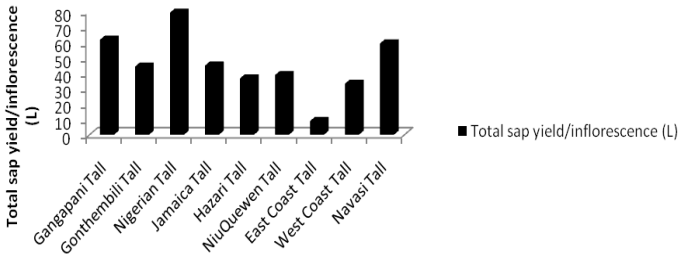


Fig.2 Total and reducing sugar content of inflorescence sap of different coconut genotypes

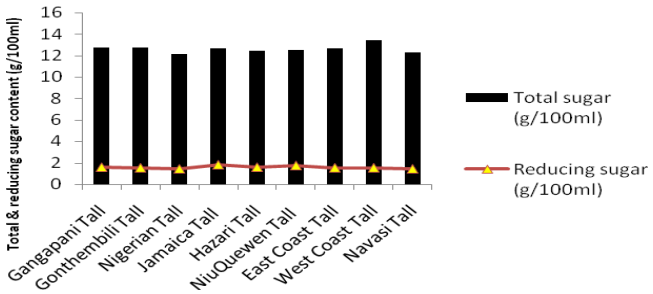


Fig.3 Protein and amino acid content of inflorescence sap of different coconut genotypes

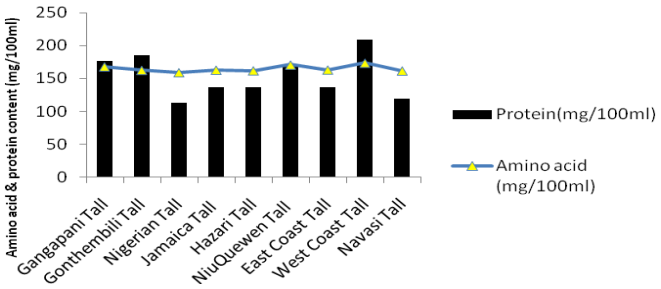


Fig.4 Sap yield in consecutive inflorescence from 2018-19 to 2019-2020 in different coconut genotypes

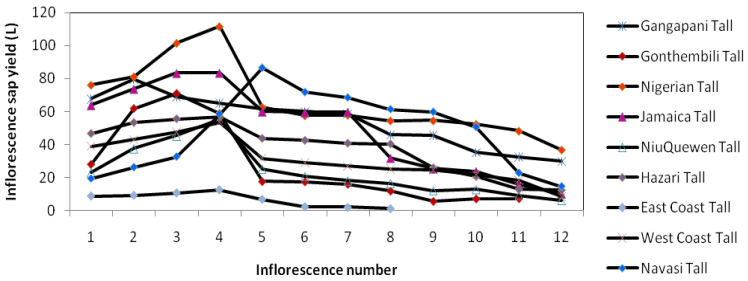
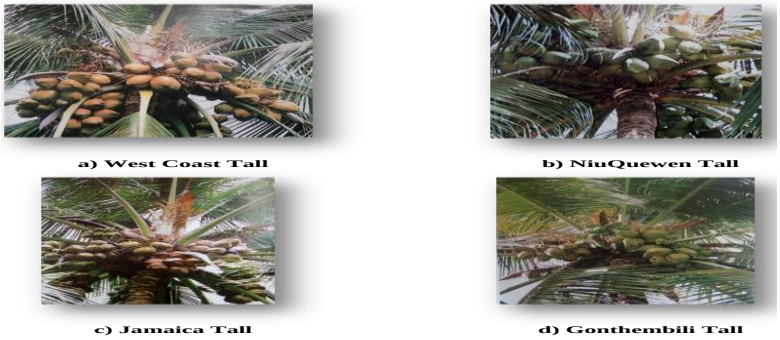


Fig.5 Tying of inflorescence for tapping of sap

Fig.6 Slicing the tip of the inflorescence for sap production

Fig.7 Coconut inflorescence sap collection in "Coco sap chiller" developed by CPCRI

Fig.8 Genotypes evaluated in the study



e) East Coast tall

f) Navassi Tall

g) Nigerian Tall

h) Gangapani Tall

i) Hazari Tall

Days taken for commencement of sap flow

There is significant variation among the genotypes for the period of initial training of the spathe. Gangapani Tall started to produce sap within 15.55 days of training of the inflorescence followed by NiuQuewen Tall (15.79 days) and Nigerian Tall (15.92 days). East Coast Tall took 23.25 days to start the flow of the sap (Table 2). In general the interval between the beginning of tapping process and the commencement of sap flow is about 15 to 21 days. In the tapping process, the inflorescence is trained initially, it involves uniform beating all over the surface of the spathe in order to rupture the cells to induce the flow of the sap. Hence the interval from the commencement of tapping to the dripping of sap depends on the skill of the tapper, the seasonal conditions prevailing and the nature of the palm. Jnanadevan (2015) observed that the interval from the beginning of the tapping to the dripping of the sap varies widely. It varied from palm to palm and from spadix to spadix in the same tree. He also reported that the initiation of sap flow takes place as early as five days to as late as 32 days after the tip of the inflorescence had been cut off for the first time. Menon and Pandalai (l958) stated that the interval from the start of tapping to the actual sap flow depends on the nature of the tree and the period varies from about 10 to 25 days.

Duration of sap production per inflorescence

Duration of sap production per inflorescence varied with different genotypes and ranged from 31.75 to 51.75 days. Single inflorescence of Navasi Tall produced sap continuously for 51.75 days followed by Gonthembili Tall (47.6 days) whereas single inflorescence of East Coast Tall tapped for least days (31.75 days) (Table 2).

Certain morphological factors are reported for the reason of highest duration of sap production. Length of the inflorescence and median circumference of the inflorescence are the most important parameters which extend the duration of sap flow. In general, collection

of sap involved in removal of a thin slice from the tip of the inflorescence. Hence, according to the length of the spathe, the time duration is longer for the exploitation of the sap. In addition, length of the inflorescence is a specific character of particular variety. Variation in duration of sap production with respect to different varieties was reported by Konan *et al.,* (2013) and he also reported that duration of sap flow varied because of variation in length of inflorescence of a particular coconut variety. Cortázar *et al.,* (2010) who also reported that the duration of sap flow varied with differences in coconut cultivars.

Duration of tapping per palm

Coconut produces spadix regularly in the consecutive leaf axils, hence tapping can be done throughout the year. However, maximum harvesting of sap can be achieved during certain part of the time in the palms. In the present study, the tapping started during August, 2018 in all the genotypes. The yield of sap per palm increased during post monsoon season (October-November), slightly reduced during winter (December-February), and seventh month onwards the sap yield started to decrease. The same trend was observed in all the genotypes (Fig. 4). This indicates that the palms required resting period after continuous tapping. Muralidharan and Nair (2013) reported that, generally tapping is practiced for a period of six months in a set of palms. Based on the vigour of the palm the tapping may be extended for even two years. Menon and Pandalai (1958) reported that some healthy, vigorous palms have been sap yielders for throughout its life in countries like Sri Lanka, Philippines and Pacific Islands. Samsudeen *et al.,* (2013) observed higher sap production during monsoon (June-September) and post monsoon (October-November) and lower sap production during winter (December-February) and summer (March-May) since soil moisture positively influenced the sap production. Naik *et al.,* (2013) reported that a palm can be tapped for six months at a stretch in a year and allowed for the next six months for normal tender nut or coconut production as a health restoration measure for the palm.

Biochemical parameters

The chemical composition of inflorescence sap reflected the chemical composition of phloem sap from the source organs MacRobbie (1971). Nakamura (2011) reported that the exudate collected from the cut end of a flower-bearing stem is derived from sieve tubes, its chemical composition is likely to be similar to that of the phloem sap. The coconut inflorescence sap contains various compounds including sugars, amino acids, inorganic cations, organic acids, proteins, etc. (Nakamura *et al.,* 2011). Phloem sap is a complex mixture of organic and inorganic substances (Komor *et al.,* 1996). Sugars and amino acids are the principal metabolites in phloem sap. Phloem sap is moderately alkaline and the acidic pH values reported in the past was likely due to contamination with xylem exudates and bark tissue (Dinant *et al.,* 2010). In the present study, pH of the inflorescence sap from different genotypes varied from 6.5 to 7.2 and there is no significant variation was observed among the genotypes (Table 2). Nigerian Tall recorded a pH of 7.2 followed by NiuQuewen Tall. The genotypes differ significantly with respect to TSS and total sugar content of the inflorescence sap. TSS of different genotypes varied from 15.10ºBrix to 16.93ºBrix (Table 2). The highest TSS content was recorded in the sap of West Coast Tall and the least was recorded by East Coast Tall. Highest total sugar content of 13.4 g/100ml was noticed in West Coast Tall followed by Gangapani Tall (12.75 g/100ml) and the lowest was noticed with Nigerian Tall (12.15 g/100ml) (Fig. 2).

TSS is an estimation of the total dissolved solids including sugars and other soluble organic acids, it is generally higher than the total sugars, and the difference between the °Brix values and the sugar content depends on the amount of other soluble organic acids (Hijaz and Killiny, 2014). There is no significant variation with regard to reducing sugar content among the genotypes and it ranged from 1.45 to 1.81 g/100ml. Protein and amino acid content of inflorescence sap found to be significantly varied among different coconut genotypes (Fig. 3). The highest protein (209.1 mg/100ml) and amino acid (173.75 mg/100ml) content was observed in West Coast Tall. Differences in the biochemical parameters of sap in different coconut varieties/genotypes were reported by Anon (2011), Samsudeen *et al.,* (2013), Joseph *et al.,* (2018) and Sudha *et al.,* (2019). Konan *et al.,* (2014) also observed variations in biochemical constitutions of different coconut ecotypes.

Morphological traits influencing Sap production factors and its correlation

In the present study, morphological traits influencing sap production viz., number of leaves, stem girth, intermodal length, length of the petiole, length and median circumference were observed. Among the genotypes, the maximum number of leaves (36), stem girth (1.26 m) and minimum petiole length (0.98 m) was noted in Nigerian Tall. Lowest intermodal length was observed in Jamaica Tall (7.5 cm) followed by Navassi Tall (7.9 cm) which was on par with Nigerian Tall, Hazari Tall, Gangapani Tall and Gonthembili Tall. Maximum length of the inflorescence of 79 cm was observed in Navassi Tall followed by Gonthembili Tall (77.6 cm). Highest median circumference of the inflorescence was recorded in Gonthembili Tall (21.75 cm) followed by Nigerian Tall (21 cm).

The relationship between the morphological traits and sap yield was assessed by correlation analysis (Table 3 and 4). The parameters such as number of leaves, stem girth, length of the inflorescence and median circumference of the inflorescence showed positive correlation with sap yield while petiole length and intermodal length showed negative correlation with sap yield. Konan *et al.,* (2013) reported a positive correlation between the yield of sap and the length and median circumference of the spathe. Secretaria *et al.,* (2002) studied six coconut varieties and reported that the length and girth of the inflorescence influence the sap production since inflorescence component characters viz., number and length of spikelets and number of buttons (female flowers) decide the length and median circumference of the inflorescence and these component characters could be the source of sap from the spathe. He also reported that the palms which have more number of leaves have the tendency to have produce more sap yield because every living leaves of bearing palms has a capacity to Support a inflorescence for sap production. Menon and Panldalai (1958) listed certain indicators for higher sap yield viz., palms with close set of crown, more number of leaves and strong and short petioles. Ranasinghe (2007) made similar observations in Sri Lanka, where the tappers traditionally use some visual criteria such as more number of leaves and long and relatively thin inflorescence sheaths, which make easy the bending of flower stalks without splitting. These parameters ensure sustainably high sap yields.

In conclusion the coconut varieties suitable for production of inflorescence sap hold the potential to revitalize the prospects of coconut farmers and coconut inflorescence sap is the promising candidate for product diversification. The present study revealed that the inflorescence sap yield and quality

varied with different coconut genotypes. Among the nine genotypes, Nigerian Tall and Gangapani Tall are suitable for tapping since recorded highest sap production and West Coast Tall recorded highest sap biochemical parameters. Morphological traits viz., number of leaves, stem girth, length and median circumference of the inflorescence are positively correlated with sap yield whereas petiole length and intermodal length were negatively correlated with sap yield. Hence these indicators may be considered while tapping. The information obtained from the study.

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