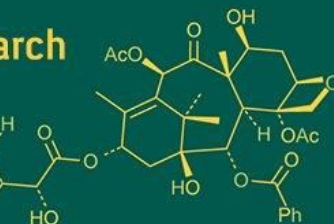


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MR Bhanusree
Agricultural College, PJTAU,
Telangana, India

K Ravi Kumar
Department of Horticulture,
Agricultural College, Naira,
UBKV, Pundibari Coochbehar,
West Bengal, India

S Chakraborty
Department of Horticulture,
North Eastern Hill University
(Tura Campus), Tura,
Meghalaya, India

CP Suresh
Agricultural College, PJTAU,
Telangana, India

S Gopal
Agricultural College, PJTAU,
Telangana, India

Corresponding Author:
K Ravi Kumar
Department of Horticulture,
Agricultural College, Naira,
Andhra Pradesh, India

Banana bunch covers for quality banana production: A review

MR Bhanusree, K Ravi Kumar, S Chakraborty, CP Suresh and S Gopal

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Abstract

India is the world's leading producer of bananas, contributing nearly 18% of the global output of approximately 139 million metric tonnes. Despite this dominant position, the country's share in international banana exports remains very low due to several quality-related and logistical challenges. The external appearance, internal quality, and market acceptability of bananas are strongly influenced by production practices adopted during cultivation. Among these practices, the use of banana bunch covers has emerged as an effective physical protection technique. Bunch covers enhance the visual appeal of the fruit by improving skin colouration and minimizing blemishes, while also modifying the micro-environment surrounding the developing bunch. This altered micro-climate can positively influence fruit development, leading to improvements in pulp quality, ripening behaviour, and overall shelf life. In addition to improving quality, bunch covers help reduce the incidence of various biotic and abiotic stresses, including insect pests, diseases, mechanical injury, sunburn, fruit cracking, bird damage, and contamination from agrochemical sprays. However, the practice can be labour-intensive, and its economic feasibility particularly the benefit cost ratio needs thorough evaluation before widespread adoption can be recommended, especially in resource-limited production systems. Although several studies from different banana-growing regions of the world have examined the effects of bunch covering, the findings remain scattered and unorganized. Recognizing this gap, we have undertaken an effort to compile, synthesize, and present the available global research on banana bunch covers. This compilation aims to provide a comprehensive reference for researchers, farmers, and extension personnel to support informed decision-making and promote improved production practices in the banana sector.

Keywords: Banana bunch covers, promoting skin colouration, quality banana production

Introduction

Banana (*Musa sapientum*) is one of the most important fruit crops in India and worldwide. Bananas are cultivated in more than 150 countries, with an annual global production of about 105 million tonnes. India alone contributes nearly 29.19% of the world's banana production, amounting to approximately 102,028.17 thousand tonnes. Despite being the leading producer, India's share in the global export market remains minimal due to several constraints, particularly those related to fruit quality and appearance.

The external appearance, internal quality, and overall market value of bananas are influenced by various factors, including pre-harvest production practices. External quality attributes such as peel colour, shape, size, and freedom from blemishes play a crucial role in consumer acceptance, especially in competitive export markets. Internal quality attributes, including taste, texture, sweetness, aroma, acidity, flavour, shelf life, and perceived nutritional value, are equally important in ensuring sustained repeat purchases (Hewett, 2006 ^[34]). Buyers in premium domestic and international markets demand uniform, well-coloured fruits with blemish-free peels.

Flowering and fruiting periods in banana vary with cultivar. Generally, banana plants require 6-8 months to produce a flower stalk, followed by an additional 4-6 months for fruit development and maturation. During this prolonged period, developing fruits are highly vulnerable to damage caused by biotic and abiotic factors. Wind is a major abiotic stress, causing peel scarring through the impact of blowing dust and debris, as well as abrasion from adjacent leaves and petioles rubbing against the developing bunch (Anon, 2003) ^[5].

Biotic factors, particularly pre-harvest insect pests that feed on the peel, also cause significant surface damage, leading to a decline in fruit marketability. In regions with high insect pressure, growers face serious challenges in producing blemish-free fruits, resulting in substantial losses in market quality.

To mitigate losses caused by these factors, several protective practices have gained popularity worldwide. With increasing consumer concern over excessive pesticide use and growing environmental awareness, there is a strong emphasis on adopting eco-friendly alternatives that improve fruit quality while reducing chemical inputs. Consequently, the use of banana bunch covers or bags has emerged as an effective physical protection method that safeguards fruits from insect damage while allowing adequate air and water exchange at an affordable cost.

Banana bunch covers, also known as banana bags, banana sleeves, ripening bags, or crop covers, are widely used in commercial banana-growing regions across the world (Muchui *et al.*, 2010) ^[46]. Bagging is a physical fruit protection technique applied to several fruit crops and is known to enhance visual quality by improving peel colouration and reducing blemishes. Additionally, it modifies the microenvironment around the developing fruit, influencing temperature and humidity, which can have multiple effects on fruit growth and internal quality (Fan and Mattheis, 1998) ^[20]. These bags are available in different colours and designs, tailored to suit specific agro-climatic conditions (Jannoyer and Chillet, 1998; Muchui *et al.*, 2010) ^[37, 46].

Commercial producers often use plastic bunch covers, sometimes impregnated with insecticides, to protect banana bunches. In the absence of such covers, some farmers resort to spraying pesticides directly on the bunches to control pests and maintain visual quality. Bunch covers effectively protect fruits from insect pests, pathogens, wind damage, leaf and petiole scarring, dust deposition, light hail, sunburn, bird damage, and mechanical injury during harvesting and transport. They have also been reported to protect bunches from low-temperature stress, particularly in temperate regions.

Bagging has been successfully used to reduce winter stress and promote early fruit maturation under favourable conditions (Muchui *et al.*, 2010) ^[46], as well as to protect fruits from low temperatures in other crops (Mohamed and Al-Qurashi, 2012) ^[44]. Export-quality bananas are characterized by attractive peel colour, minimal sunburn, reduced fruit splitting, increased finger length, and higher bunch weight (Amarante *et al.*, 2002) ^[2]. Covering banana bunches shortly after pollination significantly reduces peel damage caused by insect pests and eliminates fruit chaffing due to leaf abrasion (Weerasinghe and Ruwaphirana, 2002) ^[80]. Furthermore, fruits harvested from covered bunches have been reported to show a lower incidence of postharvest anthracnose disease.

Overall, the use of banana bunch covers results in improved fruit quality, higher marketable yield, and better economic returns. Since consumers primarily rely on visual cues when purchasing fresh produce (Shewfelt, 2009), the production of large, uniform, blemish-free bananas is essential for achieving premium prices in international markets (Johns, 1996) ^[39].

History of Banana Bunch Covers

Bunch covering is an ancient practice that has been used for centuries in banana cultivation. Traditionally, growers wrapped maturing banana bunches with dried or fresh banana leaves to protect the fruits from environmental stress and physical damage. Scientific evaluation of bunch covering began in the early twentieth century. In 1936, studies demonstrated that covering banana bunches with hessian material effectively protected fruits from winter chilling and resulted in improved fruit quality. Subsequently, paper bags were introduced, although their use remained limited.

A major advancement occurred in 1955 when Queensland pioneered the use of tubular polyvinyl chloride (PVC) covers. Following successful trials that produced record-sized bunches, growers soon adopted cheaper blue polyethylene covers. Initially, transparent plastic covers caused sunburn, particularly on the upper hands of the bunch. To overcome this issue, newspaper was placed over the first two hands before the plastic sleeve was applied. With refinements in materials and handling practices, plastic bunch covers rapidly became standard in commercial banana production, not only in Australia but also across Africa, India, and the American tropics.

By 1963, many growers shifted towards covers made of high wet-strength kraft paper treated with formaldehyde, which had already found use in garbage bags. These paper covers were easy to staple at the top, effectively prevented sunburn, withstood adverse weather conditions, and could be reused for at least one additional season. Despite these advancements, some growers continued to prefer traditional burlap due to its durability and availability.

It was recognized that the timing of cover application was critical. Growers were advised not to apply covers until the bracts had lifted from the fruits, approximately 21 days after shooting, ensuring that the young fingers were sufficiently firm to withstand friction from the cover.

Although early trials showed that several cover colours produced excellent results, the banana industry standardized on blue covers for many years. In more recent times, covers in blue, green, yellow, and clear colours, with or without silver reflective sides, have been adopted. These colour variations serve as aids in estimating bunch maturity, while silver-sided covers help reduce sunburn by reflecting excess solar radiation.

Pre-harvest Bunch Covers

The technique of banana bunch covering was scientifically developed during the 1950s in Australia (Berrill, 1956) ^[6], although the traditional practice of wrapping maturing bunches with banana leaves to protect fruits from winter chilling has been followed for centuries (Heenan, 1973; Turner, 1984) ^[33, 72]. Today, banana bunch covers are widely used in commercial banana-growing regions worldwide to improve fruit yield, quality, shelf life, and marketability, particularly for export-oriented production (Krishnamurthy and Kushallappa, 1985; Muchui *et al.*, 2010) ^[42, 46].

The effects of bunch covering on banana yield and fruit quality vary considerably and depend on several factors, including the type of cover material, colour, thickness, perforation, stage of fruit at bagging, cultivar, climatic conditions, and postharvest handling practices (Stover and Simmonds, 1987; Johns and Scott, 1989a, b; Robinson, 1996; Amarante *et al.*, 2002; Muchui *et al.*, 2010) ^[69, 40, 56, 2].

^{46]}. Reports on the influence of bagging on fruit size, maturity, and peel colour are often contradictory, which may be attributed to interactions between light intensity and temperature within the bunch microclimate (Reddy, 1989; Vilela *et al.*, 2001; Vargas-Calvo and Valle-Ruiz, 2011) ^[53, 78, 77].

In tropical and subtropical regions, bunch covers are primarily used to protect developing fruits from leaf and petiole scarring, wind-blown dust, sunburn, light hail, pests, diseases, and mechanical injury during harvest and transport (Stover and Simmonds, 1987; Robinson, 1996) ^[69, 56]. Bunch covering favourably modifies the microclimate around the developing fruit by increasing temperature and relative humidity, which can reduce winter stress and accelerate fruit maturation, especially in cooler climates (Chillet and Jannoyer, 1996; Gowen, 1995) ^[8, 55].

Bunch covers of various colours and designs (perforated and non-perforated) are used depending on climatic conditions and production objectives (Robinson, 1996) ^[56]. Perforated polyethylene covers facilitate aeration and cooling, while pesticide-impregnated covers provide effective pest control in tropical environments (Robinson, 1996) ^[56]. Based on the stage of application, bagging is classified as early, semi-early, and normal, with early bagging often enhancing finger length and reducing bunch filling time (Stover and Simmonds, 1987; Daniells *et al.*, 1992) ^[69, 17].

The use of bunch covers has been reported to reduce the interval between flowering and harvest by 5-12 days, increase finger length and diameter, improve peel colour, and enhance marketable yield in several cultivars (Robinson, 1996; Daniells *et al.*, 1992; Pathak and Mitra, 2014) ^[56, 17, 51]. Covered fruits generally exhibit fewer blemishes, reduced pest and disease incidence, lower sunburn, and improved visual appeal compared to unbagged fruits (Hewett, 2006; Muchui *et al.*, 2010; Hailu *et al.*, 2012) ^[34, 46, 28].

Colour and thickness of the cover influence fruit development. Translucent or light-coloured covers are preferred in tropical regions as they allow heat transmission while minimizing sunburn (Robinson, 1993; 1996) ^[54, 56]. Film thickness and perforation size affect durability and the greenhouse effect within the cover, with increased temperature ($\approx 0.5^\circ\text{C}$) enhancing metabolic activity and fruit growth, particularly during winter (Stevenson, 1976; Robinson, 1996) ^[68, 56]. However, excessive heat and humidity within sealed covers may increase soft rot incidence and uneven ripening (Robinson and Nel, 1982) ^[57].

Overall, pre-harvest bunch covering is an effective cultural practice that improves fruit quality, advances maturity, and enhances yield, particularly under cool or stress-prone conditions. The magnitude of benefits depends on appropriate selection of cover material, colour, perforation, and timing of application according to local agro-climatic conditions and cultivar requirements.

2.2. Pre-harvest Bunch Covers

The practice of bunch covering in banana was scientifically developed during the 1950s in Australia (Berrill, 1956) ^[6], although the traditional use of dried banana leaves to protect maturing bunches from winter chilling has been practiced for centuries (Heenan, 1973; Turner, 1984) ^[33, 72]. At present, banana bunch covers are widely used in commercial banana-growing regions across the world to improve fruit

yield, quality, shelf life, and marketability, particularly for export-oriented production (Krishnamurthy and Kushallappa, 1985; Muchui *et al.*, 2010) ^[42, 46].

The response of banana fruits to bunch covering varies widely and depends on factors such as the type of cover material, colour, thickness, perforation, stage of fruit development at bagging, cultivar, prevailing climatic conditions, and postharvest handling practices (Stover and Simmonds, 1987; Johns and Scott, 1989a, b; Robinson, 1996; Amarante *et al.*, 2002; Muchui *et al.*, 2010) ^[69, 40, 56, 2, 46]. Conflicting reports regarding the effects of bagging on fruit size, maturity, and peel colour are largely attributed to interactions between light intensity and temperature within the modified bunch microclimate (Reddy, 1989; Vilela *et al.*, 2001) ^[53, 78].

In tropical and subtropical regions, bunch covers are mainly used to protect developing fruits from wind damage, leaf and petiole scarring, dust, sunburn, light hail, insect pests, diseases, and mechanical injury during harvest and transport (Stover and Simmonds, 1987; Robinson, 1996) ^[69, 56]. Bunch covering favourably modifies the microclimate around the developing fruits by increasing temperature and relative humidity, thereby reducing winter stress and accelerating fruit development, especially under cooler conditions (Chillet and Jannoyer, 1996) ^[8]. Bagging has been shown to enhance physiological and metabolic activity, resulting in earlier fruit maturation (Johns and Scott, 1989a; Jia *et al.*, 2005) ^[40, 38].

Bunch covers of various colours and designs (perforated and non-perforated) are used depending on climatic conditions and production objectives (Robinson, 1996) ^[56]. Perforated polyethylene covers facilitate aeration and prevent excessive heat buildup, while pesticide-impregnated covers provide effective protection against insect pests (Robinson, 1996) ^[56]. Based on the stage of application, bunch covering is classified as early, semi-early, and normal, with early bagging often resulting in increased finger length and reduced bunch filling time (Stover and Simmonds, 1987; Daniells *et al.*, 1992) ^[69, 17].

Studies have reported that bunch covering can reduce the flowering-to-harvest interval by 5-12 days, improve peel colour, increase finger length and diameter, and enhance marketable yield in several banana cultivars (Robinson, 1996; Daniells *et al.*, 1992; Pathak and Mitra, 2014) ^[56, 17, 51]. Fruits from covered bunches generally show fewer blemishes, reduced pest and disease incidence, lower sunburn injury, and improved visual appeal compared to uncovered fruits (Hewett, 2006; Muchui *et al.*, 2010; Hailu *et al.*, 2012) ^[34, 46, 28].

The effectiveness of bunch covers is influenced by cover colour and thickness. Translucent or light-coloured covers are preferred in tropical climates as they allow heat transmission while minimizing sunburn damage (Robinson, 1993; 1996) ^[54, 56]. An average temperature increase of about 0.5°C inside bunch covers has been recorded, which enhances metabolic activity and fruit growth, particularly during winter (Stevenson, 1976; Robinson, 1996) ^[68, 56]. However, excessive temperature and humidity within sealed covers may increase the incidence of soft rots, uneven ripening, and fruit deformities (Robinson and Nel, 1982; Daniells *et al.*, 1992) ^[57, 17].

Bunch covering has also been reported to increase fruit weight, length, and girth, reduce mechanical blemishes, and improve the proportion of first-grade fruits (Chillet and

Jannoyer, 1996; Robinson and Nel, 1984) [8, 58]. Yield increases during winter are mainly attributed to enhanced fruit size, reduced bunch development period, or both, due to the “greenhouse effect” created by the covers (Robinson, 1995; Pathak and Mitra, 2014) [55, 51]. However, excessive bagging practices such as double covering have shown limited benefits and are not generally recommended (Johns, 1996) [39].

Overall, pre-harvest bunch covering is an effective cultural practice for improving banana fruit quality, advancing maturity, and increasing yield, particularly under cool or stress-prone conditions. The magnitude of benefits depends on the appropriate selection of cover material, colour, perforation, and timing of application according to cultivar and local agro-climatic conditions.

Advantages of Banana Bunch Covers

Microclimate Modification

Banana bunch covers create a favourable microclimate around the developing fruits by increasing temperature and relative humidity while reducing exposure to adverse environmental conditions. Studies have shown that the average temperature inside bunch covers increases by about 0.5 °C over a 24-hour period (Ganry, 1975) [23, 24, 25], with temperature rises of up to 7 °C during the warmest hours of the day (Soto, 2010) [67]. Johns and Scott (1989) [40] reported that during summer, air temperatures inside bunch covers were 3-6 °C higher than ambient, with the greatest differences observed in the late afternoon, while during winter the increase ranged from 1-2 °C. Relative humidity within the covers generally remains above 95%, and carbon dioxide concentrations may reach around 8%, though these values vary with climatic conditions and cover design.

The modified microclimate reduces winter stress and accelerates physiological and metabolic activities, resulting in earlier fruit maturation and a shortened flower-to-harvest interval by 4-14 days, depending on the type of cover and environmental conditions (Johns and Scott, 1989; Jia *et al.*, 2005) [40, 38]. This favourable environment also contributes to increased bunch weight and improved fruit quality.

Temperature Regulation

Temperature is a critical factor influencing banana fruit growth and development. Bunches emerging during cooler months require a much longer period to mature than those emerging in warmer seasons. Bunch covers help raise fruit temperature and reduce temperature gradients across the bunch, resulting in more uniform fruit development. Exposure to temperatures below 12-13 °C during fruit growth can cause under-peel discolouration, which adversely affects ripening and market acceptability, particularly for export markets (Snowden, 2010; Hailu *et al.*, 2013) [66, 29].

Historically, banana leaves and later hessian covers were used to protect bunches from chilling injury (Heenan, 1973; Turner, 1984) [33, 72]. Modern non-perforated blue or white polyethylene covers (30-35 µm thickness) have been shown to increase internal temperatures and shorten the development cycle of winter bunches (Robinson and Nel, 1982) [57]. In contrast, white perforated bags are preferred during summer as they reflect solar radiation, reduce excessive heat buildup, and improve green life. Transparent perforated polythene covers with 2-4% ventilation are also recommended to enhance temperature while preventing

overheating.

Protection from Sunburn

High air temperatures (above 38 °C) combined with intense solar radiation can cause sunburn, particularly on the upper hands of exposed bunches. While bunch covers provide protection, improper use may aggravate sunburn during hot periods. This risk can be minimized by placing protective paper between the fruit and the cover or by using covers with reflective silver coatings (Turner, 2013) [75]. During warmer months, the use of reflective and perforated covers, along with pulling a leaf over the bunch, is recommended to reduce sunburn damage. Such practices are widely adopted in export-oriented banana production systems (Daniells and Lindsay, 2005) [16].

Protection from Pests and Diseases

Bunch covers act as an effective physical barrier against birds, bats, insects, and pathogens. Bird damage, which is a major cause of loss in banana and other fruit crops, can be significantly reduced by timely bunch covering. The use of polyethylene bunch covers has also been recommended as a disease management practice in banana-growing regions of Cameroon, India, and Palestine (Jones, 2000) [41].

Several insect pests, including thrips, fruit scarring beetles, and tar honey wasps, cause superficial peel damage that greatly reduces fruit value in export markets. Banana thrips (*Chaetanaphothrips orchidii*) can be effectively controlled by covering bunches within 2-3 weeks after fruit set (Stover and Simmonds, 1987) [69]. Early bunch covering also protects fruits from scarring caused by nectar-feeding birds and bats during flowering. Additionally, bunch covers have been reported to reduce the incidence of diseases such as anthracnose, tip-end rot, cigar-end rot, brown spot, and diamond spot (Amani and Avagyan, 2014) [1]. The use of heavier-gauge covers before bract lifting further enhances protection during early fruit development.

Thrips

Several species of thrips are responsible for damage to banana fruits. Thrips are minute insects measuring approximately 1-2 mm in length and infest banana bunches during early fruit development, particularly as the bunch emerges and bracts begin to lift. Red rust thrips (*Chaetanaphothrips* spp.) cause characteristic rust-coloured blemishes on the peel due to feeding by both nymphs and adults. These insects preferentially feed on the soft skin of immature fruits, especially in concealed areas between closely packed fingers where contact occurs. Consequently, the upper hands of the bunch are usually the most severely affected.

The damage caused by rust thrips should not be confused with maturity bronzing, which occurs on the exposed outer curve of the fruit and is unrelated to finger contact. In severe infestations, longitudinal cracking of the peel may occur, and damage can extend over large portions of the fruit surface. Although thrips damage does not affect the eating quality, it significantly reduces visual appeal and market value.

Flower thrips (*Frankliniella* spp.) are also common and cause small, raised pimples capped with black spots on the fruit surface. This injury results from oviposition by adult females in the skin of soft, immature fruits. Banana rust thrips (*Chaetanaphothripsorchidii*, syn. *C. signipennis*) are

particularly destructive, as their feeding stains the peel, causes splitting, and exposes the flesh, which rapidly discolours.

Management of thrips has traditionally involved soil and pseudostem treatments, as the pest pupates in the soil. Earlier control measures included spraying insecticides such as dieldrin around the base of the pseudostem. Improved control has been achieved through the use of polyethylene bunch covers treated internally with insecticidal dusts such as diazinon. A major advancement was the introduction of polyethylene bunch covers impregnated with 1% chlorpyrifos (dursban), which eliminated the need for dusting and provided up to 85% protection against banana rust thrips. These impregnated covers retain insecticidal activity for at least one year under storage conditions.

Fruit Scarring Beetle

The fruit scarring beetle (*Colaspishypochlora*) is a common pest in most banana-growing regions, with population levels typically increasing during the rainy season. Adult beetles feed on the fruit peel, causing localized superficial scarring. Feeding wounds exude a clear fluid that later darkens, forming blackened scars. Damage is restricted to the peel and does not affect the edible portion of the fruit.

Typical symptoms include raised lesions and scars on the peel surface, particularly along the midrib area of the fruit. The beetles attack bunches when fruits are very young, making early protection essential. Adoption of good cultural practices can significantly reduce pest incidence. In addition, covering developing banana bunches with chlorpyrifos-impregnated polyethylene covers has proven effective in reducing fruit scarring beetle damage.

Fungal Diseases

A study by Amani and Avagyan (2014) ^[1] evaluated the effect of bunch covering on fungal diseases and postharvest quality of tissue-cultured banana cv. Dwarf Cavendish in Iran. Several fungal pathogens, including *Pyricularia grisea*, *Muscelliumtheobromae*, *Cercosporahayi*, *Fusarium moniliforme*, *F. solani*, and *F. pallidoroseum*, were isolated from fruit samples. In untreated bunches, symptoms such as pitting, tip-end rot, cigar-end rot, brown spot, diamond spot, and sunburn were frequently observed.

The study concluded that the use of polyethylene bunch covers significantly reduced disease incidence and improved fruit quality, recommending bunch covering as an effective practice for minimizing fungal damage and enhancing marketable yield.

Recycling of Banana Bunch Covers

Many banana plantations practice the reuse and recycling of plastic bunch covers to reduce costs and environmental impact. During harvest, workers carefully lower the bunches and remove the covers without damaging them. The used covers are collected, sorted, and those suitable for reuse are pre-washed with water and soap. They are then soaked for an extended period to remove stains and debris, wrung to remove excess water, and air-dried on lines.

Once dried, the covers are stored for approximately four weeks before reuse. Typically, plastic covers are reused three to four times. After reaching the end of their usable life, the covers are sent to plastic recycling facilities, where they are processed into products such as corner boards or edge protectors.

Mixed Ripening

“Mixed ripe” refers to banana consignments that are transported in a green condition but contain fruits that begin ripening before reaching the market. This condition complicates ripening management, reduces uniformity, and lowers market returns. Fruit maturity is influenced by both size and physiological age. Bunch covers may affect mixed ripening by altering the relationship between fruit growth and maturity, such that fruits of similar size from covered bunches may be physiologically more mature than those from uncovered bunches.

Disadvantages of Banana Bunch Covers

Although the benefits of banana bunch covers generally outweigh their drawbacks, certain limitations must be considered. The use of non-perforated covers in hot and humid climates may lead to physiological disorders such as overheating, rotting, and premature ripening. In addition, insect pests may proliferate within non-insecticide-treated covers due to the favourable microclimate.

Economic considerations include the additional costs of materials and labour required for cover application. In subtropical regions, these negative effects can be minimized by using perforated covers to ensure adequate aeration and cooling, and insecticide-impregnated covers to effectively manage pest populations.

Types of Banana Bunch Covers

Bunch covering has become an integral cultural practice in commercial banana production worldwide. The type of bunch cover recommended varies with environmental conditions, season, and production objectives. Banana bunch covers are generally made of thin plastic, most commonly low-density polyethylene (LDPE), with thickness ranging from 5 to 40 µm. These covers are usually 81.3-91.4 cm (32-36 inches) wide and 1.0-1.5 m (3.3-5.0 feet) long. Thin covers are typically designed for single use, whereas thicker covers may be reused; however, removal and reuse are often difficult and time-consuming, with a high risk of damage. Commercially available bunch covers are commonly white or translucent blue, and some are silver-coated to reflect solar radiation.

Thickness of Bunch Covers

The thickness of banana bunch covers does not directly influence their protective efficiency but affects cost, durability, and environmental impact. Thickness selection also depends on local climatic conditions, particularly temperature and wind. Generally, covers range from 12 to 25 µm in thickness. Studies have shown that very thick covers (above 130 µm) provide improved protection against cold; however, they may also cause fruit malformation and sunburn due to excessive heat buildup.

Thicker, non-perforated covers are more suitable for cooler subtropical regions where increased internal temperature is beneficial. In contrast, in tropical environments, thick non-perforated covers often result in excessive heat and humidity accumulation, leading to physiological disorders. Therefore, thin perforated covers that allow adequate aeration are preferred under tropical conditions. From an economic perspective, thinner covers are more cost-effective, as damage during use often prevents reuse.

The longevity of polyethylene banana bunch covers in relation to thickness was evaluated by Trochoulis (1975)

[71]. Four thicknesses of blue polyethylene covers (0.038, 0.050, 0.075, and 0.100 mm) were compared under field conditions. Covers with a thickness of 0.075 mm exhibited the longest field life, while the 0.100 mm covers showed a high rate of disintegration, likely due to differences in chemical composition.

Colour of Bunch Covers

Bunch covers of various colours, both perforated and non-perforated, are widely used in tropical and subtropical banana-growing regions to improve yield and fruit quality (Robinson, 1996) [56]. Commercial covers are most commonly white, translucent blue, or silver-coated. The choice of colour may vary with season, climate, and region (Stevenson, 1976) [68].

The colour of the cover influences the quantity and quality of light transmitted to the developing fruit by filtering photosynthetically active radiation (PAR; 400-700 nm). Transparent covers allow the highest light transmission (approximately 93% of PAR), while blue covers transmit about 73%. Despite lower light transmission, blue covers often produce heavier bunches because they allow heat accumulation while blocking harmful ultraviolet (UV) radiation, thereby reducing sunburn risk and preventing peel hardening.

Several studies have evaluated the effect of coloured bunch covers on banana growth and yield. Cuneen and McEntyre (1988) [15] assessed green, blue, black, orange, blue/silver, and clear/silver plastic bags and found that daytime temperatures inside the covers were up to 10 °C higher than ambient temperatures, while nighttime temperatures were slightly lower. The clear/silver bags resulted in the highest daytime temperature increase, whereas black bags showed the lowest. Although yield and quality differences among colours were generally not significant, bunches covered with clear/silver bags produced the highest yields, suggesting their suitability during winter periods. Coloured bunch covers are used to accelerate fruit development (Galan Saucó, 1992) [21], improve fruit quality and yield (Robinson and Nel, 1982) [57], and protect fruits from solar radiation, pest damage, and mechanical injury (Soto, 2010) [67].

Perforations

Perforations play a crucial role in regulating the internal microclimate of bunch covers. The presence of holes prevents excessive humidity buildup and reduces the risk of fungal development. In non-perforated covers, relative humidity may become excessively high, favouring disease incidence. Perforation size and spacing vary, with common configurations including holes of 12.7 mm at 76 mm intervals, 6 mm at 10 cm intervals, 3 mm holes, or micro-perforations, depending on climatic requirements.

Transparent Bunch Covers

Transparent polyethylene bunch covers treated to block ultraviolet and infrared radiation have been developed to improve light and temperature conditions for banana growth (Jannoyer and Chillet, 1998) [37]. These covers can be effectively used under high-density planting systems where sunscald is less likely. However, under normal planting conditions, transparent covers may increase the risk of sunburn. Choudhury *et al.* (1997) [12] reported that blue polyethylene bags were more effective than transparent bags in protecting bunches from sunscald. Similarly, Trever

(2003) observed sun scorch when transparent polyethylene was used as a bunch-covering material.

Blue Polyethylene Bags

Blue polyethylene bags are the most commonly used bunch covers in major banana-producing regions. These covers permit heat penetration while effectively blocking ultraviolet (UV) radiation, thereby reducing the incidence of sun scald on developing fruits (Muchui *et al.*, 2010) [46]. Blue polyethylene bags improve fruit quality and external appearance and provide protection against birds, insect pests, and adverse environmental factors such as wind, rain, and excessive solar radiation.

The use of blue covers facilitates faster and more uniform bunch development, leading to earlier and more reliable harvesting with proper fruit maturity. In addition, these covers minimize mechanical injuries such as scratches and abrasions caused by wind-blown debris and leaf rubbing, thereby enhancing market acceptability (Marks and scratches).

Half Blue and Half Silver Polyethylene Bags

Half blue and half silver polyethylene bags are widely used to regulate bunch temperature under varying climatic conditions. These covers consist of one blue side and one silver reflective side. The silver surface is oriented toward the sun to reflect excess heat, while the blue side faces the pseudostem to allow controlled heat absorption.

During cooler months, positioning the blue side toward the north increases heat retention, whereas during warmer months, orienting the silver side northward helps reduce internal temperature, thereby maintaining a more stable microclimate around the bunch. These bags protect banana fruits from bird damage, wind injury, and sunburn while improving fruit quality and increasing yield.

The covers are manufactured as tubular sleeves that are slipped over the bunch and loosely tied at the top, leaving the bottom open to allow air circulation and prevent overheating. Removal of the male flower bud (bell) approximately 100 mm below the last hand is recommended to enhance fruit size. A commonly used bag dimension is 1200 mm × 730 mm.

All-Season Bunch Covers

All-season bunch covers have been developed and patented to withstand harsh and highly variable climatic conditions, particularly in Australia. These covers provide year-round protection and promote uniform fruit development across all hands of the bunch.

All-season covers are manufactured from a tough blend of polymers and contain approximately 50% higher UV-protective additives compared to conventional covers. The plastic film also incorporates light-diffusing additives that scatter incoming sunlight in multiple directions, thereby reducing localized heating caused by direct solar radiation and ensuring uniform light distribution throughout the bunch.

A unique feature of these covers is that one and a half sides are printed with reflective silver ink, providing continuous protection from overhead sunlight. This design minimizes heat stress while optimizing light availability, resulting in improved fruit quality and productivity throughout the year.

PP Non-Woven Skirting Bags

Polypropylene (PP) spun-bonded non-woven fabric bags are advanced agricultural textile products used as banana bunch covers. These covers are manufactured from UV-stabilized polypropylene fabric with weights ranging from 17 to 80 GSM, depending on application requirements. Among these, white-colored 17 GSM UV-stabilized fabric has been found particularly suitable for banana bunch covering.

The non-woven fabric exhibits high vapour permeability, allowing adequate air and moisture exchange while effectively restricting the entry of dust, insects, and pathogens. The fabric may also be pigmented, as light transmittance significantly influences fruit development and ripening. These covers are designed to regulate in situ fruit ripening prior to harvest and can be used economically, with options for reuse or disposal.

PP non-woven covers are available in roll form as tubular sleeves, typically with widths of 1.6 m or 3.2 m. They are manually installed over the bunch and secured at the top using thread. Due to their lightweight nature, careful handling is required during application. When properly maintained, these covers can be reused in subsequent seasons.

Advantages of PP Non-Woven Bags

PP non-woven bags allow free circulation of air and moisture, unlike conventional polyethylene covers, thereby reducing the risk of heat and humidity buildup. They provide effective protection against insect pests and disease-causing pathogens. Reduced exposure to direct sunlight results in uniformly developed fruits that ripen to an attractive golden-yellow colour, enhancing market appeal.

Fruits covered with PP non-woven bags are generally uniform in size and exhibit a desirable round shape preferred by consumers. Adoption of these bags can generate an additional income of approximately ₹0.75-1.00 per kg of bunch, resulting in a minimum net increase of about ₹20,000 per acre. Furthermore, expenditure on pesticides and labour associated with bunch spraying can be significantly reduced.

Biodegradable Bunch Covers

Biodegradable banana bunch covers have been developed and evaluated in several countries as an environmentally friendly alternative to conventional plastic covers. These include covers made from polylactic acid (PLA) and other fully biodegradable materials that can be safely buried in the soil after use, thereby reducing plastic waste and environmental pollution.

Timing of Application

Bunch covers should be applied as soon as possible after the emergence of the inflorescence (bell). In areas where damage from birds or flying foxes is minimal, covers may be applied after the bracts enclosing the hands have fallen and the flower ends have hardened. Ideally, bunch covers are applied when the fingers begin to curve upward and floral remnants have hardened, which generally occurs about 2-3 weeks after flowering.

The period from bunch covering to harvest is usually slightly more than two months. Bunch covering has been reported to reduce the duration from bunch emergence to harvest by 5-11 days compared with uncovered bunches, with very early and early covering producing the greatest

reductions (Daniells, 1992) ^[17].

Effect of Bunch Covers

Physiological, Physical and Biochemical Effects

Bunch covering significantly influences the physiological, physical and biochemical characteristics of banana fruits. Several studies have reported increases in yield, fruit size and improvement in overall fruit quality due to bunch covering. Covered bunches generally produce fruits that are larger, cleaner, more attractive and dark green in colour. Fruits from covered bunches show minimal scratches or blemishes, whereas uncovered fruits often suffer physical injuries (Weerasinghe and Ruwanpathirana, 2002) ^[80].

Choudhury *et al.* (1996b) ^[9, 10, 11] reported that white polyethylene covers significantly reduced crop duration, including days from planting to flowering and from flowering to physiological maturity. Plants treated with white polyethylene covers matured earlier (430 days) compared with untreated plants (467.67 days). The same treatment reduced the flowering-to-maturity period (106.33 days) compared to the control (142 days) and proved economical in controlling damage caused by banana scarring beetle (*Basilepta subcostata*), thereby reducing insecticide use and increasing profitability.

Crop duration, particularly the period from flowering to physiological maturity and production per day, is influenced by different bunch cover treatments (Vargas *et al.*, 2010) ^[76]. Studies by Johns (2005) consistently reported increased finger length, higher yields and shorter flower-to-harvest intervals in covered bunches. Temperatures under covers were reported to be 2-6 °C higher, especially during cooler periods, which enhanced fruit length and accelerated fruit filling, resulting in harvest 4-14 days earlier.

Johns and Scott (1989) ^[40] and Stover and Simmonds (1987) ^[69] documented that polyethylene bagging enhanced fruit maturity in bananas. Rodrigues *et al.* (2001) ^[59] observed that harvest occurred 12 days earlier in the first crop of bananas with covered bunches. Transparent covers were particularly effective during winter, speeding up bunch filling and harvesting, while in summer their effect was similar to the control (Johns, 1996) ^[39].

Jannoyer and Chillet (1998) ^[37] reported that bunch bagging reduced radiation exposure, minimized sunscald, lowered in-bag temperatures, shortened the flowering-to-harvest period, improved fruit growth and significantly increased yield. Transparent polyethylene covers reduced the shooting-to-harvest interval by approximately 15 days. However, sealed covers were found to delay harvest by up to 16 days compared with uncovered bunches (Daniells *et al.*, 1992) ^[17].

Yield and Yield Attributes

Yield components such as bunch weight, bunch length, number of fingers per bunch, finger length and finger weight were significantly influenced by bunch covering. Choudhury *et al.* (1996a) ^[9, 10, 11] reported the highest bunch weight (15.25 kg), yield (67.78 t ha⁻¹) and cost-benefit ratio (1:3.53) under white polyethylene covers, whereas uncovered bunches recorded the lowest cost-benefit ratio (1:2.8).

Weerasinghe and Ruwanpathirana (2002) ^[80] reported that bunch covering, irrespective of material, resulted in bunches that were 32% heavier than uncovered ones. In contrast, Rodrigues *et al.* (2001) ^[59] found no significant effect of

polyethylene covers on bunch or total fruit weight. Transparent and blue polyethylene covers enhanced fruit yield by 20% and 16%, respectively, over the control (Weerasinghe and Ruwanpathirana, 2002) ^[80]. The higher harvest index under transparent covers indicated improved nutrient partitioning towards the developing bunch. Sealed covers increased bunch weight by up to 9%, primarily due to increased finger length throughout the bunch (Daniells *et al.*, 1992) ^[17]. Reddy (1989) ^[53] reported that in banana cv. Robusta grown under high-density planting, polyethylene covers significantly increased finger diameter and weight. In South Africa, Robinson (1996) ^[56] recorded a 16.5% increase in bunch mass of 'Williams' banana due to increased finger length, attributed to higher temperatures ($\approx 0.5^\circ\text{C}$) under blue covers. Choudhury *et al.* (1996b) ^[9, 10, 11] observed fewer fingers per bunch under white polyethylene compared with blue covers. Bagging with transparent and blue polyethylene consistently increased finger size and weight (Weerasinghe and Ruwanpathirana, 2002) ^[80]. Sealed polyethylene covers also increased fruit size at harvest (Amarante *et al.*, 2002) ^[2]. However, inconsistent effects on fruit size have been reported in tropical environments, indicating strong interactions with cultivar, climate and bag design.

Biochemical and Postharvest Effects

Bunch covering generally does not significantly influence starch accumulation or total soluble solids (TSS) at harvest or during ripening. Unripe bananas contain 20-25% starch in the pulp (Nascimento *et al.*, 2006) ^[49], which is rapidly converted into sugars during the climacteric phase (Seymour *et al.*, 1993) ^[62]. Bagging does not interfere with starch synthesis during growth or its degradation during ripening. Perforated bunch covers maintain humidity conditions similar to uncovered fruits during growth and postharvest handling (Amarante *et al.*, 2002) ^[2]. During ripening, peel moisture content decreases while pulp moisture increases, as water moves from peel to pulp and atmosphere (Burdon *et al.*, 1994) ^[7]. Similar cuticle structures in bagged and unbagged fruits may explain the comparable moisture dynamics (Amarante *et al.*, 2002) ^[2]. Bunch covering influenced pulp-to-peel ratios in cv. Williams during harvest and ripening. In bananas, the pulp continues to grow even at later stages of maturity (Nakasone and Paull, 1998) ^[47]. Skin colour development and other postharvest attributes are affected by bag type, perforation, timing of application, cultivar, climatic conditions and postharvest handling practices (Amarante *et al.*, 2002) ^[2]. Chlorophyll degradation during ripening leads to yellow colour development due to carotenoid expression (Gray *et al.*, 2004) ^[27]. Bagging does not significantly affect chlorophyll degradation (Shanmugasundaram and Manavalan, 2002) ^[63]. However, bagging reduced anthocyanin accumulation and red colour development in some fruits (Fan and Mattheis, 1998) ^[20], with effects

varying by cultivar, bag material and duration of bagging. Fruit firmness decreases during ripening, and bagging generally does not alter peel or pulp structure. However, early studies indicated a slight reduction in firmness during postharvest ripening in bagged bananas (Berrill, 1956) ^[6]. Variations in reported effects on firmness may be attributed to cultivar differences, bag type, covering duration and storage conditions.

Shelf Life and Ripening

Bunch bagging affects both physical and compositional quality of fruits. Narayana *et al.* (2004) ^[48] reported that bunch covering combined with postharvest hot water treatment and ethylene absorbents extended banana shelf life. In contrast, Johns and Scott (1989) ^[40] observed delayed ripening in bananas grown under sealed covers, possibly due to altered atmospheric conditions inside the bag. Sealed polyethylene covers delayed bunch maturity and ripening (Scott *et al.*, 1971; Johns and Scott, 1989) ^[61, 40], whereas perforated covers showed minimal effects on green life. Daniells *et al.* (1992) ^[17] reported a non-significant reduction of 2-4 days in green life due to delayed bunch filling under sealed covers. Polypropylene spun-bond non-woven covers resulted in the longest green life, while unbagged fruits had the shortest. Stevenson (1976) ^[68] reported that during summer, bunch covering had little effect on bunch filling regardless of cover colour, whereas in winter transparent covers significantly accelerated filling and harvesting. This highlights the need for seasonal evaluation of bunch cover materials, particularly for warm-season production, with emphasis on peel quality.

Study conducted by PFDC Kharagpur

The trial was carried out to know the effect of bunch covers on banana production at the existed banana orchard of Precision Farming Development Centre, Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, West Bengal, India during 2013-14 and 2014-15. Twenty four bunches of banana cultivar (cv.) Grand naine were randomly selected and tagged. Polypropylene spun bond non woven fabric bunch cover was applied to twelve banana bunches when the flower bracts had hardened and the hands had started to curl upwards. Remaining twelve of the tagged bunches were not covered and they served as control. Yield and yield components were recorded. The second hand of freshly harvested bunch was used to measure the fruit characteristics such as number of hands/bunch, number of fingers per hand, finger length, finger weight and finger girth. Statistical analyses were performed to significance of the treatment. In order to test the significance of different treatments individually as well as in combinations experimental Student F test was performed.

Table 1: Specifications as recommended by Bureau of Indian Standards (BIS) for non-woven polypropylene spun bounded banana cover fabric

Characteristics	Unit	Dimension
Basic Weight (minimum) Thickness	GSM, mm	17, 0.18 ± 0.02
Length (minimum)	m	300
Width (minimum) Tensile Strength-a. Machine direction b. Cross direction	M N/5 CM	1.6 & 3.2 35 25
Trapezoid tear strength -a. Machine direction b. Cross direction	N	25 25
Elongation-MD/CD Air Permeability	% M 3/M2/Min	55 to 100 350-375
UV Stability, retained after 144 h exposure	Strength > 60% of Original Sample after expose to 200 hrs in UVB	
Index puncture resistance Water absorption capacity	N %	15 20
Color-		White/as per requirement
Sleeve Sizes-	-	0.8M dia.X1.5M 0.8M dia.X1.0M or in roll form

Bureau of Indian Standards, 2015

Table 2: Banana yield parameters and quality parameters as influenced by bunch cover

Parameters	Mean		Standard Deviation	Coefficient of Variation
	Bunch Cover	Without cover		
Fingers/bunch	159.93	132.09	14.2	3.4
Fingers/hand	16.2	14.18	10.32	4.2
Hands/bunch	9.0	9.88	NS	4.1
Fruit length	19.6	16.5	1.2	1.6
Fruit diameter	4.0	3.5	0.3	4.3
Fruit weight	118.1	141.6	10.6	4.1
Fruit volume	123.7	144.5	12.1	4.8
Hand weight	3.19	2.43	0.46	3.6
Pulp weight	103.1	193.7	8.2	4.4
Peel weight	39.9	36.4	NS	4.5
Pulp to peel %	2.6	2.7	NS	0.7
PLW	16.7	15.03	0.77	1.8
Bunch length	83.67	81.12	1.63	1.2
Bunch diameter	33.74	31.43	0.73	1.2
Bunch weight	23.18	17.28	1.80	4.2
TSS	21.4	20.5	0.3	0.7
Sugar %	16.6	15.4	0.2	1.0
Total Sugar	17.4	16.1	0.5	1.7
Reducing Sugar	10.4	9.8	0.5	3.1
Non Reducing Sugar	6.9	6.3	0.6	4.3
Acidity	0.33	0.41	0.02	0.2
Sugar Acid %	53.2	39.71	2.43	2.8
Ascorbic Acid	6.12	5.80	0.15	1.8
Chlorophyll	2.64	2.66	0.06	1.4
Green life	8.56	8.27	0.57	2.0
Yellow life	4.53	4.35	0.31	0.3
Shelf life	13.09	12.61	0.66	0.7
Productivity	64.42	43.2	4.37	4.10
Cost of cultivation	1.99	1.19		
B:C %	1.26	1.41		

Table 2 shows that bunch covering had a positive influence on most yield, quality, post-harvest, and economic parameters of banana compared to uncovered bunches. Bunch-covered plants recorded higher fingers per bunch and per hand, greater fruit size, weight, volume, hand and bunch weight, resulting in increased productivity. Quality attributes such as TSS, sugars, sugar-acid ratio, and ascorbic acid were slightly higher, while acidity was lower in covered fruits. Bunch covering also extended green life,

yellow life, and overall shelf life of fruits. Although the cost of cultivation was marginally higher, the benefit-cost ratio remained favourable, indicating that pre-harvest bunch covering is an effective practice for improving yield, fruit quality, and economic returns in banana.

In conclusion, the post-harvest shelf life and market quality of bananas are strongly influenced by pre-harvest production practices, among which bunch covering plays a pivotal role. Covering the developing banana bunch shortly after flowering with perforated bunch covers has been proven to be an effective and economical technique for minimizing physical damage, insect injury, and sunscald on the fruit surface. By creating a favorable microclimate around the developing bunch, covers help in moderating temperature fluctuations, reducing mechanical abrasion caused by wind and leaf rubbing, and preventing direct exposure to pests and environmental stresses.

The use of bunch covers significantly alters both the physical and biochemical properties of banana fruits. Covered fruits generally exhibit improved peel colour, uniform size, higher bunch weight, better pulp-to-peel ratio, and delayed physiological maturity, resulting in an extended green life. These improvements contribute to enhanced shelf life and better eating quality. In addition, fruits grown under covers remain cleaner and free from dust, latex stains, and blemishes, thereby reducing the need for extensive washing and cleaning during post-harvest handling, which in turn conserves water and lowers post-harvest costs.

From a marketing perspective, the superior visual appeal of covered fruits—characterized by smooth, bright peels and minimal bruising—greatly enhances consumer acceptance. Such high-quality fruits are particularly suitable for premium domestic markets and export chains, where aesthetic attributes are critical and consumers are willing to pay higher prices for uniform, blemish-free produce. However, the advantages gained through pre-harvest bunch covering can only be fully realized when complemented with proper post-harvest handling practices. Careless harvesting, handling, transportation, or storage can negate the benefits by causing mechanical injuries and bruising. Overall, pre-harvest bagging of banana bunches is a simple, environmentally friendly, and cost-effective practice that reduces physical injury and sunscald, improves yield, enhances fruit quality, prolongs green life, and increases market value. When integrated with good agricultural and post-harvest management practices, bunch covering serves

as an important strategy for improving profitability and competitiveness of banana production, especially in regions targeting high-end and export markets.

References

1. Amani M, Avagyan G. Effect of polyethylene bunch cover on fungal diseases control of banana (*Musa acuminata* L.) in Iran. *Int J Farming Allied Sci*. 2014;3(10):1054-1057.
2. Amarante C, Banks NH, Max S. Effect of preharvest bagging on fruit quality and postharvest physiology of pear (*Pyrus communis*). *N Z J Crop Hortic Sci*. 2002;30:99-107.
3. Anonymous. USDA National Nutrient Database for Standard Reference, Release 17. Washington (DC): US Department of Agriculture, Agricultural Research Service; 2004.
4. Athani SI, Hulamani NC. Variation in bunch growth parameters at various stages and yield in banana cv. Rajapuri (*Musa* AAB) as influenced by pre-harvest treatments. *Karnataka J Agric Sci*. 2001;14:126-130.
5. Anon. Bunch covers for improving plantain and banana peel quality. *Natl Agric Res Inst Tech Bull*. 2003;4.
6. Berrill FW. Bunch covers for bananas. *Qld Agric J*. 1956;82:435-439.
7. Burdon JN, Dori S, Lomaniec E, Marinansky R, Pesis E. The post-harvest ripening of water-stressed banana fruits. *J Hortic Sci*. 1994;69(5):799-804.
8. Chillet M, Jannoyer M. Choice of bagging for the optimization of banana growth condition. *Infomusa*. 1996;5:25-27.
9. Choudhury H, Chandra K, Baruah K. Effect of bunch cover on morphological parameters and yield of banana. *Adv Plant Sci*. 1996;9:131-137.
10. Choudhury H, Chandra K, Baruah K. Influence of bunch cover treatments on infestation of fruit scarring beetle and crop duration in Dwarf Cavendish banana. *Crop Res (Hisar)*. 1996;12:50-55.
11. Choudhury H, Chandra K, Baruah K. Influence of bunch cover treatments on infestation of fruit scarring beetle and crop duration in Dwarf Cavendish banana. *Crop Res*. 1996;12:50-55.
12. Choudhury H, Chandra K, Baruah K. Effect of different bunch covers on some biochemical composition of Jahaji (AAA group) banana. *Crop Res*. 1997;13(1):91-97.
13. Costa JNM, Scarpore FJA. Protection of banana bunches 'Grand Naine' with polyethylene sacks in different periods after inflorescence. *Rev Bras Frutic*. 1999;21:131-134.
14. Cubillo D, Guzman M. Comparison of polyethylene and polypropylene bags in the development and protection of banana bunches (*Musa* AAA). *CORBANA*. 2004;30:1-10.
15. Cuneen T, McEntyre C. Does the colour of banana bags have an effect on the yield of bananas and the climate inside the bag? *Banana Bull*. 1988;52:14-15.
16. Daniells JW, Lindsay S. Banana fruit bunch covering. Queensland: Department of Primary Industries; 2005.
17. Daniells JW, Lisle AT, O'Farrell PJ. Effect of bunch-covering methods on maturity bronzing, yield and fruit quality of bananas in North Queensland. *Aust J Exp Agric*. 1992;32(1):121-125.
18. Debnath U, Suresh CP, Hasan MA. Bunch management for profitable production of winter-developing banana bunches. *Indian J Hortic*. 2001;58(3):202-207.
19. El-Kashif ME, Elamin OM, Ali SA. Effect of packaging methods and storage temperature on quality and storability of four introduced banana clones. *Gezira J Agric Sci*. 2005;3(2):185-195.
20. Fan X, Mattheis JP. Bagging 'Fuji' apples during fruit development affects colour development and storage quality. *HortScience*. 1998;33:1235-1238.
21. Galán Sauco V. El plátano. Madrid: Mundi-Prensa; 1992. p. 1-173.
22. Galán SVJ, Cabrera J, Gomez PM. Evaluation of different bunch covers (*Musa acuminata*) in the Canary Islands. *Fruits*. 1996;51:13-24.
23. Ganry J. Influence du gainage des régimes du bananier avec une housse de polyéthylène sur la température des fruits. *Fruits*. 1975;30(2):735-738.
24. Ganry J. Effect of covering banana bunches with a polyethylene sleeve on fruit temperature. *Fruits*. 1975;30:735-738.
25. Ganry J, Meyer JP. Recherche d'une loi d'action de la température sur la croissance des fruits du bananier. *Fruits*. 1975;30:375-392.
26. Gowen SR. Pests. In: Gowen S, editor. Bananas and plantains. New York: Chapman & Hall; 1995. p. 382-402.
27. Gray J, Wardzala E, Yang M, Reinbothe S, Haller S, Paul F. A small family of LLSI-related non-heme oxygenases in plants. *Plant Mol Biol*. 2004;54:39-54.
28. Hailu M, Workneh TS, Belew D. Effect of packaging materials on the quality of banana cultivars. *Afr J Agric Res*. 2012;7:1226-1237.
29. Hailu M, Workneh TS, Belew D. Review on postharvest technology of banana fruit. *Afr J Biotechnol*. 2013;12:635-647.
30. Harshash MM, Al-Obeed RS. Effect of bunch bagging colour on yield and fruit quality of date palm. *Am-Eurasian J Agric Environ Sci*. 2010;7:312-319.
31. Hasan MA, Bhattacharjee S, Debnath U. Studies on chlorophyll content of fruit peel during growth and development of banana under different bunch covers. *Orissa J Hortic*. 2000;28:36-40.
32. Hasan MA, Bhattacharjee S, Debnath U. Fruit quality and microclimate variation inside the bunch cover of Dwarf Cavendish banana. *Orissa J Hortic*. 2001;29:46-50.
33. Heenan DP. Bunch covers for bananas in Papua New Guinea. *Agric J*. 1973;24:156-161.
34. Hewett EW. An overview of preharvest factors influencing postharvest quality of horticultural products. *Int J Postharvest Technol Innov*. 2006;1:4-15.
35. Irizarry H, Rivera E, Rodriguez JA. Bunch and ratoon management for profitable production of high-quality bananas. *J Agric Univ P R*. 1992;76:119-130.
36. Israeli Y, Gazit S, Blumenfeld A. Influence of relative humidity on flower type in Cavendish banana. *Fruits*. 1980;35:295-299.
37. Jannoyer M, Chillet M. Improvement of banana growing conditions with the Kattrix® bag. *Acta Hortic*. 1998;490:127-134.
38. Jia H, Araki Y, Okamoto G. Influence of fruit bagging on aroma volatiles and skin coloration of 'Hakuho' peach. *Postharvest Biol Technol*. 2005;35:61-68.

39. Johns GG. Effect of bunch trimming and double bunch covering on yield of bananas. *Aust J Exp Agric*. 1996;36:229-235.
40. Johns GG, Scott KJ. Delayed harvesting of bananas with sealed covers. *Aust J Exp Agric*. 1989;29:719-726.
41. Jones DR. Diseases of banana, abaca and enset. Wallingford: CAB International; 2000. p. 1-544.
42. Krishnamurthy S, Kushalappa GA. Studies on shelf life and quality of Robusta bananas as affected by postharvest treatments. *J Hortic Sci*. 1985;60:81-88.
43. Kumar AR, Kumar N, Jeyakumar P. Effect of post-shooting spray of SOP on yield and quality of banana cv. Robusta. *Res J Agric Biol Sci*. 2011;4:655-659.
44. Mohamed AA, Al-Qurashi AD. Gibberellic acid spray and bunch bagging increase bunch weight and fruit quality of date palm. *Sci Hortic*. 2012;138:96-100.
45. Moreira A. Protection of banana bunches with polyethylene sacks in Amazonas State, Brazil. *Cienc Agrotec*. 2008;32:129-136.
46. Muchui MN, Mathooko FM, Njoroge CK. Effect of perforated blue polyethylene covers on postharvest quality of bananas. *J Stored Prod Postharv Res*. 2010;1:41-45.
47. Nakasone HY, Paull RE. Tropical fruits. New York: CAB International; 1998.
48. Narayana CK, Krishnan P, Sathiamoorthy S. Effect of bunch covering on banana quality during low temperature storage. In: *Proc Int Congr Musa*; 2004. p. 1-6.
49. Nascimento JRO, Junior AV, Bassinello PZ, Cordenunsi BR, Mainardi JA, Purgatto E, *et al*. Postharvest changes in banana. *Postharvest Biol Technol*. 2006;40(1):41-47.
50. Nasir N, Jumjunidang S, Harlion. Effect of bunch covers on banana fruit performance. *Penelitian Hortikultura*. 1991;4:42-53.
51. Pathak PK, Mitra SK. Assessment of low-cost polyethylene cover for scarring beetle control. *Acta Hortic*. 2014;1024:283-285.
52. Perumal A, Adam AV. Bagging of 'Giant Cavendish' banana stem in Honduras. *Trop Agric*. 1968;45:109-112.
53. Reddy SA. Effect of bunch covers on bunch maturity and fruit size in banana. *J Res APAU*. 1989;17:81-82.
54. Robinson JC. Types of planting material and preparation. In: *Handbook of growing bananas in South Africa*. Pretoria: Institute for Tropical and Subtropical Crops; 1993. p. 32-34.
55. Robinson JC. Systems of cultivation and management. In: Gowen S, editor. *Bananas and plantains*. London: Chapman & Hall; 1995. p. 15-65.
56. Robinson JC. Bananas and plantains. Wallingford: CAB International; 1996.
57. Robinson JC, Nel D. Use of banana bunch covers during summer. *Inf Bull Citrus Subtrop Fruit Res Inst*. 1982;118:8-9.
58. Robinson JC, Nel DJ. Banana bunch covers effective in winter. *Inf Bull Citrus Subtrop Fruit Res Inst*. 1984;138:5-6.
59. Rodrigues MGV, Souto RF, Meneguacci JLP. Influence of polyethylene bunch cover in irrigated banana. *Rev Bras Frutic*. 2001;23:559-562.
60. Rouse AH, Aulin H. Ascorbic acid content in relation to ripeness. *Ann Agric Fenn*. 1977;16:80-88.
61. Scott KJ, Wills RBH, Rippon LE. Sealed polyethylene covers retard banana ripening. *Trop Agric*. 1971;48:163-165.
62. Seymour GB, Taylor JE, Tucker GA, editors. *Biochemistry of fruit ripening*. London: Chapman & Hall; 1993. p. 83-106.
63. Shanmugasundaran KA, Manavalan RSA. Postharvest characteristics of Rasthali bananas. *Infomusa*. 2002;11(2):43-45.
64. Shih Chao C, Din Fon K, Chun Mei C, Mei Jen C. Comparison of kraft paper and polyethylene covers. *J Chin Soc Hortic Sci*. 2004;50:245-252.
65. Silva Filho LP, Moreira A. Bag enclosure effects on banana yield and quality. *Acta Amazon*. 2005;35:407-412.
66. Snowden AL. A colour atlas of postharvest diseases and disorders of fruits and vegetables. Vol 1. London: Manson Publishing; 2010.
67. Soto M. *Banano: Tecnologías de producción*. Tomo II. Costa Rica; 2010.
68. Stevenson D. What colour to select for banana bunch covers. *Banana Bull*. 1976;40:2-4.
69. Stover RH, Simmonds NW. *Bananas*. 3rd ed. Essex: Longman; 1987.
70. Trevor RN. Bunch covers for bananas. *Agri Facts*. 2003;6:1-2.
71. Trochoulis T. Longevity of polyethylene covers for bananas. *Banana Bull*. 1975;52:281-283.
72. Turner DW. Bunch covers for bananas. *Agfact H6.3.4*. 1984. p. 1-78.
73. Turner DW. Nutrient supply and water use of bananas. *Fruits*. 1987;42:89-93.
74. Turner DW. Postharvest physiology and storage of tropical fruits. In: Mitra SK, editor. *New York: CAB International*; 1997. p. 47-77.
75. Turner DW. Crop physiology and cultural practices in banana. *Acta Hortic*. 2013;986:41-50.
76. Vargas A, Valle H, González M. Effect of polyethylene density and colour on banana quality. *Agron Costarric*. 2010;34:269-285.
77. Vargas-Calvo A, Valle-Ruiz H. Effect of two banana bunch covers on fruit quality. *Agron Mesoam*. 2011;22(1):81-89.
78. Vilela RMG, Ferreira SR, Joao MLP. Influence of polyethylene covers on irrigated banana. *Rev Bras Frutic*. 2001;23:559-562.
79. Weerasinghe P, Premalal NHR. Influence of potassium fertilization on Embul banana. *Ann Sri Lanka Dep Agric*. 2002;4:109-117.
80. Weerasinghe SS, Ruwaphirana KH. Influence of bagging material on bunch development. *Ann Sri Lanka Dep Agric*. 2002;4:47-53.
81. Zhu SJ, Ma LY, Liu SO. Effects of bagging treatments on banana quality and storability. *Trans Chin Soc Agric Eng*. 2009;25:304-307.