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Review

# Genetically modified bananas: To mitigate food security concerns

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ABSTRACT

Banana and plantains are one of the world's most important food crops and widely consumed by people of all age groups. Bananas are a rich source of carbohydrates, important vitamins like vitamin B and C and minerals like potassium and phosphorous. Banana is an economically important cash crop as it fetch large revenue share in the domestic and international market. However, most of the production is consumed by the domestic population as it serves as the staple food for them. Bananas are vulnerable to both biotic and abiotic stress factors which limits their production. Improvement of this crop to enhance the nutrient quality and better adapt to the changing environmental conditions and to produce new disease resistant varieties is essential. Genetic engineering of banana is considered a perfect alternative for improvement of sterile cultivars or ones which are not amenable to traditional breeding methods Several successful attempts have demonstrated the strength of this technology in developing abiotic stress tolerance and disease resistant transgenic banana varieties. Only few of the Genetically Modified (GM) bananas have qualified for field studies and some are currently undergoing nutritional human trials. GM bananas aim to increase productivity and nutritional value and so could effectively contribute towards food security in the near future.



**Contents**



## 1. Introduction

Banana and plantains the major staple food crops in the developing countries are widely cultivated in tropical and subtropical regions across the world. The plant considered as a remunerative cash crop yield satisfactory returns to the growers and considered as the developing world's most important food crop after rice, wheat and maize. The annual world production of banana is about 106.7 million tonnes and India is the largest producer with a production of about 29.7 million tonnes (FAO, 2013-14). Many cultivars have poor yield but are still in cultivation because of their quality and apart from being eaten raw and cooked, bananas are also used in making beer, edible dried chips and flour. Though many varieties are grown in India, only a few are grown commercially which include Grand Nain, Robusta, Dwarf Cavendish, Nendran, Rasthali as the major varieties. The yield is more for Cavendish bananas compared to Rasthali and Nendran. Indian states of Maharashtra and Gujarat together contribute 27%, where the conditions for banana cultivation are favorable (http://nhb.gov.in/report_files/banana/BANANA.htm). The other significantly

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banana growing states in India are Tamil Nadu, Kerala and Karnataka. Among numerous varieties, Cavendish bananas constitute most of the total world export trade of 15 million tones that amounts to about US$ 4.8 billion for exporting countries. Banana is a staple food in some parts of the world and thus a viable crop for biofortification. Banana cultivation is threatened by both biotic and abiotic factors which limit its production potential. As such banana plants are sensitive to low temperatures, drought and salinity causing significant losses. Moreover, they are host to major debilitating diseases such as Fusarium wilt, sigatoka disease, banana bunchy top disease and Moko disease (Jones, 1999). These diseases can spread rapidly to an extent of causing epidemics (mostly due to monoculture practice) and capable to inflict famine conditions in major banana growing regions. Improvement of banana through genetic engineering ensures sustainable production.

Present day high throughput technologies has allowed simultaneous investigation of thousands of genes, transcripts, proteins, and metabolites involved in biotic and abiotic stress response. Genome and transcriptome sequencing of different banana cultivars have been carried out in recent past which provides valuable resource information for banana improvement (D'Hont et al., 2012; Li et al., 2013; Bai et al., 2013; Martin et al., 2016; Wu et al., 2016). The enormous data generated in these sequencing reactions provide insight in studying novel genes, differential expression profiles, comparative genomics study, evolutionary genomics research and polymorphisms which can be exploited for banana breeding and/or transgenic procedures. Transgenic banana offer environmental benefits by reduced spraying of pesticides on disease and pest resistant plants, increased productivity on the available arable land and combating climate change through abiotic stress tolerant plants. This review intends to showcase most of the studies demonstrating the potentiality of transgenic banana in tackling production constraints and ensure food security and sustainability.

## 2. Conventional versus biotechnological banana improvement approaches

Despite their importance banana and plantains are one of the least genetically improved crops, and production is based on the cultivars derived from few collections which are domesticated from ages and undergone numerous complex hybridization events (Heslop-Harrison and Schwarzacher, 2007). Banana breeding has been considered difficult due to their long life cycle, triploidy and parthenocarpic fruit development in most of the edible cultivars. Conventional breeding is complex, time consuming and their results are often not satisfying. However few institutes such as FHIA (Honduras), EMBRAPA (Brazil), CARBAP (Cameroon) NRCB (India) and IITA (Africa) are breeding banana varieties to obtain triploids and tetraploids with improved characteristics (Jacome et al., 2002; Bakry et al., 2009). Somaclonal variations induced by repeated micropropagation-selection cycles have also been attempted in banana to develop resistance to Fusarium wilt (Hwang and Ko, 2004). Genetic engineering of bananas acquire special importance as useful characters can be introduced relatively rapidly into elite cultivars without compromising their fundamental genetic makeup. Establishment of a cell suspension culture based protocol for genetic transformation of banana (Côte et al., 1996; Ganapathi et al., 2001b; Strosse, 2003; Strosse et al., 2006; Khanna et al., 2004, 2007; Chong-Pérez et al., 2012) opened up opportunities for banana improvement using genetic engineering techniques. A high throughput regeneration and transformation for a few cultivars has also been developed recently by Tripathi et al. (2015). Embryogenic cell suspensions (ECS) and *Agrobacterium tumefaciens* mediated transformation are well established for few banana cultivars and hence improvement using this technique has been envisaged recently with a few publications on disease resistance and environmental stress tolerance (Paul et al., 2011; Shekhawat et al., 2011; Shekhawat et al., 2012; Ghag et al., 2012; Sreedharan et al., 2012). The main advantage being the transfer of useful trait/s to a cultivar which has most of the desirable characters as possible. Also the leading commercially grown varieties can be engineered for multiple stress tolerance, delayed fruit ripening and nutritional quality improvement. Since most of the cultivated bananas are triploids with very low pollen fertility, apprehensions regarding transgene flow to the wild cultivated bananas are negligible.

## 3. Modern banana tissue culture and genetic transformation methods

Conventionally banana is propagated by vegetative suckers. One of the main limitations with this method is the availability of uniform age and size suckers in large numbers for a given elite variety/cultivar. *In vitro* micropropagation of banana developed for the last three decades are now considered well established (Vuylsteke and De Langhe, 1985; Wong, 1986; Vuylsteke, 1989; Arias, 1992). Now, protocols for large scale tissue culture propagation of banana using shoot tip cultures have been established (Saraswathi et al., 2016). However a few banana cultivars are recalcitrant to tissue culture and transformation protocols. Further, the protocols established are also genotype specific. In the last two decades banana biotechnologists have put in considerable efforts in optimizing parameters for banana tissue culture and regeneration in different cultivars (Ganapathi et al., 2001a, 2001b; Khanna et al., 2004; Tripathi et al., 2005). Many of the private commercial tissue culture laboratories are producing millions of plantlets and the farmers are reaping the benefits from this development. However, the shoot tip culture method of regeneration is not suitable for genetic engineering as there is a problem of chimeras (May et al., 1995). Alternatively, ECS cultures circumvent this problem as single cells transformed are regenerated into plantlets (Fig. 1). Various explants like immature male/female flower buds, scalps and shoot tip cultures have been used to initiate ECS in a few of the commercial cultivars (Escalant and Teisson, 1989; Escalant et al., 1994; Dhed'a et al., 1991; Ganapathi et al., 1999, 2001b; Grapin et al., 2000; Ghosh et al., 2009). However difficulties in obtaining ECS from several elite varieties have limited the scope for improvement and conservation of these important landraces. *In vitro* development of embryogenic callus and ECS requires appropriate and precise cocktail of hormones which one needs to optimize for each variety separately.

*Agrobacterium*-mediated genetic transformation is the method of choice used to transform banana cells (May et al., 1995; Ganapathi et al., 2001b; Khanna et al., 2004; Tripathi et al., 2005; Huang et al., 2007; Ghosh et al., 2009). However, few research groups employed biolistic/microprojectile bombardment method to deliver foreign gene into banana tissues. Becker et al. (2000) and Matsumoto et al. (2000) bombarded ECS cultures of Cavendish banana (*Musa* spp. AAA group) cv 'Grand Nain' or 'Maçã' banana (*Musa* sp. AAB group, Silk) respectively to develop stable transformants.

### *3.1. Abiotic stress resistant GM bananas*

Climate change challenges the optimum productivity of crops in tropical regions. Banana is an evergreen and shallow rooted crop and requires large quantity of water throughout its life cycle. Due to climate change there is an increase in temperature which critically disturbs plantations (Gornall et al., 2010). Further, higher temperature causes increased demand for water for cultivation leading to droughts. Although warmer temperatures will favor increased area under cultivation for banana, the corresponding rise in drought