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Dynamics of banana research and development in India for farm profitability enhancement

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Abstract

India is the largest producer of banana in the world. The crop has great significance in enhancing farmers' income, besides providing nutrition to consumers. Total annual banana production in India is 29.2 million tonnes from 0.84 million hectares. The crop accounts for more than 35% share in total annual fruit production and contributes about 2.5% of the Agricultural Gross Domestic Product (AGDP) of the country. Productivity is high, if locally grown traditional cultivars are excluded and only area and production of Cavendish cultivars (about 45% of total area) is considered. A dramatic change in production volume of banana, from 7.7 million tonnes in 1991 to about 30 million tonnes currently, is attributed to technological changes and improvement in value-chain management. The government has provided focused attention and investment for research and development, considering the crop's socioeconomic importance in India, by establishing the National Research Centre for Banana (NRCB) and through programs of the National Horticulture Mission, which facilitate farmers to adopt banana cultivation with improved techniques. A major private player for banana research and development in the country is Jain Irrigation Systems Limited (JISL), Jalgaon, Maharashtra, India. It is the largest producer of tissue-cultured banana plants in the world, producing about 70 million tissue-cultured plants annually, certified free from diseases. They also provide technical support and equipment for fertigation to a network of 5 million farmers. Although India has provided leadership in production of banana, export has been limited due to the highly competitive export market. The focus of many companies in India has shifted towards the export of banana from the country. The paper presents various facets and milestones of innovations which have led to a transformation in banana production in India.

Keywords: banana, technological changes, National Horticulture Mission, tissue-cultured plants

INTRODUCTION

Banana is the worlds' most important fresh fruit commodity in terms of volume of trade (Huang, 2004). The global banana industry is now more than a century old – it started in the late 1800s, as a result of technological advances. Banana has grown in popularity for its versatility in adaptation to many agro-climatic conditions, its non-specificity in season for fruit production making it available throughout the year, and its high productivity per unit area with a production of 40-60 tonnes of fruits per hectare annually (Singh and Chadha, 2001). In India, banana provides a higher income per unit area compared to many other crops. The spectrum of diversity coupled with varying agro-climatic conditions, especially with respect to crops cycle which varies from one climatic condition to another, allowing year-round availability of fruits. Although bananas (including the different dessert and cooking types) are cultivated in over 130 countries, India has emerged as the largest producer and consumer in the world, with an annual production of 29.2 million tonnes from an area of 0.84 million ha (Horticultural Statistics at a Glance, 2017). India has shown spectacular growth of the banana industry during the last few decades, contributing about

26% of global production, exhibiting 291% increase in production and 72% increase in productivity since the year 1991-92 and 2016-17 (Horticultural Statistics at a Glance, 2017). This has been possible through dedicated research and development strategies leading to technological changes and adoption, coupled with initiatives of the government and private players. The increasing demand and technological changes have revolutionized banana production in India, which will continue, driven by growing demand from the domestic and export markets.

The purpose of this paper is report on the development of the banana industry in India, with a focus on the technological changes which have been adopted for improving production and productivity of banana in India.

PRESENT STATUS – WORLD VS INDIA

Globally, banana production exhibits a slow growth with a production of 114.13 million tonnes cultivated on 5.39 million ha, with a productivity of 21.2 tonnes/ha, in the year 2014 (Horticultural Statistics at a Glance, 2017). The crop is produced in over 130 countries in tropical and subtropical regions of the world. India is the largest producer of banana in the world (29.2 million tonnes in the year 2017-18, 2nd estimate), followed by China (12.09 million tonnes), Philippines (8.88 million tonnes), Brazil (6.95 million tonnes), Indonesia (6.86 million tonnes), Ecuador (6.76 million tonnes) and Guatemala (3.55 million tonnes) (Horticultural Statistics at a Glance, 2017). In India, banana is produced on an area of 0.85 million ha, with a productivity of 35.00 tonnes/ha. The production of banana in the country has increased significantly in the last two and a half decades (1991-92 to 2016-17) (Fig. 1). The crop is grown in almost all the states of the country, with the major banana growing states being Gujarat, Andhra Pradesh, Tamil Nadu, Uttar Pradesh and Maharashtra. The area, production and productivity of banana in different states of India are presented in Table 1. In the country, there is a wide range of variation in productivity among the different states. Gujarat has the highest productivity because of the large-scale adoption of cultivars from the Cavendish group (AAA), especially 'Grand Naine'. In states like Tamil Nadu, Karnataka, Bihar and Kerala, many different genomic groups are grown.

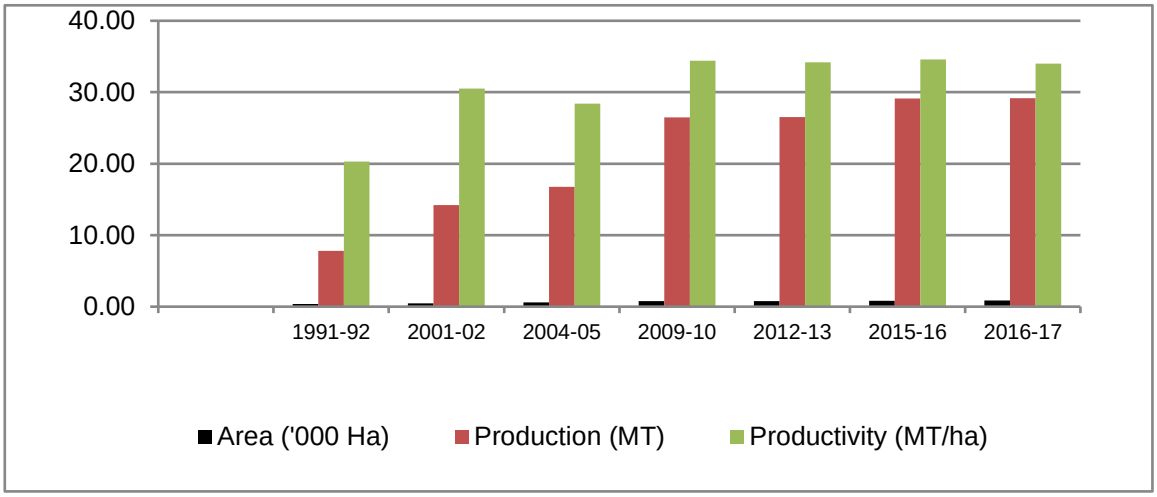

Figure 1 Growth in banana production in India (1991-92 to 2016-17). Source: Horticultural Statistics at a Glance (2017). Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India.

Table 1. Area, production and productivity of banana cultivation in different states of India (2016-17).

State	Area ('000 ha)	Production (million tonnes)	Productivity (tonnes/ha)
Gujarat	64.69	4.19	64.70
Andhra Pradesh	86.32	4.14	48.00
Tamil Nadu	94.99	0.64	38.33
Uttar Pradesh	67.40	3.08	45.68
Maharashtra	74.68	3.07	41.14
Karnataka	101.53	2.49	24.52
Madhya Pradesh	24.31	1.65	67.75
Bihar	35.15	1.55	44.12
Kerala	81.51	1.22	15.02
West Bengal	49.00	1.20	24.40
Assam	55.42	0.98	17.67
Chhatisgarh	27.06	0.62	22.87
Odisha	24.49	0.47	19.05
Others	71.55	0.87	12.16
Total	858.1	26.16	34.00

Source: Horticultural Statistics at a Glance (2017). Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India.

CHANGING DEMAND IN THE DOMESTIC MARKET

Most of the banana produced in the country is consumed domestically, as the Indian population is large. The consumption and volume of fruit production has changed with enhanced expendable income and increased health consciousness in the population, driving domestic demand. This has resulted in an expansion of banana production even in non-traditional areas. The Indo-Gangetic plains, especially Uttar Pradesh and Bihar, have now become important production areas (Singh, 2015b). The consumers are aware, and demand that practices adopted for production of banana are not harmful to their health. Therefore, the adoption of Good Agricultural Practices (GAP) is becoming essential to ensure fruit quality. Now, big corporate houses, like Reliance, ITC, Aditya Birla Group, Godrej and Walmart, have entered into retailing of fresh fruits including banana, and Jain Irrigation Systems Ltd. (JISL), Jalgaon is providing total solutions of value chain management. Due to the entrance of these companies, forward-backward linkages for the supply chain are developing, leading to availability of good-quality bananas in the retail niche market.

EXPORT MARKET

India also exports banana, mainly to the United Arab Emirates, followed by Iran, Saudi Arabia, Oman, Kuwait, Nepal, Qatar, Bahrain, Maldives and Iraq. Exports are largely for meeting the need of ethnic populations in other countries. The states which contribute for

the export in India are Gujarat, Maharashtra, Tamil Nadu and Kerala. Quality control and longer shelf-life are crucial for export. Many companies in the country have become banana exporters, and there is a success in export of traditional cultivars as well as 'Grand Naine'.

CULTIVAR DIVERSITY

India is endowed with a large diversity in cultivars which caters largely for domestic needs (Singh, 2015b). Depending upon agro-climatic conditions, at least 10-12 cultivars are grown together. The Cavendish group (AAA), including 'Grand Naine', 'Robusta' and 'Dwarf Cavendish', contributes more than 55% of production (Singh and Uma, 2007). These cultivars are largely grown because of their high yield, wide market acceptability, short crop duration and high economic returns per unit area. 'Grand Naine' is now more popular amongst the producers and traders, because of its high yield, finger characters, orientation and suitability for packaging (Singh, 2015a). 'Red Banana' (AAA) is grown for its unique colour, flavour and also medicinal properties, to cater the needs of a niche market, where it fetches a premium price. '*Ney Poovan'*, '*Elakki Bale'*, '*Njali Poovan*' (AB) are becoming very popular in the southern states, like Karnataka and Tamil Nadu, due to their unique taste. They have potential for export. '*Rashthali*' (AAB), with its distinctive flavour and texture, has a niche market, which fetches a premium price in the retail market across the country. 'Hill banana'/'Pome', also known as '*Virupakshi*'/'*Sirumalai*' (AAB), which is confined to Palani and Sheveroy Hills of Tamil Nadu, has a unique flavour, taste and good shelf life and has the potential to be placed under geographical indicators. '*Udhyan*' (ABB), released by NRCB, has become popular in areas where this group (ABB) has been growing (Uma, 2018). Apparently, there is a potential to capture the niche domestic and export market with assorted cultivars of banana (Singh, 2015a).

PRODUCTION CONSTRAINTS – BIOTIC AND ABIOTIC STRESSES

In India, biotic stresses like fungal diseases (including wilts and leaf spot diseases), viral diseases, insects and other pests as well as abiotic stresses like drought, salinity and vagaries of climates are common.

Of these, Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *cubense* (Foc), has become the main problem after the devastation of 'Gros Michel' and jeopardizing the export industry in the 1980s. Race 1 and Race 2 are known to cause havoc in Silk and Pisang Awak. Now, the industry is also under threat by the Race 4 strain affecting Cavendish clones, which replaced 'Gros Michel' in the global scenario. Race 4 was not reported in India until 2017. The impact is not yet devastating as in many countries, perhaps due to annual crop cycle*, i.e.,* annual replanting of plantations. Other major fungal disease, like the Sigatoka leaf spot complex, and minor diseases, like Cordana leaf spot and banana freckle, also cause damage. Among the viruses, *Banana Bunchy Top Virus* (BBTV) is a serious threat in traditional production systems. Prevalence of perennial plantations, a failure to control insect vectors, and lack of incentives to remove virus-affected mats have adversely affected productivity. One such example is the slow erosion of the preferred cultivar of India, i.e. 'Hill Banana'. *Banana Streak Viruses* (BSV) is another threat, especially, since the virus has integrated in the host genome and eventually in various production systems. *Banana Bract Mosaic Virus* (BBrMV) is a relatively new virus that has slowly but systematically spread from the southern states of Kerala to other neighbouring states in India (Singh and Mustaffa, 2009). Although the threat from *Cucumber Bosaic Virus* (CMV) has not been alarming, its occurrence in tissue culture-raised plantations, due to lack of indexing and failure in field detection, is expected to increase in the coming years.

Nematodes are omnipresent irrespective of the production system, climate, soil or cultivars. If not managed strategically, and in a timely manner, they can pose production losses of 20-80%. Nematodes and nematode-wilt complex interactions can seriously hamper production and productivity of the plantation. Weevils and borers are also becoming serious pests. Though it used to be restricted to the southern states of India, the pseudostem weevil has reached Northern India across the state boundaries, bringing down productivity. Though varietal preferences are reported, weevils spare no cultivars irrespective of genome or

ploidy.

Abiotic factors, like low temperatures, floods, typhoons and soil fertility, are equally devastating. Unlike biotic factors, climatic vagaries seldom give scope for preparedness. Only reframing the production system (in terms of season) can provide plantation protection. Simultaneously, the disappearance of unique species, ecosystems and crops due to over-harvesting of natural resources, rapid population growth, and invasive species, further aggravated by climate change, is extremely alarming with serious impacts on livelihoods, agro-ecologies and economies.

With the above spectrum of problems, the situation of banana industry needs to be analysed in a holistic way. Regardless of the regional differences, opportunities need to be exploited to overcome the threats.

RESEARCH AND DEVELOPMENT IN BANANA

By 2025, Indian domestic demand for banana is expected to be around 40 million tonnes per annum, which could be met with technological advancements. Banana research in India started in the early 19th century, but until 1949, research was concentrated on characterization of variability. In 1949, a project sponsored by the Indian Council of Agriculture Research (ICAR) was implemented in Tamil Nadu, and three Research Centres were established. These largely concentrated on collection, conservation and characterization. Banana research got a new focus with the establishment of the All India Coordinated Research Project (AICRP) in 1971, which addressed region-specific needs. A national focus for banana research came with the establishment of the ICAR-National Research Centre for Banana (NRCB) at Tiruchirapalli, Tamil Nadu, in 1993. The centre established collaboration with the International Network for the Improvement of Banana and Plantain (INIBAP, now Bioversity International) and has been providing leadership in banana research (Singh and Chadha, 2001; Singh and Uma, 2007). The centre has the largest collection of banana accessions in India, both in a field genebank and *in-vitro*, including cryopreservation. The centre has developed and released three cultivars and recently selected a variant resistant to Foc race 1 (Thangavelu, 2016). An intensive breeding programme is working towards developing nutrient-rich banana cultivars. Viral diagnostic techniques have been used for certification programmes. A rapid detection kit for BBrMV and CMV developed at the centre is becoming popular.

Intensive research has also been started by the private sector for the selection of elite 'Grand Naine' lines, production of disease-free planting materials, and improved production system management, bunch management and quality assurance, all focused on serving consumer preferences (Patil, 2017). Among private sectors in the country, the company Jain Irrigation System Ltd., (JISL) is doing pioneering work, and working to serve banana farmers' needs. Government of India has also adopted development strategies through various States Government in mission mode approach, wherein the Government has regulated the production of quality planting materials through certification from accredited laboratories and is supporting farmers for adoption of improved technologies (Singh *et al.,* 2011). The efforts have led to the development of a 'Seed Delivery System', which involves the maintenance of virus-free mother blocks, sequential indexing, and fidelity testing and certification standards. Certification is also enforced for tissue-culture industries and the planting materials they produce. Expertise is available in terms of diagnostic tools for BBTV, BBrMV and BSV, for which the indexing protocols have been rationalized with international procedures (Singh *et al.,* 2011).

IMPROVEMENT IN BANANA IN INDIA

Natural mutation selection and perpetuation have been the basis of evolution in vegetatively propagated crops like banana. A large number of local man-made selections for specific traits, especially for higher yield, parthenocarpy and resistance to biotic and/or abiotic stresses, have been under cultivation. '*Gandevi*', a tall mutant of 'Giant Cavendish' is selected for its high yield potential of up to 70 kg/bunch in India (Singh and Mustaffa, 2009). '*Udhayam*' is a selection in Pisang Awak for high yield (35% higher), compared to the local

'*Karpuravalli*' (Uma, 2018). Similarly, '*Kozhikkodu*' and '*Bangaladesh Malbhog*' are selections in Silk, while '*Pisang Ceylan*' is a virus-free Mysore typ1. 'GCTCV-115' and 'GCTCV-218' are Cavendish selections resistant to Foc race 4, which have found wide adaptability in areas where the pathogen is causing a threat (Thangavelu, 2016).

JISL, Jalgaon has succeeded in selecting a superior type of 'Grand Naine', which is a natural selection from large population of tissue cultured raised plants. It has sturdy pseudostem, *i.e.,* tolerates wind, has thick leaves, and compact bunch providing many hands, and therefore, has a high bunch weight. This selection is largely distributed as 'Jain Grand Naine', and about 70 million tissue-cultured plantlets of this selection are available to farmers across the county every year (Patil, 2017).

Apart from these natural selections, global breeding programmes have provided hybrids. 'FHIA-01', 'FHIA-03', 'FHIA-17', 'FHIA-21' and 'FHIA-23' from FHIA in Honduras, are promising but not finding a place in the commercial production system. 'CRBP-17' and 'CRBP-39' are selections from CARBAP in Cameroon. They are high-yielding Plantains (AAB) with resistance to black leaf streak. 'BRS-1', an improved Pome hybrid, and 'BRS-2', an improved Mysore hybrid, both released from India, are finding a place only in the homestead. They are resistant to leaf spot diseases and nematodes (Singh and Mustaffa, 2009).

At NRCB, Tiruchirapalli, mutation breeding has succeeded in improving a few cultivars but as yet these have not been commercialised. Thus, 'Grand Naine' and 'Robusta' continue to be the prominent cultivars in commercial production of banana in India.

TECHNOLOGICAL CHANGES WHICH HAVE REVOLUTIONISED BANANA PRODUCTION IN INDIA

With increasing demand and upcoming technologies, banana production in India has been transformed. The technologies which have played a role are the production of tissue-cultured, disease-free, quality plants; management of the production system; protection against diseases and pests, and more effective value-chain management (Singh, 2015b).

Production of quality planting materials: Banana is traditionally propagated through suckers or bits, a technique that continues for most cultivars, while tissue-culture plants are adopted largely for the commercial Cavendish cultivars, such as 'Grand Naine'. Tissue-culture plants are no longer a luxury, but an economic reality. The initial dissemination of the tissue-culture technology was slow, not because the technology was not good but rather due to a lack of awareness. Now farmers are confident of getting higher returns, hence adoption of the technology is spreading (Singh and Singh, 2017). To safeguard the farmers, the entrepreneurs and the banana industry, a certification system for tissue-culture developed banana planting material was introduced in India, involving a series of steps before "Freedom from virus certificates" is issued to the industries (Singh *et al*., 2011). Recognizing the increasing demand for tissue-cultured banana plants, automation in production and hardening is adopted by JISL, Jalgaon. The company is the largest producer of disease-free tissue-cultured plants in the world, with a production of 70 million plants annually, capturing 65% of the Indian market (Patil, 2017). Tissue culture in banana has been rewarding not only for farmers; it has also provided opportunities to entrepreneurs, with more than 90 tissue-culture production units being established. At NRCB, mass multiplication through Embryonic Cell Suspension (ECS), has been standardized, and is awaiting commercialization (Uma, 2018).

Production system management: There has been a spectacular change in production system management, which includes high-density planting (2500-3000 plants/ha), drip irrigation, fertigation, mat management and bunch management. Nutrients are applied based on nutrient analysis of the soil, and no side suckers are permitted until maturity of the bunch. Diseases and pests are managed through an integrated management system. Bunch injection is becoming popular to safeguard the fruit against thrips and post-harvest diseases. Through this system, many farmers are obtaining yield levels of 80-90 tonnes/ha. Considering yield loss in ratooning, farmers are now shifting from 2-3 cropping cycles to a single cropping cycle, *i.e.,* annual replanting. This also helps in avoiding diseases

and pests. Interestingly, 'Grand Naine' seems largely well-adapted to the semi-arid tropics and subtropics, for reduced disease pressure.

Value-chain management: The above-mentioned production system management, including management of the bunch, is important for the value chain. Pre-harvest quality and efficient post-harvest management ultimately determine the quality assurance for consumers (Singh, 2015b). Pre-harvest practices have a major role to play in obtaining quality fruits. In pre-harvest practices, besides the cultivar choice, plant architectural management, balanced use of nutrients including micronutrients, water quantity and quality, protection from diseases and physiological disorders, bunch management for appropriate size and colour of fruit, and time of harvest are some of the factors which determine the quality. Work has been done on these aspects and the practices are adopted by farmers to boost production. Post-harvest management needs appropriate handling at the time of harvest and during transport to the pack house. After reaching the pack house, the bunch is de-handed, cleaned and packed in appropriately-sized boxes and transported under cool conditions. At all marketing centres, fruits have to be ripened slowly at 18-20°C to reach the right colour ('Grand Naine'). Cold storage and ripening chambers play a crucial role in the value-chain management of banana, for ensuring extended shelf-life whilst maintaining quality (Singh and Uma, 2007). To obtain better post-harvest quality and maximum shelf life, bananas are harvested before the fruit is mature. This technology allows storage and transport for 3-4 weeks at 13°C (55°F). On arrival, bananas are stored at about 17°C (63°F) and treated with a low concentration of ethylene. After a few days, the fruit begins to ripen and is distributed for final sale (Singh, 2015a). Carbon dioxide (which bananas also produce) and ethylene absorbents extend the fruit life even at high temperatures. This effect can be exploited by packing bananas in a polyethylene bag and including an ethylene absorbent, *e.g.* potassium permanganate. There is an increasing trend for establishing packhouses both at production and marketing centers across the country. In the traditional value chain, farmers take the harvested bunches directly to the nearest auction platform (commission agent) by loading them into the lorry or sell to the local aggregator/collector (middle man) without any value addition. The aggregator collects the materials from different farmers and transports them to the nearest market/auction platform for auction. Retailers buy the bunches in the auction and take them to their shop, where they perform value addition by de-handing and ripening and removing damaged/bruised/injured or under-graded fruits. In the present value-chain management, farmers are using assured quality plants, technical guidance and facilitation in marketing, which is encouraging farmers to expand their banana production.

EMERGING CHALLENGES AND APPROACHES

Some of the challenges listed are not new but need to be highlighted and more effective approaches to be taken to address them. There is a need for inter-regional support to boost output. Broadening of the genetic base through intensification of collection missions and development of strong breeding programmes; development of cultivars that suit the regional needs of small and marginal farmers and with good adaptability to limited water use; bio-technological tools for crop improvement; fertilizer tailoring and judicious water harvesting; and use of technologies to reduce production costs, are some of the approaches that should be adopted. Ensuring quality of planting material, using indexing and fidelity testing tools, and an efficient supply chain system with integration of quality control are needed.

To contain their spread, common disease forecasting models to furnish information on disease or pest distribution, spread, strains and dispersal pathways are essential. Contingency plans are needed to combat the outbreak of diseases in a new region. The emergence of Foc race 4 is of major cause of concern. Characterization and mapping of VCG diversity in the Foc pathogen needs to be accelerated to establish transborder quarantining and sanitation. Development of non-chemical control strategies, including resistant cultivars, improved crop dynamics, biotization with endophytes and non-pathogenic Fusarium forms, all offer effective pest control approaches. It is essential to develop and

deploy rapid diagnostic tools for banana diseases and rationalize the existing diagnostic protocols, as has been done for BBrMV and BMV at NRCB, Tiruchirapalli (Uma, 2018). Elimination of BBrMV from the germplasm maintained in several regional genebanks for efficient use and exchange needs to be prioritized. Tools to eliminate viruses from the host system (from valuable germplasm) through cryo- or chemotherapy are required to contain the likely damage caused by diseases. Common varieties of the region should have the access to each other. Knowledge sharing through human resource development programmes, and the development of rationalized techniques for disease diagnostics and other molecular biology tools to tackle banana production constraints can strengthen the efforts.

Some problems are region-specific, and there is high variability in productivity among the states in the country. Productivity in Gujarat is 64.0 tonnes/ha, while in the North Eastern region, it is less than 15 tonnes/ha. This variation requires to be tackled by the region through the adoption of appropriate technologies.

In India, for commercial banana production, fertilization is scheduled based on soil analysis and largely applied through drip irrigation, economizing on the quantity of fertilizer used in banana production. Further, it may be mentioned that Sigatoka leaf spots are not a serious disease in India, as the crop is grown in arid environments, supplemented with irrigation in the traditional farming of banana. Also the application of fertilizer is rarely practiced here. Therefore, no contamination of water or environmental pollution has been reported in the banana-growing zones of India. Also, to help farmers increase their income, new technologies like pseudostem utilization for fiber and potash-rich manure need to be promoted.

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