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Review

Biology, propagation and utilization of elite coconut varieties (makapuno and aromatics)

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ABSTRACT

Coconut farming is not only a vital agricultural industry for all tropical countries possessing humid coasts and lowlands, but is also a robust income provider for millions of smallholder farmers worldwide. However, due to its longevity, the security of production of this crop suffers significantly from episodes of natural disasters, including cyclone and tsunami, devastating pest and disease outbreaks, while also affected by price competition for the principal products, especially the oil. In order to reduce these pressures, high-value coconut varieties (makapuno and aromatics) have been introduced in some regions, on a limited scale, but with positive outcomes. Even though these two varieties produce fruit with delicious solid or flavoursome liquid endosperm, their distinct biochemical and cellular features unfortunately prevent their *in situ* germination. In fact, embryo rescue and culture have been developed historically to nurture the embryo under *in vitro* conditions, enabling effective propagation. In an attempt to provide a comprehensive review featuring these elite coconut varieties, this paper firstly introduces their food values and nutritional qualities, and then discusses the present knowledge of their biology and genetics. Further possibilities for coconut in general are also highlighted, through the use of advanced tissue culture techniques and efficient seedling management for sustainable production of these highly distinct and commercially attractive varieties of coconut.

Contents

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1. Introduction

Being one of the most important palm crops, coconut (*Cocos nucifera* L.) provides direct food and vital revenue for millions of farmers across tropical and subtropical regions of the world. The palm is well-known for the diversity of its products, particularly within the realms of food, drink, structural material and energy supply. In fact, coconut oil remains the dominant commercial product from the global production base of 12 Mha, including 3 Mt traded around the world annually (Arancon, 2013). There is a wide range of industrial and edible products derived from the oil, as well as its desiccated kernel, coconut water, nectar, sugar, charcoal, fibre and coco peat produced in many locations where there has been investment in processing technology. However, producers are facing a number of agro-economic challenges including the declining productivity of ageing palms – as the main stimulus to undertake plantings was many decades ago. Also there is the falling price of the traditional products, and intense price competition from highly productive and mechanisable crops such as oil palm (*Elaeis guineensis* Jacq.) (Samosir et al., 2006). In addition, the field cultivation of coconut in some regions has been seriously threatened by a wide variety of biotic and abiotic factors, including lethal diseases and pests, and natural calamities (Nguyen et al., 2015). The major era of establishment of coconut plantations for export of copra and oil was the period of its very high price, between the years 1900 and 1930. Due to the decline of the price paid for oil and copra from the 1960s until the present It is reported that at least one half of the 12 Mha of plantations needs regeneration through replanting (Foale, 2003; APCC-Secretariat, 2016). According to a recent report from the Asia and Pacific Coconut Community, ideally around 700 million palms should be replanted each year in the next two decades (APCC-Secretariat, 2016).

The coconut palm is also potentially vulnerable to acute insect and microbial bio-hazards specific to diverse locations world-wide, such as the Lethal Yellowing phytoplasma, *Phytophthora* bud-rot fungus and the *Brontispa* leaf beetle (Bila et al., 2015). The capacity provided by cloning technology, to multiply material from resistant or tolerant populations, would provide a means to achieve protection (Nguyen et al., 2015). Hence, there is an urgent need to foster alternative coconut products with higher economic value, which can help sustain the viability of the smallholder and the entire coconut industry. In this context, elite coconut types with unique attractive endosperm properties are potential candidates. There are two widely acknowledged varieties: those with a tasty jelly-like endosperm and those with flavoursome aromatic water (Samosir et al., 2006). Attention in this review will be focussed on these two valuable elite mutant forms of coconut fruit, because these are particularly valuable at the farm gate, thereby offering the farmer a boost to income wherever there is demand for these forms. Success achieved in cloning these elite genotypes would contribute directly to multiplication of main-stream genotypes from which all the products mentioned above can be derived.

The variety with fruit containing a jelly-like endosperm is known as 'makapuno' (or macapuno), a word derived from a Filipino term meaning 'tends to fullness' (Lauzon, 2005). This variety was first identified in the Philippines and communicated by Gonzalez (1914) who described the fruit as one where the cavity becomes completely or partially filled with white, gelatinous endosperm. It was also found that not every fruit from a makapuno-bearing palm had these attributes (Torres, 1937). Interestingly, there are many similar varieties found in other countries with different local names: Dua Sap (Vietnam); Dikiri Pol (Sri Lanka); Kopyor (Indonesia); Maphrao Kathi (Thailand); Dahi Nariyel (Myanmar); Thairu Thengai (India); Dong Kathy (Cambodia); and Niu Garuk (Papua New Guinea) (Fig. 1A). The delicious makapuno endosperm can be consumed directly, or used to make a wide array of foods, or as a flavouring agent in ice-cream and pastries (Santoso et al., 1996).

The second elite variety, that has refreshing fragrant, flavoursome water, is commonly known as the 'aromatic' coconut. This kind of fruit is highly regarded in many coconut growing countries, particularly in the Southeast Asia region, where it is consumed as a fresh drink. Despite the growing demand for aromatic coconut, supplies from the existing palm populations are somewhat limited. The cultivation of both varieties of palm is hindered by their inability to naturally germinate. This is believed to be due to natural mutation in the formation of the endosperm, in which both biochemical and physical properties fail to nurture the embryo through the early stages of germination (Ramirez, 1991). A combination of a short fruit storage life and a wide geographic dispersal of the unique parent palms has created a situation whereby these two elite coconut varieties have become highly valuable (Luengwilai et al., 2014). For example, an aromatic fruit in Thailand is worth roughly double the price of a normal fruit, and the makapuno in the Philippines is priced up to 10 times higher than an ordinary coconut (Samosir et al., 2006).

In the past, much effort has been put into understanding the cause of low-germinability in the elite coconut varieties. The early cytological studies showed that an abnormally high frequency of small, polyploid cells were found in the makapuno endosperm (Abraham et al., 1965). The multiplication of these highly disorganized, unsystematically shaped microcells by irregular cytokinesis (de la Cruz and Ramirez, 1968) led to the uncontrolled proliferation of the endosperm tissue. The resulting endosperm tissue was therefore unable to nurture the development of the zygotic embryo haustorium during germination. In the early 1980s, biochemical research provided further insight into the distinctive properties of the makapuno endosperm. Deficiencies of the enzymes α-D-galactosidase and β-mannosidase were discovered, and found to be associated with a unique accumulation of galactomannan. This was thought to prevent the mobilisation of other reserved polysaccharides, thereby preventing germination (Mujer et al., 1983a, 1984a). In addition, higher activity of β-mannanase was found in the makapuno endosperm than in normal endosperm, which led to the galactomannan being less viscous (Samonte et al., 1989). It is believed that the changes in enzyme balance noted in the