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Response of soil-plant nutrition on yield and quality of coconut inflorescence sap and importance of coconut inflorescence sap on human health: A review

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Abstract
Coconut palm is one of the most useful plants to mankind, because it supports the livelihood security of millions of small and marginal farmers. Every part of the plant is very useful in one way or another. Among the various products from coconut, coconut inflorescence sap (CIS) attracts the maximum interest on view of the large number of by products that can be produced which are highly income generating. The available nutrient content of soil and tissue nutrient concentration influences the quantity and quality of coconut inflorescence sap. It is important to identify the nutrients such as N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Na and Cl content of soil and tissue that influence CIS output and its nutritional qualities. The nutrient requirement for coconut palms being tapped is much higher than palms maintained for nut production. CIS is a rich source of reducing and non-reducing sugars with plenty of minerals and vitamins. It is also a good source of iron, phosphorous and ascorbic acid. The most significant characteristic of coconut inflorescence sap is its low glycemic index an indication of the extent of sugar absorbed into the blood which makes it suitable even for consumption for diabetic patients.

Keywords: Soil-plant nutrition, CIS, yield, quality and human health

Introduction
Coconut inflorescence sap is collected by tapping the unopened spa the of coconut palm which yields a sweet, oyster white and translucent sap (Gupta *et al*., 1980) [8]. Coconut inflorescence sap (CIS) is extracted by a method called tapping which involves selective bleeding of unopened coconut inflorescence which is a traditional practice in all coconut growing countries. The exuding sap is a sweet translucent juice, oyster white in colour with high nutritive value. It is a rich source of reducing and non-reducing sugars with plenty of minerals and vitamins. It is also a good source of iron, phosphorous and ascorbic acid. The most significant characteristic of coconut inflorescence sap is its low glycemic index an indication of the extent of sugar absorbed into the blood which makes it suitable even for consumption for diabetic patients (Manohar *et al*., 2007) [17]. In recent times there is a huge global demand for low GI sugars while its availability is limited. CIS which is a natural source of low GI sugars can fill up this gap. The available nutrient content of soil and tissue nutrient concentration influences the quantity and quality of coconut inflorescence sap. It is important to identify the nutrients such as N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Na and Cl content of soil and tissue that influence CIS output and its nutritional qualities. The nutrient requirement for coconut palms being tapped is much higher than palms maintained for nut production. The response of tapping palms to higher doses of fertilizers has to be evaluated. It will be helpful in developing specific nutrient management plans for tapping coconut palms. Effect of soil-plant nutrition on yield and quality of coconut inflorescence sap.

CIS yield
Secretaria *et al*. (1998) reported that the differences in coconut varieties, climatic conditions and nutrition status of the palms contributed significantly to the differences in sap and nut yields. According to Wasantha *et al*. (2009) [36], sap flow in coconut depends on variety and soil condition on which palm is grown. The greater soil depth, water holding capacity of soil and larger leaf area of palm are reported to be positively correlated with higher sap flow. A study conducted by Marvilla and Magat (1993) [18] on laguna tall variety revealed that leaf nutrient concentration in terms of N, P, K, Ca, Mg, Na, Cl, S and B concentrations was not affected by tapping for coconut inflorescence sap compared to palms maintained for nut production and those for sequential coconut toddy and nut production.

The results indicate that there is no adverse effect of coconut inflorescence tapping on the nutrient status of coconut palms. Sunil *et al*. (2009) [31] found that on an average a coconut palm yields 1.8 - 2.4 liters of neera. The sap yield from coconut palms varies from 2 - 4.5 liters depending on the health of palms and management practices adopted (Muralidharan and Deepthi, 2013) [20]. The yield of coconut inflorescence sap was significantly influenced by the application of increased levels of NPK (175% POP recommendation) fertilizer (Raghu and Joseph, 2020) [27].

Sap production duration

Cortazar *et al*. (2010) [6] stated that the duration of production of inflorescence sap was about 20 - 30 days per spathe. Konan *et al*. (2013) [16] assessed the sap production parameters from spathes of four coconut cultivars in Cote d' Ivora. The results indicated that the hybrid PB 113 had the highest sap production duration of 46.78 days, while the dwarf variety MYD registered the lowest sap production duration of 24 days. The sap production duration is a function of the length of spathe and regularity in sap flow during the tapping cycle. Samsudeen *et al*. (2013) [29] observed that the sap production duration of WCT, Laccadive ordinary tall, Chawghat orange dwarf and COD × WCT ranged from 60 - 70 days. Raghu and Joseph, (2020) [27] reported that there was no significant influence of treatments on sap production duration.

Biochemical composition

Purnamo (1992) [25] stated that fresh coconut inflorescence sap contains sugar components and small amounts of protein, fat, minerals and vitamins. Muralidharan and Deepthi (2013) [20] observed that neera has a pH of 3.9 - 4.7, total solids of 15.2 - 19.7 g $100ml^{-1}$, total sugars of 14.4 g $100ml^{-1}$, reducing sugar of 9.85 g $100ml^{-1}$ and no alcohol content. Naik *et al*. (2013) [21] reported that Keramritham (Neera) is much superior to tender coconut water and contains 15 -18% total sugars, 1.3 mg $100ml^{-1}$ vitamin C and 8.0 mg $100ml^{-1}$ of phenols. They also observed that neera has a pH of 6.8 and acidity of 10.0 m eql^{-1}. There is an influence of soil and climatic condition on the absorption of water and minerals which in turns affects photosynthesis and the production of carbohydrates by coconut palms (Konan *et al*., 2014) [15].

Hori *et al*. (2001) [11] reported that the composition of fresh coconut inflorescence sap is influenced by variety, stage of maturity of spathe, climatic conditions and soil fertility status. Sunil *et al*. (2009) [31] observed that fresh coconut inflorescence sap contains 15.2 - 19.7% total solids, 12.3 - 17.4% sucrose, 0.11 - 0.41% total ash, 16.0 - 30.0% ascorbic acid and 0.23 - 0.32% protein.

Ranasinghe and Silva (2007) [28] reported that the high level of soluble sugar in leaf tissue and correspondingly in the sap producing coconut palms is due to the translocation of sugars from leaves and their conversion into soluble sugar in the sustaining leaf. They also suggested that coconut inflorescence sap exudation is as a result of the movement of the aqueous phase from sieve tube system of coconut trees to the bleeding site in the tapping inflorescence. Pethiyagoda (1978) [24] observed that the high volume of CIS and its high sugar content points its origin to materials derived from stored resources rather than sugar currently synthesized.

Van Die (1974) [34] reported that the requirement of assimilates for tapping coconut palms is much higher than palms maintained for nut production as the amounts of assimilates removed during tapping of coconut inflorescence is several times more than the assimilates removed had that inflorescence yielded nuts. There was no significant correlation between sap yield and the carbohydrate content in plant, net assimilation rate and nut yield before tapping (Ranasinghe and Silva, 2007) [28]. Pethiyagoda (1978) [24] observed that high nut producing palms need not produce larger volumes of coconut inflorescence sap.

The biochemical properties like reducing sugar (0.57 g $100ml^{-1}$), non-reducing sugars (10.27 g $100ml^{-1}$), total sugars (10.84 g $100ml^{-1}$), alcohol (0.09%), phenols (2.56 mg $100ml^{-1}$) and vitamin C (2.19 mg $100ml^{-1}$) were significantly higher in the treatment receiving 175% POP recommendation (Raghu and Joseph, 2020) [27].

Nutritional composition

Muralidharan and Deepthi (2013) [20] reported that coconut inflorescence sap is rich in iron (0.15 g $100ml^{-1}$), phosphorous (7.59 g $100ml^{-1}$) and vitamin-C (16-30 mg $100ml^{-1}$). Mineral content of neera was 90.5 ppm of potassium, 60.0 ppm of calcium, 15.0 ppm of phosphorous, 45.0 ppm of iron and 9.5 ppm of sodium (Naik *et al*., 2013) [21]. Coconut inflorescence sap is rich in minerals with 90.6 mg $100ml^{-1}$ of sodium, 168.4 mg $100ml^{-1}$ of potassium, 3.9 mg $100ml^{-1}$ of phosphorous, 0.012 mg $100ml^{-1}$ of manganese, 0.031 mg $100ml^{-1}$ of copper, 0.020 mg $100ml^{-1}$ of zinc and 0.053 mg $100ml^{-1}$ of iron (Hebbar *et al*., 2015) [9]. Raghu and Joseph, (2020) [27] reported that the content of nitrogen, phosphorous, potassium, secondary nutrients (Ca, Mg and S) and total mineral content in the sap showed an upward trend with increasing levels of NPK (175% POP recommendation) fertilizers. Importance of utilization of coconut inflorescence sap

As a drink

Iwuoha and Eke (1996) [12] and Gupta *et al*. (1980) [8] stated that fresh coconut inflorescence sapgets easily fermented into a drink with 5 - 8% alcohol and finally gets converted to an acidic liquid with 4 - 7% acetic acid content.

Aalbersberg *et al*. (1997) [1] reported that fresh coconut inflorescence sap is used as a sugar and alcoholic beverages by local people and has high nutritive value and has good digestive properties. According to Jirovetz *et al*. (2001) [13], fermented palm sap or palm toddy or palm wine is used as an alcoholic refreshing beverage. Tuley (1965) [33] revealed that coconut inflorescence sap (CIS) is very popular as a drink with lower sections of the society. It is good for health with properties of improving eye sight and sedative actions.

High nutritive value

In Indonesia coconut sugar is a valuable ingredient in traditional cooking both in food and beverages (Purnomo, 1992; Purnomo and Suryoseputro, 2007) [25, 26]. Kalaiyarasi *et al*. (2013) [14] stated that coconut inflorescence sap is highly nutritious with great medicinal value. Chandrasekhar *et al*. (2012) [5] reported that palm wine is rich in calories (300 calorie/l), proteins (0.5 - 2.0 g/l) and is a good source of vitamins. It also has the potential to improve eye sight and can be used to correct eye ailments.

Health benefits

Manohar *et al*. (2007) [17] reported that coconut inflorescence sap and sugar have low glycemic index (< 35) which makes it ideal sugar source for diabetic patients. Trinidad *et al*. (1993) and Wolever *et al*. (1994) [37] observed that CIS and palm sugar have low glycemic index (35 - 42) which makes them a

good sugar source for both healthy people and patients with diabetes. Akochi *et al*. (1997) [2] stated that coconut inflorescence sap contains sucrose, fructose and amino acids which are precursors of alkylpyrazines in food. Barh and Mazumder (2008) [3] reported that the balanced administration of fresh and fermented date sap was found to improvise the treatment of hemoglobin deficient anaemic patients and to supplement vitamin B_{12} level in the vitamin deficient patients.

Production of palm sugar, alcohol, vinegar etc.

Coconut inflorescence sap is very nutritious and can be used as a raw material for alcohol and vinegar industries (Ezeagu and Fafunso, 2003; Van der Vossen and Chipungahelo, 2007) [7, 35]. Purnomo (1992) [25] reported that in South East Asia coconut inflorescence sap is used as a juice by local communities and in the manufacture of palm sugar, vinegar and acetic acid.

Michael *et al*. (1988) [19] noticed that the fermentation of CIS can be arrested and processed in jaggery industry. Opara *et al*. (2014) [23] also revealed that on natural fermentation coconut inflorescence sap can be converted into an alcoholic beverage and into vinegar and acetic acid. Ho *et al*. (2007) [10] observed that coconut inflorescence sap on heat processing can be converted into a natural sweetener. Palm wine is rich in nutrients and can be utilized as a sweetener on cooking and baking (Ezeagu and Fafunso, 2003) [7].

Fresh coconut inflorescence sap contains 12 - 18% sucrose which can be consumed as such or through alcoholic fermentation it can be converted into an alcoholic drink and vinegar (Nathanael, 1966; Pethiyagoda, 1978) [22, 24]. Batra and Millner (1974) [4] suggested that in Asia fermented coconut inflorescence sap can be used as a source of inoculum for cottage industries producing native leavened bread like nan and Sonnon.

Conclusion

The response of tapping palms to higher doses of fertilizers has to be evaluated. It will be helpful in developing specific nutrient management plans for tapping coconut palms. CIS is a rich source of reducing and non-reducing sugars with plenty of minerals and vitamins. It is also a good source of iron, phosphorous and ascorbic acid. In recent times there is a huge global demand for low GI sugars while its availability is limited. CIS which is a natural source of low GI sugars can fill up this gap.

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