THE EVALUATION OF DIFFERENT BANANA BUNCH PROTECTION MATERIALS ON SELECTED BANANA CULTIVARS FOR OPTIMUM FRUIT PRODUCTION AND QUALITY IN NAMPULA PROVINCE, MOZAMBIQUE

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DECLARATION

This dissertation is my original work and has not been presented for a degree in any other university. **The results of this study are accepted for publication in Journal of Tropical Agriculture: Trinidad and Tobago**

Signature…………………………………… Date……………………………

Rodrick Kutinyu

This dissertation has been submitted for examination with my approval from my supervisor and it will be subjected to turn–it-in for detection of plagiarism if the need arises.

Supervisor

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DEDICATION

This study is dedicated to my wife Spiwe Naomi Kutinyu (Manjiche), my children Kirsty T. Kutinyu and Ariel R.N. Kutinyu. I also dedicate this study to all employees from the Technical services department of Matanuska Mozambique Lda.

Thanks for being there for me when I needed you most. God bless you always and help you to achieve your dreams.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
AEZ	Agricultural Eco Zones
BSR	Box stems ratio
CRBD	Complete Randomised Block Design
EU	European Union
GLM	General Linear Model
PAR	Photo Synthetic Active Radiation
UAE	United Arab Emirates
UPD	Under peel discolouration
UV	Ultra Violet
IR	Infrared Radiation
RH	Relative Humidity

The evaluation of different banana bunch protection materials on selected banana cultivars for optimum fruit production and quality in Nampula Province, Mozambique

ABSTRACT

Mozambique has potential to boost its banana exports. To fully realise this, agronomic practices in production should be fully developed to combat physiological disorders associated with banana within the region. Currently, lower temperatures are being experienced in some production sites, consequently affecting yield and quality. The objective of this study was to evaluate use of bunch protection covers on banana cultivars Grand Nain and Williams banana cultivars, for performance under different fruit protection materials to determine best fruit protection bag suitable for Metocheria, Nampula. Plants were not selected near plantation borders, drainage canals, cable way and roads, as this would influence the growth pattern of plants and fruit development.

Treatments consisted of control (no bag on bunches), white perforated polyethylene, white non-perforated polyethylene, blue perforated polyethylene, blue non perforated polyethylene, green perforated polyethylene, green polyethylene non perforated and cheese cloth bags arranged in a complete randomised block designed CRBD with 26 plants replicated eight times.

During 2012/2013, bagging treatments did not considerably improve weight in hands, banana finger weight, total fruit weight, marketable weight and percentage marketable fruit weight and box stem ratio (BSR) of Grand Nain. However there was reduction of fruit defects in all bagging treatments compared to control (no bags). In Williams during the 2013 season bagging treatments improved weight but no significant differences were observed on weight of hands in 2012. Bagging of banana bunches reduce defects in both seasons. Both green and blue perforated bags improved box stem ratio. Bagging treatments increased Williams's cultivar yield (per ton) in both seasons.

Keywords: *banana bunch cover, early bagging, de-handing.*

CHAPTER 1
1.0 INTRODUCTION

Banana (*Musa* sp.) is the most consumed fruit in the world. In Mozambique as in other banana producing countries bananas constitute a part of the staple diet in most families. Bananas are also an important part of the smallholder farming communities and families living in rural areas. Edible bananas (*Musa* sp.) are believed to have originated from Asia and were distributed throughout the world during early migration of Polynesians (Simmonds, 1962, Lorenzen , 2010). Bananas are said to have been brought into East Africa by the Portuguese expeditions during the fifteenth century (Purseglove, 1975). The most important banana cultivars are the AAA-triploid cultivars originating from *Musa acuminate* and are mainly consumed as desserts according to Lahav and Israeli, 1986. Most of the banana production in the rural areas in Mozambique is done in small sized farms, around the household plots, in low lying areas or close to annual water streams. Mozambique climate is suitable for banana production; bananas have become an important part of the food security strategies of most rural families. Banana cultivation in Mozambique still has a few challenges to overcome such as low level of technical know-how, and poor fruit quality which does not meet the export market standards. However, the availability of good technology and knowledge can bring about the best marketable export crop from Mozambique.

Bananas can be cultivated under tropical and subtropical climates (Marriot, 1980, Panis and Thinh, 2001). The climate in the Northern parts of Mozambique has been the reason for establishing the Metocheria Farm. This climate is coupled with good soil conditions is ideal for the cultivation of high quality bananas. Good cropping practises and post-harvest management help in producing the superior banana quality required. The other competitive edge of the banana industry in Mozambique is proximity to the port, good government land legislation, infrastructure and good foreign exchange controls for investors. However, the climate changes, lack of data and experience with some growing conditions has brought challenges that need to be overcome in the production of quality bananas for the export markets. The lower than average expected winter temperatures, very high wind speeds and knowledge or skilled worker experience are still the main obstacle to meet export quality standards. Low temperatures can affect bunches over a long period, if the normal harvest is 14 weeks, the stems developed during the winter season can be formed poorly and this can result in delays ranging from 5 to 6 weeks.

Major banana growing areas of the world are geographically situated in the tropics between the Equator and latitudes 20° north and 20° south (Stover and Simmonds 1987; Robinson, 1993). Production of bananas in the subtropical regions is situated between 20° north and 30° south (Stover and Simmonds, 1987). The value of banana exports from Mozambique is higher than those of most fruits such as oranges, apples and vegetables (Frison and Sharrock, 1999). Bananas are consumed for their nutritive and therapeutic values (Stover and Simmonds, 1987). The cooking and dessert bananas are a rich source of energy of approximately 128kcal and 116kcal per 100g (Gowen, 1995). They provide carbohydrates and are low in cholesterol, salt free and therefore are suitable for overweight and geriatric patients (Stover and Simmonds, 1987).

According to Muchui (2010) chilling of banana fruit is a function of time and temperature and damage resulting from chilling can affect exportation of fruit to the European market. The physical appearance of the peel is important in the highly competitive export markets. Buyers in these prime markets require consistent supplies of uniform coloured fruit with blemish-free peels. Banana bunch covers allow for production of high quality bananas that are not bruised and hence of acceptable visual appearance. Consumers use visual quality to purchase fresh produce in the retail markets (Shewfelt, 1999, Shewfelt 2009). The returns to farmers are also higher based on the marketing of generally larger fruit which is blemish free.

According to studies conducted by Irizarry in 1992, low temperature also reduces the growth thus extending the period between the flowering and the harvest of the fruit. For centuries, old banana leaves have been wrapped around maturing bunches in New Guinea. It was not until 1936 that they demonstrated that covering bunches with hessian material protected them against winter chilling and improved fruit quality (Turner, 1984). Temperatures coupled with wind blows and debris affect the delicate outer skin causing cellular damage and subsequent fruit scarring. Considerable physical injury and damage to the fruit peels can also be caused by the blowing of adjacent leaves and rubbing leaf petioles onto the developing bunch (Anon, 2003). This leaf chaffing during growth has also been prevented by bunch covers (Weerasinghe and Ruwapathirana, 2002).

Banana fruit protection bags are used throughout the commercial banana growing areas of the world. These bags are mainly used to improve fruit production and quality, especially fruit intended for the export markets. Fruit protection bags of various colours, perforated and non-perforated, have been extensively used in both tropical and subtropical banana growing countries to improve yield and quality (Stover and Simmonds, 1987). Some of these quality parameters include acceptable skin appearance and colour, increase in finger length and bunch weight as well as reduced fruit defects for example sunburn and fruit splitting (Amarante *et al.,* 2002). Various materials have also been used to protect bunches from low temperatures (Gowen, 1995; Robinson, 1996; Harhash and Al-Obeed, 2010) and has shown to reduce winter stress under supra-optimal condition (Harhash and Al-Obeed, 2010), which resulted in early fruit maturation (Robinson 1984; Daniels 1987 and 1992; Irizarry 1992 and Sauco 1996).

Historical climatic data originally collected from a weather station close to Metocheria farm showed average winter temperatures of 15-16˚C. However, recent data collected from the weather stations on the same site, showed a continued decrease in average to 11.8 ºC temperatures for the years 2010 to 2012. Temperatures below 12 to 13 ºC can cause under peel discolouration (UPD) which indicates that the fruit was subjected to chilling temperatures during the development stages. Under peel discolouration consists of a reddish-brown streaking in the vascular tissue just below the epidermis of the fruit. It is visible in green fruit only by peeling back the epidermis with a knife (Robinson *et al.,* 2010). Once this discoloration occurs, it is irreversible, thus subsequent damage is cumulative in a plantation with bunches of different ages. Fruit with severe UPD does not ripen to a bright yellow colour and therefore become unacceptable to export markets.

Decrease in temperatures reduces fruit growth which will extend the period from flowering to harvest of the fruit. For example, if the normal flower to harvest period is 12 or 13 weeks during summer months, this period can be extended by 4 to 6 weeks which influences markets estimates. In several countries Kraft paper bags were used to reduce the effect of cold temperatures, for example in La Lima, Honduras Kraft paper was used to reduce the chilling incidence and in Colima, Mexico producers periodically use paper bags over polyethylene bags to reduce this problem.

Besides protection against temperature variations, fruit protection bags are also used to protect bunches against wind (leaf scarring) damage, insect damage, and sunburn as well as increase fruit uniformity.

The aim of this study was to develop banana management strategies and hence different colour polyethylene bags, perforated and non-perforated together with cheese cloth bag combinations were evaluated to determine the most effective bag to be used during the cool winter months at Metocheria Farm, Mozambique. The current study will provide basic agronomic practices suitable for competitive banana industry in Mozambique.

1.2 PROBLEM STATEMENT

There has been a shift in banana industry from South Africa to Mozambique due to land claims and other political uncertainties related to land in South Africa. Recently, Industrial Development Cooperation (IDC) has shown interest in the banana industry in Mozambique over the past years. The initial projects set up or feasibility studies were based on historical climatic data which showed generally high winter temperatures averaging 15-16˚C. However, recent data collected from the farm weather stations showed a decrease in temperatures during the past 3 years with minimum winter temperatures dropping to 11.8˚C. The effect of lower than average winter temperatures may result in under peel discolouration of fruit due to chilling injury and the bananas become unacceptable for the export markets. These markets require consistent supply of uniform, good quality fruit with an acceptable physical appearance. The ability to supply these markets with such fruit becomes more difficult when fruit development takes place during the cool winter months. Despite these challenges, it is not known which bags are suitable for winter production.

Different bags were used for bunches developed during winter and summer. The use of non-perforated blue or white polyethylene bags with a thickness of 30-35 micron have increased temperatures inside the bag and shorten the development cycle of winter bunches (Robinson and Nel, 1984). White perforated bags have been used in summer and are ideal for hot humid conditions. Reflection of direct solar radiation, which results in lower temperature inside the bunch, has resulted in better green life. However, it is also not known which cultivars are best suited to such agronomic management practices in Mozambique.

1.3 RESEARCH RATIONALE

The production of bananas on a commercial scale in northern part of Mozambique has been modelled according to experiences and conditions of Central American and Southern African countries as well as banana growing areas in the southern parts of Mozambique. However, the climatic conditions (low temperatures, high winds, low humidity, and a short rainy season) as well as the pests and disease pressure and the effect thereof on banana production in the north of the country have proven to be different than originally predicted, including effect of the lower temperatures and chilling injury when temperatures below 13˚C are experienced which can result in non-exportable fruit quality. The commercial production of bananas in the north of Mozambique is based on exporting at least 95% of all production. It is important to determine the effect of different bunch protection bags on fruit development and quality during the winter months. In the beginning of the project the materials used for bunch protection have been sourced from other commercial banana producing countries i.e. Costa Rica, Philippines, Zimbabwe and South Africa, but locally produced bags are now being used in most of banana cultivars. These bags differed in colour (blue and white), perforated and non-perforated and have different thickness (20–40 micron) and give different results on fruit quality especially during the winter months.

The re-formulation of a growth model for commercial banana production in this region is required. This will ensure very realistic crop production cycles, yield estimates and the supply of fruit of a consistent export quality throughout the year to maximize returns for the business. The need to evaluate bunch protection materials during the winter months has been identified due to long production cycles. This has an effect on the planning of the business and fruit quality mainly coming out of winter and potential chilling damage. The viability of setting up farms for commercial banana production in this region was based on the shorter production cycles which result in increased returns and more bunches per hectare per farm per season per year.

The changes in climatic conditions, especially low winter temperatures, which may result in chilling injury on the fruit and longer fruit development cycles will have a huge effect on fruit with export quality and potential income/return per dollar invested. This has prompted the need for further research on different bunch protection materials in this region. Various studies have shown that both yield and quality are significantly being improved by the use of fruit protection bags (Robinson *et al*, 1984). It was also proven that winter fruit fill faster under covers which accelerated bunch development which resulted in overall shorter cycle times (Daniells *et al*, 1987).

1.4 AIM

To evaluate bunch protection covers on Grand Nain and Williams cultivars suitable for banana production and achieve exportable fruit quality in northern Mozambique.

1.5 OBJECTIVES

Evaluate cultivar performance of Williams and Grand Nain under different fruit protection bags.

1.6. HYPOTHESIS

The fruit protection bags do not influence cultivar performance of William and Grand Nain suitable for banana production at Metocheria Farm, Namialo.

1.7. ETHICAL CONSIDERATIONS OF THE RESEARCH

No ethical considerations are in discern (Appendix 3)

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Classification of banana

The banana plant belongs to Musaceae family. This family has two genera, *Musa* and *Ensete*. The earliest classification of bananas was made by Linnaeus in 1783 when he named all dessert bananas *Musa sapientium* which are sweet when ripe and are eaten as fresh (Robinson *et al*., 1984). The name *Musa paradisiaca* was given to the plantain group which are cooked and consumed while starchy. The modern classification of edible bananas was given by Robinson (1984). The modern edible banana comes from two wild species which are seeded *Musa acuminata* (donor of A genome) and *Musa balbisiana* (donor of B genome). Clones containing A and T genomes or even A, B and T genomes have been identified in Papua New Guinea. However, the edible bananas belong to the *Eumusa* and have 22, 33 or 44 chromosomes however the basic haploid number is 11 but cultivars can only be diploid, triploid or tetraploid (Robinson and Nel, 1984).The most cultivated bananas and also plantains are triploids (Robinson and Nel, 1984). These cultivars were derived by natural hybridisation between the two diploid species *Musa acuminata* and *Musa balbisiana.* The *Musa* genotypes are classified in the natural germplasm by ploidy level and the relative expression of *M. acuminata* and *M. balbisiana* characteristics. According to this method, the Cavendish and East African highland bananas were categorised as AAA, plantains as AAB and most of the cooking bananas as ABB (Robinson *et al*, 1984).

2.2 Nutritional value of banana

The commercial bananas are called dessert bananas; these have become very popular in modernised countries and are widely eaten across all ages (de Valdenebro *et al*, 2006). Bananas have a very good nutritional value with 1.1g protein; 0.2g fat; 22g carbohydrates; 7 g calcium; 27g phosphorous ; 0.9 g iron; 10 g vitamin C and A, B per every 100g of any edible portion (de Valdenebro *et al*, 2006). They are an important source of energy and are fed to sports people as they are also cholesterol –free and very high in fibre. The only difference in banana nutrition exists between genotypes dessert bananas and cooking bananas have high calcium (Ca) and magnesium (Mg) levels than ordinary plantains (de Valdenebro *et al*, 2006).

2.3 Botanical description of banana

The banana plant is a monocotyledonous, herbaceous and evergreen perennial of which plantations can last up to 50 years (personal communication, Chiquita CTO, 2012).The plant consists of subterranean stem or rhizome that bears developing suckers, an adventitious root system, a pseudo stem, leaves and an inflorescence that bears flowers which subsequently bear the fruit. The banana flower consists of a stout peduncle on which flowers are arranged. Flowers are found on nodal structures with each node comprised of two rows of flowers (National Agriculture Research Institute Guyana, 2003). On the basal (proximal) nodes the female flowers are borne and these develop into fruit and sometimes range in numbers from 5 to 16 nodes per stalk. On these nodes, when they contain double rows of fruits they are then called hands and the individual fruit itself is called a finger. On the distal part, the nodes contain male flowers which remain tightly closed and these form the bell. Between the male and female nodes are several nodes containing hermaphrodite (male and female) flowers which develop into edible banana fruits. In commercial practices the bells is cut when the distance between the last hand and the top bell is about 15cm and meristem growth is prevented (National Agriculture Research Institute Guyana, 2003) This helps to direct the plant photosynthetic energy to increasing the fruit size. The hermaphrodite flowers below the developing fruit usually abscise and leave a callus scar on the stalk.

After fruit harvest the aerial parts die down to the ground and there are no woody components. New suckers grow up from the base of the mother plant to replace aerial parts that have died. Banana plants can reach a height of 3 metres or more depending on variety and conditions (Karamura *et al*, 1995). In the fruit, the most abundant constituent is water within the pulp and peel of the banana fruit. In comparison the pulp of a dessert banana has higher water content than a plantain fruit. The water content increases at ripening, however it is then lost from the peel externally due to transpiration and the ripening process will continue to degrade the peel which then reduces further water loss. A fully ripe banana has 75% water of its pulp mass whilst the plantain has 66% of its pulp water mass (Robinson *et al*, 1984).

The two main components of yield of bananas are fruit mass (hands per bunch, fingers per bunch, finger length and calliper) and cycle time (harvest to harvest intervals). Improving yield therefore involves either an increase in fruit mass or a reduction in cycle time. These two components as well as fruit quality are affected by the environment, cultural practises, biological and post-harvest factors. Being a tropical plant, subtropical climatic conditions seasonally restrict fruit development and quality. These factors need to be identified in order to adapt management practices to increase production and improve quality (Eckstein, 1994).

2.4 Climatic conditions in Nampula, Mozambique

The studies were carried out over two consecutive seasons i.e. 2012 and 2013. The site average temperatures were 24.9°C and 23.7°C for 2012 and 2013 respectively. However, in week 29, 2012 the average temperature recorded was 20.23ºC with a maximum temperature of 30.7°C and a minimum temperature of 11.70°C for 2013 week 29 the average temperature recorded was 20.57°C with a maximum of 27.9°C and a minimum of 12.6°C. These data are indicative of the effect that climate has during the winter months of banana production which can result in chilling damage to the fruit and slowing growth. According to Stover and Simmonds (1987) and Robinson (1993), optimum climatic requirements for the banana are a mean daily temperature of 27ºC, mean minimum temperature not below 20ºC and well distributed rainfall of 75 – 100 mm per month. A mean daily temperature of 16ºC represents the minimum for leaf area increase (development), while 14ºC is the minimum for growth for bananas (Robinson, 1993).

There are also a range of fruit physiological disorders resulting from low temperature exposure during certain plant development stages. For example, if the fruit is exposed to chilling temperatures during development, a discoloration of the vascular tissue occurs, leading to brown stripes which mask the normal yellow colour of the fruit when ripe. This is called “under-peel discoloration” (Robinson, 1993). Some of these physiological disorders can be avoided to a limited extent by adapting some of the agricultural practices, such are example using different fruit protection bags in the winter from those in the summer.

Uneven de-greening, a kind of ripening disorder in banana peels, occurs seasonally in Taiwan where it is a serious quality problem. The affected bananas are characterised by either partial or delayed yellowing of the peels in mild cases or by remaining green in severe ones following ethylene treatment. Some factors suspected for its occurrence include chemical hazards, virus infection, and overuse of nitrogen fertiliser, low temperatures and genetic factors. Temperatures below 20 °C in winter during bunch development and genetics have been so far considered as the major contributory factors of uneven de-greening. An integrated strategy was designed to reduce uneven de-greening (Chao and Hwang, 1998), including the use of cultivars of low susceptibility to the disorder, elimination of affected plants from stocks nurseries which supply suckers for micro propagation programs and the use of brown paper covers instead of blue polyethylene covers for bunch protection) (Chao, and Hwang, 1998)

2.5 Wind

Wind blows dust and debris which hits the delicate outer skin of the banana fruit causing cellular damage and subsequent fruit scarring (Anon, 2003). Considerable physical injury and damage to the fruit peels can also be caused by the blowing adjacent leaves and rubbing fruit petioles onto the developing bunch (Anon, 2003). Anon (2003) reported that it is economical to establish windbreaks if the prevailing wind constantly tears new leaves into strips of less than 50mm wide. Though windbreaks have many disadvantages in this instance they will become beneficial as they will improve the fruit quality from the effect of wind damage.

2.6 Nutritional requirements

Bananas require large amounts of mineral nutrients to maintain high yields mainly on commercial farms. Nutrient supply can either be from establishing the plants in very fertile soils, fertilisation, and giving supplements to the crop through fertilisers to improve soil fertility (Jaizme-Vega *et al*, 1995). Major nutrients required by bananas are nitrogen (N), potassium (K) and low level of phosphorous (P). The optimum level of nitrogen (N) 275kg nitrogen per hectare per year, this will be an equivalent of 980kg LAN per hectare per year with LAN containing 28% N, Potassium is recommended at 800kg K /ha/year. This will be derived from using KCL, which is potassium chloride which will be 1,600kg per hectare per year with KCL containing 50% K.

2.7 Protection bags

Cuneen and McEntrye (1988) evaluated whether the colour of banana bunch covers has an effect on the yield of bananas and the climate inside the bag within the cover bunch. Coloured bags are used to cover bunches for several reasons, that is to reduce the time between flower emergence (Sauco, 1992) and early harvesting (Sauco, 1992), to improve banana quality and quantity (Robinson and Nel, 1984), as protection to against injuries caused by solar radiation or by pests or mechanical injuries (Soto, 1995). From the studies conducted by Cuneen and McEntyre (1988) with different coloured plastic bags (green, blue, black, orange, blue/silver and clear/silver) enclosed in a wire frame indicated that during the day temperatures inside the bag were 10˚C higher than the outside air temperature and that during the night the temperature inside the bags fell slightly below the outside temperature (Cuneen and McEntyre ,1988)

The clear/silver bag resulted in the highest day-time temperature increase and the black bag the lowest increase (Cuneen and McEntyre ,1988). In studies using the bags as bunch covers, no significant differences in yields and quality were found for the different coloured bags, although yields were highest for bunches inside the clear silver bags (Cuneen and McEntyre, 1988) it was suggested that the clear/silver bags may be of value during the winter period (Cuneen and McEntyre, 1988). Bunch covering and harvest delay combinations on the environment inside the bunch covers and on fruit yield and quality parameters (Cuneen and McEntyre, 1988). During clear weather in January between flower emergence and fruit bunch filling in the North West of Australia (average air temperatures were 3, 5 and 6°C above ambient inside unsealed single standard covers, unsealed double covers and sealed double covers respectively. Differences were smallest at dawn and greatest in the late afternoon. During clear weather in July between flower emergence and harvesting the temperatures were 1°C, 1.5°C and 2°C above ambient, respectively (Cuneen and McEntyre, 1988).

In subtropical banana growing countries, with cold winters and strong winds, the benefits of bunch covers are both physiological (improved microclimate) and physical (larger fruit and reduced chaffing from dust and leaves). According to reports from Daniells, 1994 and Johns, 2005 they describe increased finger length, higher yield and shorter flower to harvest interval in various subtropical countries. Temperatures under the cover were 2˚C to 6˚C warmer and during cool times of the year this increased fruit length and hastened fruit filling (harvest duration was 4 to 14 days earlier). The yields are much less during the warmer months and special care needs to be taken to avoid sunburn under covers during these warmer months. This involves the use of reflective silver covers and pulling down a leaf over the cover. Perforated covers are commonly used to reduce sunburn damage for export production overseas (Daniells and Lindsay, 2005). Bunch trimming (removal of male bud and several distal hands from bunches soon after flowering), and double covering (use of 2 bunch covers simultaneously) of banana that emerged during winter in South Wales showed an increase in size. Bunch emergence to harvest interval was reduced by an average of 5 days by bunch trimming. Finer length increased with the average length for the top 6 hands increased by 2,3% ($P<0.01$) for the 10 hand treatment to 6.1% ($P<0.001$) (Johns, 2005).Finger length increased with increasing severity of bunch trimming , weights for six top hands increased by up to 14% ($P<0.001$),(Johns, 2005). In tropical countries no differences were observed in yield, finger length or flower to harvest interval between covered or uncovered bunches, benefits were related more to blemish control and reduction of pest damage (Rodrigues et al, .2008).   Robinson and Nel 1982) used different bunch cover combinations during the summer at Burgeshall in South Africa. Bunches of Dwarf Cavendish bananas arising from flowers emerging in late November to early December were enclosed in brown paper bags of polyethylene covers of different colour combinations, this was after bunches emerged and flower bracts started to open up. The proportion of clean fingers was low (9-12%) with up to 48% damaged by thrips and mites. Fruit surface temperatures especially in the front and relative humidity in the afternoon were highest in polyethylene bags, resulting in the highest percentages of soft rots (15%) and uneven ripening (Robinson and Nel, 1982).

The effect of banana bunch covering especially in the tropics has demonstrated inconsistent results on the size of fruit. Double covering increased finger weight of the top six hands by 4% ($P<0.01$) (Johns, 2005). Trimming to 10, 8 and 6 hands increased the yield per bunch of extra grade fruit by 18%, 23% and 39% (Johns, 2005) maturity. Double covering did not affect the yield of extra-large fruit significantly (Johns, 2005). Bunch covering had no significant ($P>0.05$) effect on the pulp/peel ratios of fruits of cv. Williams at harvest and during ripening. It was seen that in bananas, the pulp portion continues to grow even in the later stages of maturation (Turner, 1997, Nakasone and Paul, 1998), skin colour development (Turner,1997) and other post-harvest (Turner,1997). However, this may be due to the different types of bags for bunch covering used, the age of the fruit at covering, fruit and cultivar response, the climatic conditions and also the conditions in which fruit is held pre and post-harvest and all these factors influence fruit quality (Amarante *et al,* 2002). External appearance includes key attributes such as colour, shape, size and no blemishes. Internal attributes such as taste, texture, sweetness, aroma, acidity, flavour, shelf life and presumed nutritional values of the fruit which are important in ensuring repeat buys for sustained repeat purchase (Hewett, 2006).

The findings reported by Stevenson (1976) showed that with summer bunch covering no particular colour of covering material substantially accelerated bunch filling, but in winter the use of transparent material speeded up the filling and harvesting of banana bunches. This raises the need to further evaluate banana bunch covering materials for the warm season for evaluating peel quality (Stevenson, 1976).

A banana bunch cover thickness micron plays a very important role in influencing temperatures inside the bag within the bunch. Economically, it is better to use thinner bunch covers as damage is bound to occur and plastic damaged not being able to be re-used again (Trochoulias,1975). Blue polyethylene banana bunch covers 0.075mm thick lasted longer than either 0.050 or 0.100 mm film. The 0.100mm covers suffered from a high incidence of disintegration due to bag chemical composition (Trochoulias, 1975).

The longevity of polyethylene bunch covers for bananas in relation to thickness was evaluated by Trochoulias (1975). The author reported that four thicknesses of blue polyethylene bunch cover (0.038, 0.050, 0.075 and 0.100mm) for bananas were compared for longevity under field conditions. The longevity index, days in the field and condition score of covers increased as the film thickness increased from 0.038 to 0.075mm but 0.100mm covers were better than the 0.038mm covers. After one year, the 0.100mm covers performed poorly compared with the thinner films (Trochoulias, 1975).

The covering of bunches has become a cultural practice in commercial dessert banana production. Choudhury *et al*. (1996a) investigated the effects of bunch covers (black, white or blue polyethylene, gunny bags or dry banana leaves) and soil application of mustard oil cake (1kg/plant, alone or in combination with white polyethylene bunch covers) on the growth and yield of bananas (cv.Dwarf Cavendish).Yield (bunch weight, bunch length, number of fingers per bunch, finger length, finger weight, finger volume and weight of second hand) was significantly influenced by bunch cover treatment with the highest bunch weight of 15.25 kg and yield of 67.78 tonnes per hectare. The cost: benefit ratio of this treatment was low (1:2.8). The lowest cost: benefit ratio (1:1.92) was obtained from the mustard oil cake treatment. The highest cost: benefit ratio (1:3.53) was observed in white bunch cover treatment (Choudhury et *al,* 1996a).

Choudhury *et al,* (1996b) reported that using white polyethylene covers resulted in the lowest number (10.67) of banana fingers per bunch was obtained using a white polyethylene bunch cover treatment. The authors also reported that crop duration, particularly days taken from planting to flowering, and flowering to physiological maturity and production per day was significantly influenced by different bunch cover treatments. Plants treated with a white polyethylene cover and a soil application of mustard oil cake matured earlier (430.00 days) compared to the untreated control plants (467.67 days) (Choudhury *et al*, 1996b). The same treatment also shortened time (106.33 days) from flowering to physiological maturity in comparison with the untreated control (142.00 days) and economical for controlling damage caused by *Basilepta subcostatum,* and avoided the use of insecticides thus resulting in higher yields or profits (Choudhury, 1996b).

Early removal of smaller distal hands leaving only one nurse finger to stop peduncle rot has been found to improve the export quality of the banana bunch (Farrell *et al*, 1987). The removal of up to three distal hands is now a standard practise on Cavendish bananas in the tropics as it helps to increase finger length on the remaining hands per bunch.

The trimming of banana bunches covered with polyethylene bags of a plant crop of cv. Williams were also reported by Daniells *et al,* (1987). The authors reported that banana bunches of a plant crop cv. Williams covered with polyethylene covers one week after abscission of the last female flower bract while others were left uncovered and were also subjected to one of three bunch trimming treatments (0, 1 or 2 distal hands were removed). In a second experiment the same bunch trimming treatments were applied to a ratoon crop without bunch covers (Daniells *et al,* (1987). Bunch covering increased weight per bunch by 4% and decreased the period of bunch emergence to harvest by 5 days. Bunch trimming increased finger length of fruits at the proximal end of the bunch. Removal of 1 hand/bunch reduced yields/bunch in both experiments by 7% and removal of 2 hands/bunch reduced yields by 15% and 13% in two experiments respectively.

Yield reductions occurred without any improvements in fruit grades (Daniells *et al*, 1987). Four bunch trimming treatments (retention of all hands and the bell, or retention of 10, 8 or 6 hands and removal of the bell) were combined with 2 covering treatments (use of 1 or 2 blue /silver covers/bunch) in June and July 1987(Johns,1988). Bunches harvested between 8 November and 29 December with six hand treatment produced 35% more extra-large fruits than the untrimmed control, but produced fewer large fruits and no medium sized fruits. The use of a second bunch cover resulted in only a slight increase in yield over the use of a single cover (Johns, 1988).

John (1996) evaluated the effects of bunch trimming and the use double bunch covers on the yield of bananas in winter in Australia. The banana bunches (on 10-year-old Great Cavendish cv. Williams plants) were either trimmed to 6, 8 or 10 hands or left untrimmed (male bud retained) (John, 1988).The bunch harvest interval was reduced by an average of 5 days by bunch trimming. Finger length increased by 2.3% for the 10-hand treatment and by 6.1% for the 6-hand treatment. From the studies carried out by Johns (1988) the results also showed the finger weight increased with increasing severity of bunch trimming, with weights for the top 6 hands increased by up to 14% by the 6-hand treatment. Double covering increased finger weight of the top 6 hands by 4%. Trimming to 10, 8 and 6 hands increased the yield per bunch of extra-large grade fruits by 18, 23 and 39%, respectively (Johns, 1988).

2.8 De-handing and sucker management

De-handing and sucker management is also very critical on bunch quality and yield of bananas and plantains (Irizarry *et al*, 1992). The authors also reported that suckers affect the fruit quality through competition for nutrients and water. Large suckers reduce transmission of radiation; compete with the parent plant affecting the latter by extending the cycle and resulting in yield reduction. According to Robinson and Sauco (2010), allowing suckers to reach 500mm to 800mm before removal, the average yield per hectare per annum after three cycles was reduced by 7.6% and 15.6% respectively ompared with the standard practises off removing the suckers at no more than 300mm (Robinson and Sauco, 1990). Good sucker selection and proper de-handing practises are essential in getting a good quality bunch. From two long-term banana experiments conducted to determine the effect of bunch bagging, the removal of lower hands and sucker management on fruit and bunch characteristics and total yield. Irizarry *et al*, (1992) reported that removal of lower hands increased individual fruit size. Bunches covered with either Dursban-treated or untreated perforated polyethylene bags yielded 10 539 kg/ha more than uncovered bunches during a 40-month production period. Considering the price that quality bananas command at the farm gate and the cost of bagging (materials and labour), this practice represents a net profit of $3 329.25/ha (Irizarry *et al*, 1992). The removal of the 3 lower hands from the immature racemes significantly reduced bunch mean weight and total yield. However, both removal of lower hands and bunch bagging increased size of individual fruits in the distal hand, thus up-grading fruit quality. In addition, these practices also reduced the number of days required from bunch-shooting to harvest (Irizarry *et al*, 1992). The selection of a vigorous sword sucker soon after planting, combined with repeated pruning of other competing suckers, produced the highest yield of 183 744 kg/ha during a 40-month period (Irizarry *et al*, 1992).

2.9 Banana diseases

Fruit diseases such as cigar end rot, *Verticillium theobromae, Trachysphaera fructigena*, crown-rot, c*olletotrichum musae, Fusarium moniliforme, Fusarium pallidoroseum* and Anthracnose peel blemish *C. Musae* (Robinson and Sauco, 1990). Cigar-end rot from fungi *Verticillium theobromae,Trachysphaera fructigena* pathogen attacks flowers thus infecting the perianth. In the development phase, the initial perianth infection spreads slowly along the fruit causing the banana peel skin to blacken. Banana tip area is usually covered with powdery spores which resemble the ash of a cigar (Robinson and Sauco, 1990). Polyethylene bunch covers also help to prevent infection (Robinson *et al*, 1990). Crown rot usually occurs in packing houses which are not clean with good and strict sanitation. The most common fungi *Colletotrichum musae* is very common in different banana producing countries. Spores of the fungi colonise the wound excised from the banana bunch causing the rotting to spread from the cut surface into the crown of the hand or bunch during transit of fruit. Immature fruit in the field is usually the source of anthracnose peel disease, the infection originates from immature fruit but signs of lesions development are seen only when fruit ripens when the fungus is able to penetrate the fruit peel. Large oval lesions develop with salmon coloured fruiting spore bodies (Robinson and Victor, 2010).

Pests such as thrips, *Chaetanaphothrips* sp. feed on the soft skin of immature fruit under the hidden surfaces and between closely packed fingers. Once fruit develops, rust like blemishes become roughened and occasionally cracked. Most species are controlled by the use of banana bunch covers especially the early bagging system which is just after bunch emergence. Other pests such as beetles can also infect at a later stage of bunch development but are also controlled by bunch covers (Robinson and Sauco, 2010).

In further investigations on the control of *Hercinothrips bicintus* and *Tetranychus lombardini* on bananas in South Africa, triazophos and chlorpyrifos adequately controlled both pests on uncovered fruit when applied at intervals of 6 weeks in August-January during fruit development after flower bracts dropping. A single application to young bunches before covering them with plastic bags (a practice that became common in the winter of 1978) controlled the pests until harvest. In addition, a segment of dichlorvous strip measuring 2x1.5cm controlled both pests when placed in young bunches that were then covered with a bag (Choudhury *et al,* 1996b). The mite *Calacarus citrifolii Keifer* was observed for the first time as a pest on the experimental site where it occurred more on covered bunches than on uncovered ones and was not adequately controlled by Dichlorvos; over-mature bunches were particularly prone to damage and correct timing of harvesting is recommended in preference to the application of the acaricides against *C. citrifolii* (Jones, 1979).

In field studies were conducted in India on the influence of bunch cover treatments on infestation of fruit scarring beetle and crop duration in Dwarf Cavendish banana. The lowest number (10.67) of banana fingers per bunch infected by *Basilepta subcostatum* was obtained using a white polyethylene bunch cover treatment (Kimani *et al*. 2010). This was 7.50% of the total number of fingers per bunch compared with 54.67 (52.91% of total fingers per bunch) in untreated controls. Crop duration days from plant to flower development and flowering to physiological maturity and production per day was significantly influenced by different bunch cover treatments (Kimani *et al*, 2010). Plants treated with white polyethylene cover and a soil application of mustard oil cake matured earlier (430 days) compared to untreated control (142 days) (Choudhury *et al*, 1996b). This treatment had highest production of fruit (157.63 kg/ha per day) which was equal to the white polyethylene bunch cover treated plants (153.73 kg/ha per day) (Choudhury *et al,* 1996b). The authors also suggested that the bunch cover treatments with polyethylene were effective and economical for controlling damage caused by *B. subcostatum* and this avoided the use of insecticides which eventually gave higher yields.

SUMMARY

The uses of banana bunch covers improve fruit peel quality, reduce bunch emergence to yield periods, protect the fruit from insect and pest damage. The two yield parameters important for optimum banana production are bunch weight and cycle times, which are evidently, influenced by the environment and management practices done by commercial farmers.

The management practice of using fruit protection (bunch cover) bags during certain stages of bunch development has positively impacted on the production of bananas. The export quality of banana can only be achieved by producing a blemish free fruit. Post-harvest shelf life is significantly influenced as banana bunch covers effectively reduce both physical and insect damage to the peel. The advantages include increased yield with larger fruit, more uniform fullness of the fruit within the bunch the protection from mechanical damage while the fruit is hanging in the plantation and in the transportation to the packing houses. Fruit appearance is better under bunch covers which is what a consumer needs as the impression of a blemish free fruit is one of the major factors of influencing a buyer for the fruit.

Fruit under covers is clean compared to that which is grown uncovered which implies reduced water usage during post-harvest preparation of the fruits. Bunch covers can be used non-perforated during the cooler months and perforated during the warm months to avoid any sunburn to the fruit.

The post-harvest handling procedures must be done properly to ensure that the clean, visually appealing fruits are not bruised during the post-harvest period. Training of employees in this area by improving skills level will help enhance the bunch cover effect on the fruit as all this fruit will be for export markets such as Europe, Middle East and Asia markets. The review also shows that the use of bunch covers increase profits for the banana grower as quality is improved quality, increase in yields and better profit margins due to good export quality fruit.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Experimental site, bunch harvesting, processing and stem diagnostics:

This trial was conducted at Metocheria Farm, Mozambique located at a latitude South (14.88˚ S), longitude east (40.04˚ E), and altitude of 235 metres above sea level. The plant spacing is double lines 2 metres apart and in row of 1.8 m. The space between the 2 tramline spatial arrangements is 3 metres (3m x 2m x 1.8m).Total plants for final selection were 320. The cultivars used were Williams and Grand Nain. Banana flowers of the same uniform plant health were marked and fruit was protected on a weekly basis using the different fruit protection bags. The study was conducted over two consecutive seasons i.e. 2012 and 2013. Temperature data were recorded using a temptale USB data logger. The experimental site average temperatures were 24.9 ˚C and 23.7 ˚C for the 2012 and 2013 growing seasons.

Banana plants were clearly marked and bunch were marked using different colour ribbons which coincide with the same colours as the rest of the farm for age grade control. The ribbon colour is used to indicative of the week which the bunch protection cover was applied, the ribbon colour is used to plan fruit inventory at harvesting and projecting volumes for harvesting and marketing purposes. For example in week 29 total bunches covered will be 45,000. These are also identified by ribbon colour for example red. Estimates are then done to project when the bunch will be ready to harvest hence plan shipments, harvesting, sales and cash from for the project.

(a) Green polyethylene bag **(b)** Blue polyethylene bag

Figure 1 Typical banana bunch covers of different colours.

Selection procedures

3.2.1 Selection and marking of five uniform plants and flowers per variety Williams and Grand Nain per treatment per week for eight consecutive weeks. A total of three hundred and twenty bunches were selected.

3.2.2 The bunches were selected as follows, for example the first bunch selected was Treatment 1, the second one Treatment 2, the third one Treatment 3, and so forth until all treatments were completed (Banana flowers randomly emerge, they do not all appear next to each other in the same row during the same week, which cause treatments to be applied randomly). The trial was conducted in a completely random block design.

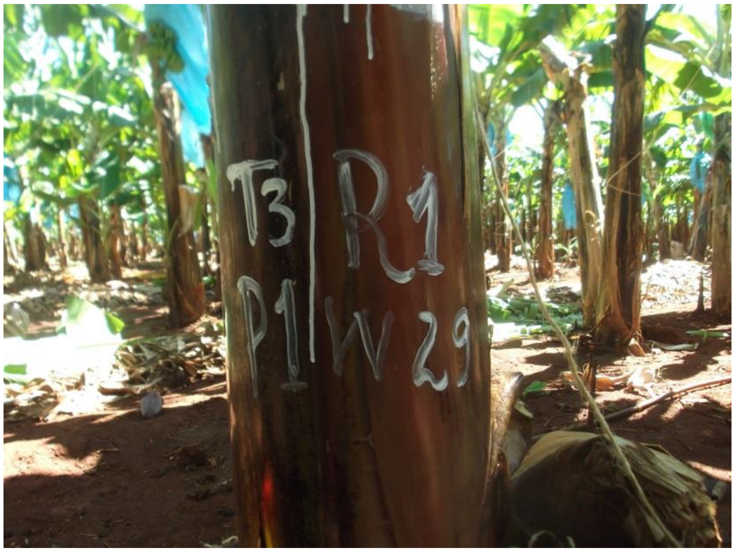

Figure 2 Plants marked

3.2.3 Plants from or near plantation borders, drainage canals, cable way and roads were not selected as these positions affect fruit quality and yield.

3.2.4 All the covers were applied using the early bagging system which means once the bunch emerges and the bell drop, the bunch protection covers were applied (early bagging practice).

Figure 3 Early bagging method, bunch cover applied before bracts open

3.2.5 All bunches were de-handed, false +2 which is the normal standard operational procedure for the farms at Metocheria farm.

3.2.6 Harvesting was done using age grade control, using colour ribbons and calibration.

3.2.7 Weighing scales used a dial Avery type with maximum weight of 50 kg.

3.2.8 Calliper used was the Hecho En type. Ranges from 28/32 to 60/32.

3.2.9 Measuring fruit was done using a Dole International flexible tape calibrated in both inches and centimetres.

3.3 Experimental Design and Treatments

Randomized block design (RCBD) with eight treatments replicated five times were used for the study in both the 2012 and 2013 seasons per week for eight consecutive weeks were used for the study. Bunch covers were applied after the bracts covering the hands have fallen when the fingers were curling upwards, and the floral remnants have hardened. Covers were slided up from the bottom of the stalk and secured tired to the bunch stalk above the first hand of the fruit. Covers were left on bunches until harvest.

Table 1. Illustrations of the treatments included in this study

	Treatments Description	Pictures
1	Control – No bag	
2	Blue polyethylene bag, perforated	
3	Green polyethylene bag, non-perforated	

4	White polyethylene bag, non-perforated	
5	Blue polyethylene bag, non-perforated	
6	White polyethylene bag, perforated	
7	Green polyethylene bag, perforated	

8	Cheese cloth	

3.4 Variables evaluated

Bunch covers were applied after the bracts covering the hands had fallen when the fingers were curling upwards, and the floral remnants had hardened. Covers were slid up from the bottom of the stalk and secured tied to the bunch stalk above the first hand of the fruit. Covers were left on bunches until harvest. Temperature loggers were placed in for all treatments up to the day of harvesting (Tables 2 and 3).These were hung in the middle of the bunch.

Table 2 Average temperature (˚C) in Grain Nain banana bunch covers for the 2012 and 2013 season

Type of cover	2012			2013		
	Minimum temperature˚C	Maximum temperature˚C	Average temperature˚C	Minimum temperature˚C	Maximum temperature˚C	Average temperature˚C
Control	13.4	44.7	27.5	13.1	45.1	27.9
Blue perforated	14.1	42.2	27.9	14.8	41.8	28.3
Green-non perforated	13.2	41.6	28.1	14.2	43.0	31.0
White-non perforated	15.1	41.6	27.8	15.8	42.6	29.5
Blue-non perforated	14.5	43.3	29.6	15.5	43.8	30.6
White perforated	13.9	42.5	28.8	14.0	40.5	29.3
Green perforated	14.4	38.0	26.9	15.2	41.3	28.1
Cheese cloth	15.6	44.4	28.5	15.0	43.8	29.1

Table 3 Average temperature (˚C) in Williams's banana bunch covers for the 2012 and 2013 season

Type of cover	2012			2013		
	Minimum temperature˚C	Maximum temperature˚C	Average temperature˚C	Minimum temperature˚C	Maximum temperature˚C	Average temepraturе˚C
Control	12.1	42.1	28.1	12.9	44.8	28.8
Blue perforated	13.1	41.4	27.7	13.6	41.0	29.2
Green non perforated	13.0	42.8	27.3	14.4	42.6	30.1
White non perforated	14.7	43.0	28.2	14.2	44.4	30.5
Blue non perforated	13.8	40.8	28.6	14.5	43.9	28.1
White perforated	12.7	41.5	27.6	13.8	39.5	28.2
Green perforated	13.4	41.8	25.7	14.6	41.8	26.5
Cheese cloth	14.8	43.4	29.6	14.3	44.8	29.9

At harvest, data recording done on several yield parameters; including weight of hands, box stem ratio, yield and marketability.

Justifications of these variables measured

3.4.1 Total bunch weight

The bunch weight was evaluated so that after processing the actual marketable weight which has an effect on yield and income is determined.

3.4.2 Marketable fruit (%) per bunch

The marketable fruit is one of the key elements to determine exportable quantities; the marketable fruit can be affected by banana bunch sleeve quality which can affect yield and fruit quality.

Total Fruit Weight-Total Defects = Marketable Fruit Weight

Total fruit weight is net fruit weight after taking off Total bunch weight-Stalk weight

3.4.3 Defects

The total defects which affect yield and quality.

Fruit free from below defects is deemed marketable.

PERMISSIBLE SEVERITY OF FRUIT DEFECTS

Black tip	none	Maturity stain	Light
Bruises	none	Scarring	Light
Cigar end	none	Speckling	Light
Fruit spots/speckling	none	Thrips injury	Light
Fused fingers	none	All other defects	Light
Malformed hand / finger	none		
Mutilated fingers	none		
Ripe and turning	none		
Rots and molds	none		

Mealy bug	none
Scale insects	none
Blossom	none
Chemical residue	none
Split Peel	none
Broken neck	none
Dirty Fruit	none
Flower	none
Chimera	none
Knife cut	none
Under calibration	none
Over calibration	none

3.5 BSR (Box/stem/ratio)

The Box to Stem Ratio is the true reflection of yield and quality. This is the actual packed fruit after processing the bunch. This indicates the actually achieved yield per bunch.

BSR (Box to stem ratio) Unit of measure used to forecast yield potential, actual productivity on a daily basis.

Standard market box weight is 13.5 kgs net fruit weight.

Calculation of BSR: Marketable fruit weight (net fruit weight)/13,5

The higher the BSR i.e. 1.1; 1.3 the more your packed net fruit meaning higher yields per hectare. The lower the BSR the lower the yield potential. Meaning once you see you BSR going down you notice the yield potential is lower due to various factors but mainly defects

3.6 Statistical Analysis

Data collected were analysed using the General Linear Model (GLM) procedure and variance analysis using SAS version 8.0 2003 (SAS Institute Inc., 2003) and Duncan Multiple range test (DMRT) was used to separate the means.

CHAPTER 4: RESULTS

4.1. Results

During 2012/2013, bagging treatments did not significantly improve weight in hands, banana finger weight, total fruit weight, marketable weight, and percentage marketable fruit weight and box stem ratio (BSR) of Grain Nain (Table 4 and 5). However, there was significant reduction of fruit defects in all bagging treatments compared to the control (no bags). Again, bagging treatments significantly increased Grand Nain yield per ton in both seasons.

Table 4 Effects of bunch covers on yield performance of Grand Nain banana variety in 2012

Treatment Tree bags	**Weight hands (kg)**	**Defects (kg)**	**Weight in Kilos (kg)**	**Total Fruit Weight (kg)**	**Marketable Weight (kg)**	**Marketable Percentage (%)**	**Box stems ratio (BSR)**	**Annual Yield/ ton (kg)**
Control	3.13 a	4.66 a	1.90 a	17.63 a	13.67 a	77.90 a	1.03 a	32.75 b
Green perforated	3.21 a	4.01 b	2.13 a	17.88 a	13.86 a	76.35 a	1.04 a	39.81 a
Green-non perforated	2.86 a	3.13 b	1.88 a	17.33 a	14.01 a	81.54 a	1.05 a	39.25 a
White perforated	2.48 a	2.23 b	1.98 a	16.63 a	11.40 a	72.93 a	0.85 a	39.77 a
White-non perforated	3.04 a	2.33 b	1.79 a	17.21 a	14.89 a	86.78 a	1.10 a	41.68 a
Blue perforated	2.88 a	3.61 b	1.90 a	16.71 a	13.10 a	77.28 a	0.96 a	36.68 a
Blue-non perforated	3.18 a	3.96 b	1.81 a	16.36 a	11.70 a	69.79 a	0.86 a	38.29 a
Cheese Cloth	2.95 a	2.64 b	1.81 a	17.63 a	13.95 a	84.53 a	1.03 a	39.05 a

Means in a column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT)

Table 5 Effects of bunch covers on yield performance of Grand Nain banana variety in 2013

Treatment Tree bags	Weight hands (kg)	Defects (kg)	Weight in Kilos (kg)	Total Fruit Weight (kg)	Marketable Weight (kg	Marketable Percentage (%)	Box stems ratio (BSR)	Annual Yield/ ton
Control	2.95 a	13.88 a	1.65 a	15.94 a	9.43 a	59.98 a	0.68 a	26.40 b
Green perforated	3.33 a	5.03 b	1.70 a	17.70 a	12.66 a	70.76 a	0.95 a	35.50 a
Green non perforated	3.15 a	3.95 b	2.03 a	17.09 a	13.14 a	76.24 a	0.98 a	36.80 a
White perforated	2.95 a	5.13 b	1.85 a	15.68 a	10.54 a	64.51 a	0.78 a	29.51 a
White non perforated	2.81 a	4.22 b	1.84 a	16.94 a	12.71 a	75.40 a	0.96 a	35.61 a
Blue perforated	3.06 a	4.59 b	1.25 a	17.00 a	12.41 a	80.19 a	0.93 a	34.75 a
Blue non perforated	2.94 a	3.33 b	1.61 a	16.66 a	13.34 a	71.13 a	0.99 a	37.35 a
Cheese Cloth	3.12 a	4.09 b	1.51 a	15.74 a	11.65 a	71.45 a	0.86 a	32.63 a

Means in a column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT)

In William banana cultivar, bagging treatment tended to be inconsistent in the two seasons During 2013 bagging, treatments significantly improved weight, whereas no significance differences were observed on weight of hands during 2012 (Table 6 and 7).

Table 6 Effects of bunch covers on yield performance of Williams's banana variety in 2012

Bagging treatment	Weight hands (kg)	Defects (kg)	Weight in Kilos (kg)	Total Fruit Weight (kg)	Marketable Weight (kg)	Marketable Percentage (%)	Box stems ratio (BSR)	Annual Yield/ ton (kg)
Control	3.09 a	3.48 b	1.75 b	16.37 a	12.05 b	73.93 a	0.89 b	31.02 b
Green perforated	3.09 a	4.32 a	1.90 a	16.47 a	12.99 b	79.30 a	0.97 b	36.37 a
Green non perforated	2.90 a	5.11 a	3.07 a	15.75 a	20.75 a	64.42 b	4.25 a	33.75 a
White perforated	3.07 a	3.72 a	2.40 a	17.13 a	13.41 b	79.88 a	1.00 b	37.55 a
White non perforated	3.01 a	3.60 a	2.00 a	17.33 a	13.74 b	79.44 a	1.02 b	38.46 a
Blue perforated	2.94 a	4.47 a	2.54 a	15.47 a	17.66 a	71.89 a	3.55 a	32.16 a
Blue non perforated	3.13 a	4.10 a	1.84 a	17.04 a	12.88 b	73.21 a	0.92 b	34.97 a
Cheese Cloth	3.12 a	3.35 b	1.96 a	17.34 a	13.98 b	80.85 a	1.03 b	39.14 a

Means in a column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT)

Table 7 Effects of bunch covers on yield performance of Williams's banana variety in 2013

Treatment Tree bags	Weight hands (kg)	Defects (kg)	Weight (kg)	Total Fruit Weight (kg)	Marketable Weight (kg)	Marketable Percentage (%)	Box stems ratio (BSR)	Annual Yield/ton (kg)
Control	2.30 b	6.19 a	1.45 b	15.94 a	9.75 a	60.71 a	0.72 a	27.29 b
Green perforated	2.73 a	4.99 b	1.55 a	15.89 a	10.90 a	67.93 a	0.80 a	30.52 a
Green non perforated	3.02 a	5.03 b	1.47 a	15.77 a	10.75 a	67.23 a	0.79 a	30.07 a
White perforated	2.75 a	4.70 ab	1.62 a	16.20 a	11.50 a	70.28 a	0.85 a	32.18 a
White non perforated	2.79 a	6.46 a	1.53 a	16.24 a	9.78 a	59.19 a	0.72 a	32.19 a
Blue perforated	2.70 a	4.53 b	1.47 a	15.13 a	10.61 a	69.76 a	0.78 a	29.71 a
Blue non perforated	2.68 a	4.65 b	1.63 a	15.80 a	11.15 a	68.55 a	0.83 a	31.22 a
Cheese Cloth	2.81 a	4.42 b	1.71 a	15.51 a	11.09 a	70.68 a	0.82 a	31.06 a

Means in a column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT)

Bagging of banana bunches reduces defects in both seasons, though no major significant response was shown in marketability percentage. In 2012/2013, marketable weight tended to be inconsistent with blue perforated cloth and green non-perforated significantly increasing marketable weight. However, no significant differences were observed during 2013. Both green and blue perforated bags significantly improved BSR. However, no significant differences were observed on the parameters during 2013. Bagging treatments significantly increased William's cultivar yield per ton in both seasons (Table 6 and 7).

Discussions

Results shown from the trials indicate that yield and quality performance of bunch covered banana fruits is dependent on a number of factors, including type of cover, season and cultivar. Bunch cover application resulted in increase in yield even though inconsistent results were drawn from other parameters. These could be due to interaction between different light intensity and temperature. Such temperatures fluctuations inside the bunch covers due to weather patterns and bunch cover designs were shown in banana production across the north and the south west regions (Cuneen and McEntye, 1988; Johns and Scott, 1989a).

The average temperatures inside the bags in both banana cultivars were higher than the outside air temperature. The blue and green non perforated bags resulted in the highest temperature increase of 2˚C – 3˚C than the other bag types. In studies done by Cuneen and McEntye (1988), no significant differences in yields and quality were found for the different coloured bags, although yields were highest for bunches inside the clear silver bags. In some instances in the tropics benefits are related more to blemish control and reduction of pest damage (Anon, 2003). In winter, even the use double bunch covers improved the yield of bananas (Johns, 1996). Use of bunch covers to prevent chilling would also reduce incidences of under peel discolouration (Snowden, 2010).

Bunch covers can also increase the marketability of banana fruits through increase in size and quality. The use of different bunch cover combinations during summer in South Africa resulted in low proportion of clean fingers (9-12%) with however a high relative humidity in polyethylene bags resulting in the highest percentages of soft rots (15%) and uneven ripening (Robinson and Nel, 1982). Building up of high relative humidity inside the banana bags can however be reduced with use of perforated bags (Anon, 2003, Muchui *et a*l, 2010), ultimately preventing multiplication of fungi. Sizes of the holes should also vary with climatic conditions within production areas. Besides effect of presence of holes on changes in humidity and temperature inside bunch covers, colour of the covers also plays a role in the micro environment characteristics.

Muchui *et al*, (2010) reported that using perforated dull and shiny blue bunch covers resulted in higher quality and yields of bananas. Bunch appearance and size of hands was also affected by colour of the bunch covers and polyethylene density in banana produced in the Caribbean (Vargas *et al*, 2010). Crop duration, particularly days taken from flowering to physiological maturity and production per day can also be influenced by different bunch cover treatments (Vargas *et al*, 2010). The use of covers of various colours may also be dependent on seasons (Stevenson, 1976). Bunch covers performed the same in summer but in winter the use of transparent material speeded up the filling and harvesting of banana bunches (Johns, 1996; Johns and Scott, 1989; Stevenson, 1976).

The use of various colours in different seasons, climate or regions has shown their different performance capabilities towards banana physiological growth. Photo synthetically Active Radiation which is responsible for light intensity required in growth and development becomes filtered through various bunch cover colour designs. Transparent covers let in more light than blue of green covers. However, banana production regions mostly use blue covers as they let in heat without causing sun scald (Muchui *et al*, 2010), because it blocks UV rays. Transparent covers can further be treated to block ultraviolet and infrared rays. These transparent bunch covers with specific UV and IR permeability properties were found to allow better light and temperature conditions for banana growth (Jannoyer and Chillet, 1998).

(i) unbagged **(ii)** bagged

Figure 4 Visual appearance of banana cultivar Grand Nain at harvest

A few of the covered fruits suffered sunburn, which adversely affected fruit quality (Figure 5). This affected bunches which the leaves did cover during growth. The top hand of the bunch was mainly affected especially for bunches covered with dull blue polyethylene covers probably due to more heat absorbed inside the cover compared to the shiny blue polyethylene covers which reflected some heat away. Elsewhere, bagging of bananas resulted in sun scorching of the fruits irrespective of the colour of the bunch covers (Weerasinghe and Ruwapathirana, 2002),this is overcome by maintaining enough leaves on the plant which helps to shade the plant and by using reflective blue covers (Anon, 2003). Pulling leaves over the covered bunches may also reduce and prevent sunburn. In addition, inserting a newspaper on the inside of the bunch cover to cover a top hand to prevent them from sun scorch was found to be effective (Linbing *et al*, 2004). The blue polyethylene covers have been shown to absorb more blue-green and ultraviolet lights, which may cause sunburn to banana fruits (ShihChao *et al*, 2004).

Economic model

Bunch covers are highly specialised items available from a few companies which are found mainly in areas and countries of commercial banana production. The costs of bunch covers are as follows:

The additional cost of using a bunch cover averages US$0.13.

The data using the economic model of 2,000 bunches per hectare at 1.4 cycles per year for bagged bunches gives an annual carton 2,800 per year (13.5kg cartons). However data for the control or non-bagged bunches show that at 2,000 bunches per hectare per year at 1.2 cycles per year gives an annual carton of 13.5kg of 2,400 per year (Castillo, 2007). The trial resulted in the following:

Williams: 2012 and 2013 season

Control season's average BSR was 0.81

0.81 x 2000 x 1.2 = 1,944 cartons per hectare per year

Green perforated bags seasons average BSR was 0.90.

0.90 x 2000 x 1.4 = 2,520 cartons per hectare per year

Blue perforated bags seasons average BSR was 2.19

2.19 x 2000 x 1.4 = 6,132 cartons per hectare per year

White perforated bags seasons average BSR was 0.93

0.93 x 2000 x 1.4 = 2,604 cartons per hectare per year

Cheese cloth seasons average BSR was 0.93

0.93 x 2000 x 1.4 = 2,604 cartons per hectare per year

These results show that it is more economical to use bunch covers in Williams as this increased yields making it more profitable. The positive benefits achieved from using bunch covers makes the price of US$0.13 per bunch cover very reasonable as this results in improved profit margins for the farmer.

Gran Nain: 2012 and 2013 season
Control season's average BSR was 0.86

0.86 x 2000 x 1.2 = 2,064 cartons per hectare per year

Green perforated bags season average BSR 0.995

0.995 X 2000 X 1.4 = 2,786 cartons per hectare per year

Blue perforated bags season average BSR was 0.945

0.945 x 2000 x 1.4 = 2,646 cartons per hectare per year

White perforated bags season average BSR was 0.82

0.82 x 2000 x 1.4 = 2.296 cartons per hectare per year

Cheese Cloth season average BSR was 0.96

0.96 x 2000 x 1.4 = 2,688 cartons per hectare per year

The above data shows that it is cheaper to use tree bags as these results in increased yields per hectare per year in both varieties. The physical appearance of the peel is especially important in the export market. Buyers in these markets require consistent supplies of uniform coloured fruit with blemish free peels. This helps retain customers and fruit can receive premium prices.

Conclusions, the studies conducted are evident that bagging treatments significantly increased yield per tonne of Grain Nain and Williams cultivars with significant reductions of fruit defects. Based on the study Williams variety had a BSR ratio of 2.19 hence the blue perforated polyethylene tree bag the best for this cultivar. Grand Nain gave the best results on both blue and green polyethylene tree bags. The study shows that bags which gave the best quality were with micro perforations as this reduced insect damage and maintained a good climate inside the bag still allowing air circulation. Therefore, bagging treatments are recommended in marginal climatic conditions of Namialo in Northern Mozambique.

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APPENDICES

APPENDIX 1

Grand Nain: Evaluation of banana bunch protections materials for optimum fruit and quality.

Weight per hand

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	4.05207968	0.28943426	1.08	0.3996
Error	46	12.33021540	0.26804816		
Corrected Total	60	16.38229508			

R-Square	Coeff Var	Root MSE	Whand Mean
0.247345	17.38126	0.517734	2.978689

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	2.60342603	0.37191800	1.39	0.2335
REP	7	1.44865365	0.20695052	0.77	0.6136

Weight in kilograms

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	3.93750435	0.28125031	2.33	0.0157
Error	46	5.54183991	0.12047478		
Corrected Total	60	9.47934426			

R-Square	Coeff Var	Root MSE	wghtkilos Mean
0.415377	18.29972	0.347095	1.896721

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	0.67476093	0.09639442	0.80	0.5913
REP	7	3.26274342	0.46610620	3.87	0.0022

Total Fruit weight

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	145.8184262	10.4156019	0.92	0.5419
Error	46	519.0740328	11.2842181		
Corrected Total	60	664.8924590			

R-Square	Coeff Var	Root MSE	Totfruitwt Mean
0.219311	20.05394	3.359199	16.75082

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	79.58983997	11.36997714	1.01	0.4384
REP	7	66.22858625	9.46122661	0.84	0.5613

Fruit Defects

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	102.6568116	7.3326294	1.31	0.2398
Error	46	257.9300737	5.6071755		
Corrected Total	60	360.5868852			

R-Square	Coeff Var	Root MSE	defects Mean
0.284694	70.25525	2.367948	3.370492

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	40.35765906	5.76537987	1.03	0.4247
REP	7	62.29915254	8.89987893	1.59	0.1632

Marketable Weight in kilograms

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	233.9324732	16.7094624	1.24	0.2795
Error	46	618.7039202	13.4500852		
Corrected Total	60	852.6363934			

R-Square	Coeff Var	Root MSE	Mktwgtkilos Mean
0.274364	27.40916	3.667436	13.38033

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	73.1658577	10.4522654	0.78	0.6096
REP	7	160.7666155	22.9666594	1.71	0.1308

Marketable Percentage

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	5996.43954	428.31711	1.38	0.1990
Error	46	14226.93849	309.28127		
Corrected Total	60	20223.37803			

R-Square	Coeff Var	Root MSE	makerperc Mean
0.296510	22.38202	17.58639	78.57377

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	1756.138449	250.876921	0.81	0.5826
REP	7	4240.301088	605.757298	1.96	0.0817

Box Stems Ratio

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	1.26621807	0.09044415	1.20	0.3088
Error	46	3.47115898	0.07545998		
Corrected Total	60	4.73737705			

R-Square	Coeff Var	Root MSE	bsr Mean
0.267283	27.65130	0.274700	0.993443

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	0.41684133	0.05954876	0.79	0.6000
REP	7	0.84937674	0.12133953	1.61	0.1572

Yield per tonne

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	1743.817890	124.558421	1.25	0.2762
Error	46	4593.053585	99.848991		
Corrected Total	60	6336.871475			

R-Square	Coeff Var	Root MSE	Yieldperton Mean
0.275186	26.61395	9.992447	37.54590

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	521.510821	74.501546	0.75	0.001
REP	7	1222.307069	174.615296	1.75	0.1212

APPENDIX 2

Williams: Evaluation of banana bunch protections materials for optimum fruit and quality.

Dependent Variable: Weight per hand

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	15.02004249	0.39526428	1.57	0.0256
Error	203	51.10458560	0.25174673		
Corrected Total	241	66.12462810			

R-Square	Coeff Var	Root MSE	Whand Mean
0.227147	16.44393	0.501744	3.051240

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	1.41274583	0.20182083	0.80	0.5867
REP	31	13.60729666	0.43894505	1.74	0.0126

Dependent Variable: Fruit Defects

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	713.282668	18.770597	2.71	<.0001
Error	203	1408.456712	6.938210		
Corrected Total	241	2121.739380			

R-Square	Coeff Var	Root MSE	defects Mean
0.336178	66.09017	2.634048	3.985537

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	70.2551246	10.0364464	1.45	0.1885
REP	31	643.0275431	20.7428240	2.99	<.0001

Dependent Variable: Weight in kilograms

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	190.802355	5.021115	0.96	0.5361
Error	202	1052.732084	5.211545		
Corrected Total	240	1243.534440			

R-Square	Coeff Var	Root MSE	wghtkilos Mean
0.153436	105.3570	2.282881	2.166805

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	39.2005606	5.6000801	1.07	0.001
REP	31	151.6017949	4.8903805	0.94	0.5650

Dependent Variable: Total fruit weight

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	843.609098	22.200239	1.79	0.0057
Error	202	2507.272894	12.412242		
Corrected Total	240	3350.881992			

R-Square	Coeff Var	Root MSE	Totfruitwt Mean
0.251757	21.16161	3.523101	16.64855

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	106.0451873	15.1493125	1.22	0.2929
REP	31	737.5639109	23.7923842	1.92	0.0042

Dependent Variable: Marketable Weight in kilograms

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	5246.22491	138.05855	1.15	0.2632
Error	204	24433.96036	119.77432		
Corrected Total	242	29680.18527			

R-Square	Coeff Var	Root MSE	Mktwgtkilos Mean
0.176758	75.33362	10.94415	14.52757

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	1707.108514	243.872645	2.04	0.0522

REP	31	3539.116398	114.165045	0.95	0.5427

Dependent Variable: Marketable percentage

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	26431.41355	695.56351	2.43	<.0001
Error	204	58390.52678	286.22807		
Corrected Total	242	84821.94033			

R-Square	Coeff Var	Root MSE	makerperc Mean
0.311611	22.34377	16.91828	75.71811

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	6280.33902	897.19129	3.13	0.0036
REP	31	20151.07453	650.03466	2.27	0.0004

Dependent Variable: Box Stems Ratio

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	1109.536290	29.198323	1.12	0.3080
Error	206	5389.189669	26.161115		
Corrected Total	244	6498.725959			

R-Square	Coeff Var	Root MSE	bsr Mean
0.170731	311.9553	5.114794	1.639592

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	374.2404948	53.4629278	2.04	0.0502
REP	31	735.2957951	23.7192192	0.91	0.6129

Dependent Variable: Yield per tonne

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	7007.50923	184.40814	2.02	0.0010
Error	206	18823.50277	91.37623		
Corrected Total	244	25831.01200			

R-Square	Coeff Var	Root MSE	Yieldperton Mean
0.271283	26.87727	9.559091	35.56571

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	7	1838.696024	262.670861	2.87	0.0069
REP	31	5168.813208	166.735910	1.82	0.0075

2013-01-23

Ref. Nr.: 2012/CAES/050

To:
Student: Mr R Kutinyu **Student nr: 43554377**
Supervisor: Prof F Mudau
Department of Agriculture and Animal Health
College of Agriculture and Environmental Sciences

Dear Prof Mudau and Mr Kutinyu

Request for Ethical approval for the following research project:

The evaluation of different banana bunch protection materials on selected banana cultivars for optimum fruit production and quality in Nampula province, Mozambique

The application for ethical clearance in respect of the above mentioned research has been reviewed by the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa. Ethics clearance for the above mentioned project (Ref. Nr.: 2012/CAES/050) **is granted** after careful consideration of all documentation and submitted to the CAES Ethics committee.

Please be advised that the committee needs to be informed should any part of the research methodology as outlined in the Ethics application (Ref. Nr.: 2012/CAES/050), change in any way. In this instance a memo should be submitted to the Ethics Committee in which the changes are identified and fully explained.

We trust that sampling, data gathering and processing of the relevant data will be undertaken in a manner that is respectful of the rights and integrity of all participants, as stipulated in the UNISA Research Ethics Policy.

The Ethics Committee wishes you all the best with this research undertaking.

Kind regards,

Prof E Kempen,
CAES Ethics Review Committee Chair

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2012-11-30

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1. A permission letter from the Matanuska Farm where research will be conducted has not been submitted.
2. Clarification is needed whether any collection of data has occurred, as the proposal has indicated data collection within 2012 – 2013.
3. Clarification is needed whether secondary data will be used.

Please be advised that the committee needs to be informed should any part of the research methodology as outlined in the Ethics application (Ref. Nr.: 2012/CAES/050), change in any way. Should this be the case, a memo should be submitted to the Ethics Committee in which the changes are identified and fully explained.

We trust that sampling, data gathering and processing of the relevant data will be undertaken in a manner that is respectful of the rights and integrity of all participants, as stipulated in the UNISA Research Ethics Policy.

The Ethics Committee wishes you all the best with this research undertaking.

Kind regards,

Prof E Kempen,
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THE EVALUATION OF DIFFERENT BANANA BUNCH PROTECTION MATERIALS ON SELECTED BANANA CULTIVARS FOR OPTIMUM FRUIT PRODUCTION AND QUALITY IN NAMPULA PROVINCE, MOZAMBIQUE RODRICK KUTINYU 43554377 DISSERTATION FOR THE MASTERS OF SCIENCE IN AGRICULTURE DEPARTMENT 35OF AGRICULTURE AND ANIMAL HEALTH UNIVERSITY OF SOUTH AFRICA FLORIDA CAMPUS, FLORIDA, GAUTENG SOUTH AFRICA SUPERVISOR: PROFESSOR F.N. MUDAU Co- SUPERVISOR: MRS C. FRASER A dissertation submitted in fulfilment 2for the degree of Master of Science in Agriculture at the University of South Africa, Faculty of Agriculture and Animal Sciences MAY 2014 15Formatted: Font: (Default) Arial, Complex Script Font: Arial, Check spelling and grammar DECLARATION This dissertation is my original work and has not been presented for a degree in any other university. The results of this study are accepted for publication in Journal of Tropical Agriculture: Tinidad and Tobago

Signature…………………………………… Date…………………………… Rodrick Kutinyu This dissertation has been submitted for examination with my approval from my supervisor and it will be subjected to turn it for detection of plagiarism if the need arise. Supervisor Signature………………………………. Date…………………………… Prof. Fhatuwani N. Mudau University of South Africa Republic of South Africa i DEDICATION This study is dedicated to my wife Spiwe Naomi Kutinyu (Manjiche). My children Kirsty T. Kutinyu and Ariel R.N. Kutinyu. I also dedicate this study to all employees from the Technical services department of Matanuska Mozambique Lda. Thanks for being there for me when I needed you most. God bless you always and help you to achieve your dreams ii ACKNOWLEDGEMENTS I thank the Almighty God for giving me the strength, courage, energy and guidance to come this far in my life and career. Further to this I express my sincere thanks to Prof. F.N. Mudau for his invaluable advice, guidance and academic counsel throughout this study. To Mrs C. Fraser for her valuable guidance, professional help, understanding and encouragement. I acknowledge the support of Matanuska Mozambique Lda, for sponsoring the major part of this study. Special thanks also go to the Technical Services Department of Matanuska Mozambique Lda for support and assistance during my research studies. Special thanks and gratitude goes to Ms Penny Ngcobo of the University of South Africa, Florida Campus for her endless support, patience and commitment in getting me a Supervisor to see me achieve my academic success. To my in-laws, Mr & Mrs Manjiche, brothers and sister in law. Thank you for your prayers and encouragement. My sisters thank you for your prayers. iii TABLE OF CONTENTS Comment [MF1]: No align straight

 LIST OF ABBREVIATIONS AND ACRONYMS ANOVA Analysis of variance AEZ Agricultural Eco Zones BSR Box stems ratio CRBD Complete Randomised Block Design EU European Union GLM General Linear Model UPD Under peel discolouration RH Relative Humidity UAE United Arab Emirates viii The Evaluation of different Banana bunch protection materials on selected Banana cultivars for optimum fruit production and quality in Nampula Province, Mozambique ABSTRACT Mozambique has potential to boost its banana exports. To fully realise this, agronomic practices in production should be fully developed to compact physiological disorders associated with banana within the region. Currently, lower temperatures are being experienced in some production sites, consequently affecting yield and quality. 39The objective of this study was to evaluate use of bunch protection covers on Grain Nain and Williams's banana cultivars, for performance under different fruit protection materials to determine best fruit protection bag suitable for Metocheria, Nampula. Plants were not selected near plantation borders, drainage canals, cable way and roads, as this would influence the growth pattern of plants and fruit development. Treatments consisted of control (no bag on bunches), white perforated polyethylene, white non-perforated polyethylene, blue perforated polyethylene, blue non perforated polyethylene, green perforated polyethylene, green polyethylene non perforated and cheese cloth bags arranged in a complete randomised block designed CRBD with 26 plants as replicated 8 times. Summary of results During 2012/2013, bagging treatments did not considerably improve weight in hands, banana finger weight, total fruit weight, marketable

weight and percentage marketable fruit weight and box stem ratio BSR of Grand Nain. However there was reduction of fruit defects in all bagging treatments compared to control (no bags).In Williams during the 2013 season bagging treatments improved weight but no significant differences were observed on weight of hands in 2012. Bagging of banana bunches reduces defects in both seasons. Both green and blue perforated bags improved box stem ratio (BSR). Bagging treatments increased Williams's cultivar yield per ton in both seasons. Keywords: banana bunch cover, early bagging, de-handing, calliper ix Comment [MF3]: Why underline CHAPTER 1 1.0 INTRODUCTION Banana (Musa sp.) 21is the most consumed fruit in the world. In Mozambique as in other banana producing countries bananas constitute a part of the staple diet in most families. Bananas are also an important part of the smallholder farming communities and families living in rural areas. 20Edible bananas (Musa spp.) are believed to have originated from Asia and were distributed throughout the world during early migration of Polynesians (Simmonds, 1962, Lorenzen , 2010). Bananas are said to have been brought into East Africa by the Portuguese expeditions during the fifteenth century (Purseglove, 1975). The most important banana cultivars are the AAA-triploid cultivars originating from Musa acuminate and are mainly consumed as desserts according to (Lahav and Israeli, 1986). Most of the banana production in the rural areas in Mozambique is done in small sized farms, around the household plots, in low lying areas or close to annual water streams. With the climate in Mozambique being able to sustain and produce bananas throughout the year they have become an important part of the food security strategies of most rural families. Banana cultivation in Mozambique still has a few challenges to overcome such as low level of technical know-how, poor fruit quality which does not meet the export market standards. However, the availability of good technology and knowledge can bring about the best marketable export crop from Mozambique. The cultivation of bananas can be under tropical and subtropical climates (Marriot, 1980, Panis and Thinh, 2001). The climate in the Northern parts of Mozambique has been the reason for the Metocheria Farm project set up. This coupled with good soil conditions ideal for the cultivation of high quality bananas. Good cropping practises and post-harvest management will go a long way in getting superior banana quality. Other competitive edge of banana industry in Mozambique is proximity to the port, good government land legislation, infrastructure and good foreign exchange controls for investors. However, the climate changes, lack of data and experience with some growing conditions has brought some areas needed to overcome in the production of quality bananas for the export markets. The lower than average expected winter temperatures, very high wind speeds and knowledge or skilled worker experience is still 10 15Formatted: Font: (Default) Arial, Complex Script Font: Arial, Check spelling and grammar a main obstacle to meet export quality standards. Low temperatures can affect bunches over a long period, if the normal harvest is 14 weeks, the stems developed during the winter season can be formed poorly and this can result in a delayed harvesting period of 5 or 6 weeks more. Major banana 32growing areas of the world are geographically situated in the tropics between the equator and latitudes 20° North and 20° South (Stover and Simmonds 1987; Robinson, 1993). Production of bananas in the subtropical regions is situated between 20° North and 30° South (Stover and Simmonds, 1987). The value of banana exports is higher than those of most fruits such as oranges, apples and vegetable that is tomatoes and potatoes (Frison and Sharrock, 1999). Bananas are consumed for their nutritive and therapeutic values (Stover and Simmonds, 1987). The cooking and dessert bananas are a rich source of energy of approximately 128kcal and 116kcal per 100g (Gowen, 1995). They provide carbohydrates and are low in cholesterol, salt free which makes them be recommended for overweight and geriatric patients (Stover and Simmonds, 1987). According to

Muchui (2010) chilling of banana fruit is a function of time and temperature and this damage can affect exportation of fruit to the European market. The physical appearance of the peel is important in the highly competitive export markets. Buyers in these prime markets require consistent supplies of uniform coloured fruit with blemish- free peels. Banana bunch covers allow for production of high quality bananas that are not bruised and hence acceptable visual appearance. Consumers use visual quality to purchase fresh produce in the retail markets (Shewfelt, 1999, Shewfelt 2009). The returns to farmers are also higher based on the marketing of generally larger fruit which is blemish free. According to studies conducted by Irizarry in 1992, the low temperature also reduces the growth extending the period between the flowering and the harvest of the fruit. 4For centuries, old banana leaves have been wrapped around maturing bunches in New Guinea. It was in the year 1936 that they 10demonstrated that covering bunches with 11 Hessian protected them against winter chilling and improved fruit quality (Turner, 1984). Temperatures coupled with wind blows and debris which affect delicate outer skin causing cellular damage and subsequent fruit scarring. Considerable physical injury and damage to the fruit peels can also be caused by the blowing of adjacent leaves and rubbing leaf petioles onto the developing bunch (Anon, 2003). This leaf chaffing during growth has also been eliminated by bunch covers (Weerasinghe and Ruwapathirana, 2002). Banana fruit protection bags are widespread used 8throughout the commercial banana growing areas of the world. These bags are mainly used to improve fruit production and quality, especially fruit intended for the export markets. Fruit protection bags of various colours, perforated and non-perforated, have been extensively used in both tropical and subtropical banana growing countries with the aim of improving yield and quality (Stover and Simmonds, 1987). Some of these quality parameters include acceptable skin appearance and colour, increase in finger length and bunch weight as well as reduced fruit defects for example sunburn and fruit splitting (Amarante et al., 2002). Several studies have also been used to protect bunches from low temperatures (Gowen, 1995; Robinson, 1996; Harhash and Al-Obeed, 2010) and has shown to reduce winter stress under supra-optimal condition (Harhash and Al-Obeed, 2010), which resulted in early fruit maturation (Robinson 1984; Daniels 1987 and 1992; Irizarry 1992 and Sauco 1996). Historical climatic data originally collected from a weather station close to Metocheria farm showed average winter temperatures of 15-16˚C. However, recent data collected from the weather stations on site, showed a continued decreased in temperatures for the years 2010 to 2012 with temperatures dropping to 11.8˚C. Temperatures below 12 to 13 ºC can cause under peel discolouration (UPD) which indicates that the fruit was subjected to chilling temperatures during the development stages. Under peel discolouration (UPD) consists of a reddish-brown streaking in the vascular tissue just below the epidermis of the fruit. It is visible in green fruit only by peeling back the 12 epidermis with a knife (Robinson et al., 2010). Once this discoloration occurs, it is irreversible, thus subsequent damage is cumulative in a plantation with bunches of different ages. Fruit with severe under peel discolouration (UPD) will not ripen to a bright yellow colour and will therefore not be acceptable to export markets. Low temperatures also reduce fruit growth which will extend the period from flowering to harvest of the fruit. For example, if the normal flower to harvest period is 12 or 13 weeks during summer months, this period can extend with 4 to 6 weeks which influences markets estimates. In several countries Kraft paper bags were used to reduce the effect of cold temperatures, for example in La Lima, Honduras Kraft paper was used to reduce the chilling incidence and in Colima, Mexico producers are periodically use paper bags over polyethylene bags to reduce this problem. Besides protection against temperature variations, fruit protection bags are also use to protect bunches against wind (leaf scarring) damage, insect damage, and sunburn as well as increase fruit uniformity. 49The aim of the study was to develop banana management strategies, different colour polyethylene bags, perforated and non-perforated and with different thicknesses together with paper bag combinations will be evaluated to determine the most effective bag to be used during the cool winter months at Metocheria Farm, Mozambique. The current study will provide basic agronomic practices suitable for competitive banana industry in Mozambique. 13 1.2 PROBLEM STATEMENT There has been a shift in banana industry from South Africa to Mozambique due to land claims and other political uncertainties related to land in South Africa. Recently, Industrial Development Cooperation (IDC) has huge exposure in banana industry in Mozambique over the past years. The initial projects set up or feasibility studies were based on historical climatic data which showed generally high winter temperatures averaging 15-16˚C. However, recent data collected from the farm weather stations showed a decrease in temperatures during the past 3 years with minimum winter temperatures dropping to 11.8˚C. The effect of lower than average winter temperatures may result in under peel discolouration of fruit due to chilling injury and will not be acceptable for the export markets. These markets require consistent supply of uniform, good quality fruit with an acceptable physical appearance. The ability to supply these markets with such fruit becomes more difficult when fruit development takes place during the cool winter months. Different bags were used for bunches developed during winter and summer. The use of non-perforated blue or white polyethylene bags with a thickness of 30-35 micron have increased temperatures inside the bag and shorten the development cycle of winter bunches (Robinson and Nel, 1984). White perforated bags have been used in summer and are ideal for hot humid conditions. Reflection of direct solar radiation, which results in lower temperature inside the bunch, has resulted in better green life. However, it is also not known which cultivars will be best suitable for such an agronomic management practices in Mozambique. 14 1.3 RESEARCH RATIONALE The production of bananas on a commercial scale in Northern part of Mozambique has been modelled according to experiences and conditions of Central American and Southern African countries as well as banana growing areas in the Southern parts of Mozambique. However, the climatic conditions (low temperatures, high winds, low humidity, and short rainy season) as well as the pests and disease pressure and the effect thereof on banana production in the North of the country have proven to be different than originally predicted. The effect of the lower temperatures and chilling injury when temperatures below 13˚C are experienced. Thus, results in non-exportable fruit quality. The commercial production of bananas in the North of Mozambique is based on exporting at least 95% of all production. It is important to determine what the effect of different bunch protection bags on fruit developing and quality during the winter months. In the beginning of the project the materials used for bunch protection have been sourced from other commercial banana producing countries i.e. Costa Rica, Philippines, Zimbabwe and South Africa, but locally produced bags are being used in most of banana cultivars. These bags differed in colour (blue and white), perforated and non-perforated and had different thickness (20 – 40 micron) and gave different results on fruit quality especially during the winter months. The re-writing of a growth model for commercial banana production in this region is required to ensure very realistic crop production cycles, yield estimates and the supply of fruit of a constant export quality throughout the year to maximize returns for the business. The need to evaluate bunch protection materials during the winter months has been identified due to long production cycles which have affected the planning of the business and fruit quality mainly coming out of winter and potential chilling damage. The viability of setting up farms for commercial banana production in this region was based on the shorter production cycles which results in increased returns and more bunches per hectare per farm per season/year. 15 The changes in climatic conditions, especially low winter temperatures which may result in chilling injury on the fruit and longer fruit development cycles will have a huge effect on fruit with export quality and potential income/return per dollar invested. This has prompted the need to further do research on different bunch protection materials in this region. Various studies have shown that both yield and quality are significantly being improved by the use of fruit protection bags (Robinson et al, 1984). It was also proven that winter fruit fill faster under covers which accelerated bunch development which resulted in overall shorter cycle times (Daniells et al, 1987). 1.4 AIM To evaluate bunch protection covers on selected cultivars and to develop management practices suitable for banana production and achieve exportable fruit quality in Northern Mozambique. 1.5 OBJECTIVES Evaluate cultivar performance of Williams and Grand Nain under different fruit protection bags. 1.6. HYPOTHESIS The fruit protection bags do not influence cultivar performance of William and grand Nain suitable for banana production at Metocheria Farm, Namialo. 16 28CHAPTER 2 2.0 LITERATURE REVIEW 2.1 Classification The banana plant belongs to Musaceae family. The family has two genera, Musa and Ensete. The earliest classification of bananas was made Linnaeus in 1783 when he named 16all dessert bananas Musa sapientium which are sweet when ripe and are eaten as fresh (Robinson et al., 1984). 16The name Musa paradisiaca was given to the plantain group which are cooked and consumed while starchy and generally called the cooking banana. The modern classification of edible bananas was given by Robinson (1984). The modern edible banana comes from two wild species which are seeded that is Musa acuminata (donor of A genome) and Musa balbisiana (donor of B genome). Clones containing A and T genomes or even A, B and T genomes have been identified in Papua New Guinea. However, the edible bananas belong to the Eumusa and have 22, 33 or 44 however the basic haploid number is 11 but cultivars can only be diploid, triploid or tetraploid (Robinson et al, 1984).The 25most cultivated bananas and also plantains are triploids (Robinson et al, 1984). These cultivars were derived by natural hybridisation between the 25two diploid species Musa acuminata and Musa balbisiana. The Musa genotypes are classified in the natural germplasm by ploidy level and the 43relative expression of M. acuminata and M. balbisiana characteristics. According to this method, the Cavendish and East African highland bananas were categorised as AAA, plantains as AAB and most of the cooking bananas as ABB (Robinson et al, 1984). 2.2 Nutritional value of banana The commercial bananas are called dessert bananas; these have become very popular in modernised countries and are widely eaten across all ages (de Valdenebro et al, 2006). Bananas have a very good nutritional value with 1.1g protein,0.2g fat, 22g carbohydrates, 7 g calcium, phosphorous 27 g , 0.9 g iron, 10 g vitamin C and A, B per every 100 g of any edible portion (de Valdenebro et al, 2006). They are an important source of energy and are fed to sport people as they are also cholesterol –free and very 17 high in fibre. The only difference in banana nutrition exists between genotypes dessert bananas and cooking bananas have high Calcium (Ca) and magnesium (Mg) levels than ordinary plantains (de Valdenebro et al, 2006). 2.3 Botanical description The banana plant is a monocotyledonous, herbaceous and evergreen perennial of which plantations can last up to 50 years (personal communication, Chiquita CTO, 2012).The plant consist of subterranean stem or rhizome that bears developing suckers, an adventitious root system, a pseudo stem, 26leaves and an inflorescence that bears flowers which subsequently bear the fruit. The banana flower is structure consists of a 26stout peduncle on which flowers are arranged. Flowers are found on nodal structures with each node comprised of two rows of flowers (National Agriculture Research Institute Guyana, 2003). On the basal (proximal) nodes the female flowers are borne and these develop into fruit and sometimes range in numbers from 5 to 16 nodes per stalk. On these nodes, when they contain double rows of fruits they are then called hands and the individual fruit itself is called fingers. On the distal part, the nodes contain male flowers which remain tightly closed and these form the bell. Between the male and female nodes are several nodes containing hermaphrodite (male and female) flowers which develop into edible banana fruits. In commercial practises the bells in cut when the distance between the last hand and the top bell is about 15cm and meristem growth is prevent(National Agriculture Research Institute Guyana, 2003) Thus help direct the plant photosynthetic energy to increasing the fruit size. The 29hermaphrodite flowers below the developing fruit usually abscise and leave a callus scar on the stalk. After fruit harvest the aerial parts die down to the ground and there are no woody components. New suckers grow up from the base of the mother plant to replace aerial parts that have died. Banana plants can reach a height of 3 metres or more depending on variety and conditions (Karamura et al, 1995). In the fruit, the most abundant constituent is water within the pulp and peel of the banana fruit. In comparison the pulp of a dessert banana has higher water content than a plantain fruit. The water content 18 increases at ripening, however it is then lost from the peel externally due to transpiration and the ripening process will continue to degrade the peel which then reduces further water loss. A fully ripe banana has 75% water of its pulp mass whilst the plantain has 66% of its pulp water mass (Robinson et al, 1984). The two main components of yield of bananas are fruit mass (hands per bunch, fingers/bunch, finger length and calliper) and cycle time (harvest to harvest intervals). Improving yield therefore involves either an increase in fruit mass or a reduction in cycle time. These two components as well as fruit quality are affected by the environment, cultural practises, biological and post-harvest factors. Being a tropical plant, subtropical climatic conditions seasonally restrict fruit development and quality. These factors need to be identified in order to adapt management practices to increase production and improve quality (Eckstein, 1994). 2.4 Climatic conditions The studies were carried out over two consecutive season's i.e. 2012 and 2013. The site average temperatures were 24.9°C and 23.7 °C for 2012 and 2013 banana growing season. However in week 29, 2012 the average temperature recorded was 20.23 ^{0} C with a maximum temperature of 30.7 °C and a minimum temperature of 11.70 °C for 2013 week 29 the average temperature recorded was 20.57 °C with 44a maximum of 27 .9°C and a minimum of 12 .6°C. This data is indicative of the effect climate has during the winter months of banana production damaging fruit quality and slowing growth. According to Stover and Simmonds (1987) and Robinson (1993) optimum climatic requirements for the banana are a mean daily temperature of 27 ^{0}C, mean minimum temperature not below 20 ^{0}C and well distributed rainfall of 75 – 100 mm/month. A mean daily temperature of 16 ^{0}C represents the minimum for leaf area increase (development), while 14 ^{0}C is the minimum for growth for bananas (Robinson, 1993). There are also a range of fruit physiological disorders resulting from low temperatures exposure during certain plant development stages. For example, if the fruit is exposed to chilling temperatures during development, a discoloration of the vascular tissue 19 occurs, leading to brown stripes which mask the normal yellow colour of the fruit when ripe. This is called "under-peel discoloration" (Robinson, 1993). Some of these physiological disorders can be avoided to a limited extend by adapting some of the agricultural practices, for example using different fruit protection bags in the winter than in the summer. Uneven de-greening, a kind of ripening disorder in banana peels, occurs seasonally in Taiwan where it is a serious quality problem. The affected bananas are characterised by either partial or delayed yellowing of the peels in mild cases or by remaining green in severe ones following ethylene treatment. Some factors suspected for its occurrence include chemical hazards, virus infection, and overuse of nitrogen fertiliser, low temperatures and genetic factors. Temperatures below 20 °C in winter during bunch development and genetics have been so far considered as the major contributory factors of uneven de-greening. An integrated strategy was designed to reduce uneven de-greening (Chiang., Tang., Chao and Hwang, 1998), including the use of cultivars of low susceptibility to the disorder, elimination of affected plants from stocks nurseries which supply suckers for micro propagation programs and the use of brown paper covers instead of blue polyethylene covers for bunch protection) (Chiang., Tang., Chao, and Hwang, 1998) 2.5Wind Wind blows dust and debris which hits the delicate outer skin causing cellular damage and subsequent fruit scarring (Anon, 2003). Considerable physical injury and damage to the fruit peels can also be caused by the blowing adjacent leaves and rubbing fruit petioles onto the developing bunch (Anon, 2003). Anon (2003) reported that it is economical to establish windbreaks if the prevailing wind constantly tears new leaves into strips of less than 50mm wide. Though windbreaks have many disadvantages in this instance they will become beneficial as they will improve the fruit quality from the effect of wind damage. 20 2.6 Nutritional requirements Bananas require large amounts of mineral nutrients to maintain high yields mainly in commercial farms. Nutrient supply can either be from establishing the plants in very fertile soils, fertilisation, and giving supplements to the crop through fertilisers to improve soil fertility (Jaizme-Vega et al, 1995). Major nutrients required by bananas are Nitrogen (N), Potassium (K) and low level of Phosphorous (P). The optimum level of Nitrogen (N) 275kg N/ha/yr ,this will be an equivalent of 980kg LAN per hectare per year with LAN containing 28% N, Potassium is recommended at 800kg K /ha/year. This will be derived from using KCL, which is potassium chloride which will be 1,600kg/ha/year with KCL containing 50% K. 2.7 Protection bags Cuneen and McEntrye (1988) evaluated whether the colour of banana bunch covers has an effect on yield of bananas and the climate inside the bag within the cover bunch. Though coloured bags are used to cover bunches for several reasons, i.e. to reduce the time between flower emergence (Sauco, 1992) and early harvesting (Sauco, 1992), to improve banana quality and quantity (Robinson and Nel, 1984), as protection to against injuries caused by solar radiation or by pests or mechanical injuries (Soto, 1995). The studies with different coloured plastic bags (green, blue, black, orange, blue/silver and clear/silver) enclosed in a wire frame indicated that during the day indicates that temperatures inside the bag were 10˚C higher than the outside air temperature (Cuneen and McEntyre ,1988) and that during the night the temperature inside the bags fell slightly below the outside temperature (Cuneen and McEntyre ,1988) The clear/silver bag resulted in the highest day-time temperature increase and the black bag the lowest increase (Cuneen and McEntyre ,1988). In studies using the bags as bunch covers, 27no significant differences in yields and quality were found for the different coloured bags, although yields were highest for bunches inside the clear silver bags (Cuneen and McEntyre, 1988) it was suggested that the clear/silver bags may be of value during the winter period (Cuneen and McEntyre, 1988). 7Bunch covering and 21 harvest delay combinations on the environment inside the bunch covers and on fruit yield and quality parameters (Cuneen and McEntyre, 1988). During clear weather in January between flower emergence and fruit bunch filling in the North West of Australia (average air temperatures 7were 3, 5 and 6°C above ambient inside unsealed single standard covers, unsealed double covers and sealed double covers respectively. Differences were smallest at dawn and greatest in the late afternoon. During clear weather in July between flower emergence and harvesting the temperatures were 1°C, 1.5°C and 2°C above ambient, respectively (Cuneen and McEntyre, 1988). In subtropical banana growing countries, with cold winters and strong winds, the benefits of bunch covers are both physiological (improved microclimate) and physical (larger fruit and reduced chaffing from dust and leaves). According to reports from Daniells ,1994 and Johns,2005 they describe increased finger length, higher yield and shorter flower to harvest interval in various subtropical countries. Temperatures under the cover were 2˚C to 46˚C warmer and during cool times of the year this increased fruit length and hastened fruit filling (harvest duration was 4 to 14 days earlier). The yields are much less during the warmer months and special care needs to be taken to avoid sunburn under covers during these warmer months. This involves the use of reflective silver covers and pulling down a leaf over the cover. Perforated covers are commonly used to reduce sunburn damage for export production overseas (Daniells and Lindsay, 2005) 1Bunch trimming (removal of male bud and several distal hands from bunches soon after flowering), and double covering (use of 2 bunch covers simultaneously) of banana that emerged during winter in South Wales showed an increase in size. 1Bunch emergence to harvest interval was reduced by an average of 5 days by bunch trimming. Finer length increased1with the average length for the top 6 hands increased by 2,3% ($P<0.01$) for the 10 hand treatment to 6.1% ($P<0.001$) (Johns, 2005).Finger length 1increased with increasing severity of bunch trimming , weights for 6 top hands increased by up to 14%($P<0.001$) for the 6 hand treatment (Johns, 2005). In tropical countries no differences were observed in yield, finger length or flower to harvest interval between covered or uncovered bunches, benefits were related more to blemish control and reduction of pest damage (Rodrigues et al, .2008). Robinson and Nel (1982) used 22 different bunch cover combinations in during the summer at Burgeshall in South Africa. Bunches of Dwarf Cavendish bananas arising from flowers emerging in late November/early December were enclosed in brown paper bags of polyethylene covers of different colour combinations, this was after bunches emerged and flower bracts starting to open up. The proportion of clean fingers was low (9-12%) with up to 48% damaged by trips and mites. Fruit surface temperatures especially in the front and relative humidity in the afternoon were highest in polyethylene bags, resulting in the highest percentages of soft rots (15%) and uneven ripening (Robinson and Nel, 1982). The effect of banana bunch covering especially in the tropics has demonstrated inconsistent results on the size. 1Double covering increased finger weight of the top 6 hands by 4% ($P<0.01$). Trimming to 10, 8 and 6 hands increased the yield per bunch of extra grade fruit by 18, 23 and 39 % (Johns, 2005) maturity (double covering did not affect the yield of extra-large fruit significantly (Johns, 2005). Bunch covering had 45no significant ($P>0.05$) effect on the pulp/peel ratios of fruits of cv. Williams at harvest and during ripening. It was seen that in bananas, the pulp portion continues to grow even in the later stages of maturation (Turner, 1997, Nakasone and Paul, 1998), skin colour (Turner,1997) and other post-harvest (Turner,1997). However, this may be due to the different types of bags for bunch covering used, the age of the fruit at covering, fruit and cultivar response, the climatic conditions and also the conditions in which fruit is held pre and post-harvest and all this factors influence fruit quality (Amarante et al, 2002). External appearance includes key attributes such as colour, shape, size and free from defects. Internal attributes such as taste, texture, sweetness, aroma, acidity, flavour, shelf life and presumed nutritional values of the fruit are important in ensuring repeat buys for sustained repeat purchase (Hewett, 2006). The findings reported by Stevenson (1976) showed that with summer bunch covering no particular colour of covering material substantially accelerated of delayed bunch filling, but in winter the use of transparent material speeded up the filling and harvesting of banana bunches. Thus, raises the need to further evaluate banana bunch covering materials for the warm season for evaluating peel quality (Stevenson, 1976). 23 Banana bunch cover thickness (µm) plays a very important role in influencing temperatures inside the bag within the bunch. Economically, it is better to use thinner bunch covers as damage is bound to occur and plastic damaged not being able to be re-used again. Blue polyethylene banana bunch covers of 0.075mm thickness lasted longer than either 0.050 or 0.100 mm film. The 0.100mm covers suffered from a high incidence of disintegration (Trochoulias, 1975). The longevity of polyethylene bunch covers for bananas in relation to thickness was evaluated by Trochoulias (1975). The author reported that four thicknesses of blue polyethylene bunch cover (0.038, 0.050, 0.075 and 0.100mm) for bananas compared for longevity under field conditions. The longevity index, days in the field and condition score of covers increased as the film thickness increased from 0.038 to 0.075mm but 0.100mm covers were better than the 0.038mm covers. After one year, the 0.100mm covers performed poorly compared with the thinner films (Trochoulias, 1975). The covering of bunches has become a cultural practice in commercial dessert banana production. Choudhury et al., (1996a) investigated the effects of bunch covers (black, white or blue polyethylene, gunny bags or dry banana leaves) and soil application of mustard oil cake (1kg/plant, alone or in combination with white 7polyethylene bunch covers) on the growth and yield of bananas of banana (cv.Dwarf Cavendish).Yield (bunch weight, bunch length, number of fingers per bunch, finger length, finger weight, finger volume and weight of second hand) was significantly influenced by bunch cover treatment. The highest bunch weight (15.25 kg) and yield (67.78 t/ha). The cost: benefit ratio of this treatment was low (1:2.8). The lowest cost: benefit ratio (1:1.92) was obtained from the mustard oil cake treatment. The highest cost: benefit ratio (1:3.53) was observed in white bunch cover treatment (Choudhury et al, 1996a). Choudhury et al, (1996b) reported that using white polyethylene covers resulted in the lowest number (10.67) of banana fingers per bunch and Gas lepta subcostatum was obtained using a white polyethylene bunch cover treatment. The authors also reported 24 that crop duration, particularly days taken from planting to flowering, and flowering to physiological maturity and production per day was significantly influenced by different bunch cover treatments. Plants treated with a white polyethylene cover and a soil application of mustard oil cake matured earlier (430.00 days) compared to the untreated control plants (467.67 days) (Choudhury et al, (1996b). The same treatment also shorten time (106.33 days) from flowering to physiological maturity in comparison with the untreated control (142.00 days) and economical for controlling damage caused by Basilepta Subcostatum, and avoided the use of insecticides thus resulting in higher yields (Choudhury, 1996b). Early removal of smaller distal hands leaving only one nurse finger to stop peduncle rot has been found to improve the export quality of the banana bunch (Farrel et al, 1987). The removal of up to three distal hands is now a standard practise on Cavendish bananas in the tropics helping increase finger length on the remaining hands per bunch. The trimming of banana bunches covered with polyethylene bags of a plant crop of cv. Williams were also reported by Daniells et al, (1987). The author's reported that banana bunches of a plant crop cv. Williams covered with polyethylene covers one week after abscission of the last female flower bract while others were left uncovered They were also subjected to one of three bunch trimming treatments (0, 1 or 2 distal hands were removed). In a second experiment the same bunch trimming treatments were applied to a ratoon crop without bunch covers (Daniells et al, (1987). Bunch covering increased weight /bunch by 4% and decreased the period of bunch emergence to harvest by 5 days. Bunch trimming 1increased finger length of fruits at the proximal end of the bunch. Removal of 1 hand/bunch reduced yields/bunch in both experiments by 7% and removal of 2 hands/bunch reduced yields by 15% and 13% in two experiments respectively. Yield reductions occurred without any improvements in fruit grades (Daniells et al, 1987). Four bunch trimming treatments (retention of all hands and the bell, or retention of 10, 8 or 6 hands and removal of the bell) were combined with 2 covering treatments (use of 1 or 2 blue /silver covers/bunch) in June and July 1987(Johns 1988). Bunches harvested between 8 November and 29 December. The six (6) hand treatment 25 produced 35% more extra-large fruits than the untrimmed control, but produced fewer large fruits and no medium sized fruits. The use of a second bunch cover resulted in only a slight increase in yield over the use of a single cover (Johns, 1988). John (1996) evaluated the 1effects of bunch trimming and the use double bunch covers on the yield of bananas in winter. The banana bunches (on 10-year-old Great Cavendish cv. Williams plants) 1were either trimmed to 6, 8 or 10 hands or left untrimmed (male bud retained) (John, 1988).The 1bunch harvest interval was reduced by an average of 5 days by bunch trimming. Finger length increased with1by 2.3% for the 10-hand treatment and by 6.1% for the 6-hand treatment. From the studies carried out by Johns (1988) the results also showed the 1finger weight increased with increasing severity of bunch trimming, with weights for the top 6 hands increased by up to 14% by the 16-hand treatment. Double covering increased finger weight of the top 6 hands by 4%. Trimming to 10, 8 and 6 hands increased the yield per bunch of extra-large grade fruits by 18, 23 and 39%, respectively (John, 1988). 2.8 De-handing and sucker management De-handing and sucker management is also very critical on bunch quality and yield of a bananas and plantains (Irizarry et al, 1992). The authors also reported that suckers affect the fruit quality through competition for nutrients and water. Large suckers reduce transmission of radiation; compete with the parent plant affecting the latter by extending the cycle and resulting in yield reduction. According to Robinson and Sauco (2010), 31allowing suckers to reach 500 mm to 800 mm before removal, the average yield per hectare 31per annum after three cycles was reduced by 7.6 and 15 .6% respectively compared with the standard practises off removing the suckers at no more than 300mm (Robinson and Sauco, 1990). Good sucker selection and proper de handing practises are essential in getting a good quality bunch. From two long-term banana experiments conducted to determine the effect of bunch bagging, the removal of lower hands and sucker management on fruit and bunch characteristics and total yield. Irizarry et al, (1992) reported that removal of lower hands increased individual fruit size. Bunches covered with either Dursban-treated or untreated perforated polyethylene 10 539 kg/ha 26 more than uncovered bunches during a 40-month production period. Considering the price that quality bananas demand at the farm gate and the cost of bagging (materials and labour), this practice represents a net profit of $3 329.25/ha (Irizarry et al, 1992)). The removal of the 3 lower hands from the immature racemes significantly reduced bunch mean weight and total yield. However, both removal of lower hands and bunch bagging increased size of individual fruits in the distal hand, thus up-grading fruit quality. In addition, these practices also reduced the number of days required from bunch- shooting to harvest (Irizarry et al, 1992). The selection of a vigorous sword sucker soon after planting, combined with repeated pruning of other competing suckers, produced the highest yield of 183 744 kg/ha during a 40-month period (Irizarry et al, 1992). 2.9 Banana diseases Fruit diseases such as Cigar end Rot, sp. Verticillium theobromae, Trachysphaera fructigena, Crown rot sp Colletotrichum musae,Fusarium moniliforme,Fusarium pallidoroseum and Anthracnose peel blemish sp C. Musae (Robinson and Sauco, 1990). Cigar-end rot from fungi Verticillium theobromae,Trachysphaera fructigena pathogen attacks flowers thus infecting the perianth. In the development phase, the initial perianth infection spreads slowly along the fruit causing the banana peel skin to blacken. Banana tip area is usually covered with powdery spores which resemble the ash of a cigar (Robinson and Sauco, 1990). Polyethylene bunch covers also help to prevent infection (Robinson et al, 1990). Crown rot usually occurs in packing houses which are not clean with good and strict sanitation. The most common fungi Colletotrichum musae is very common in different banana producing countries. Spores of the fungi colonise the wound excised from the banana bunch causing the rotting to spread from the cut surface into the crown of the hand or bunch during transit of fruit. Immature fruit in the field is usually the source of Anthracnose peel disease, the infection originates from immature fruit but signs of lesions development are seen only 27 when fruit ripens then the fungus is able to penetrate the fruit peel. Large oval lesions develop with salmon coloured fruiting spore bodies (Robinson and Victor, 2010). Pests such as thrips Chaetanaphothrips spp. feed on the soft skin of immature fruit under the hidden surfaces and between closely packed fingers. Once fruit develops, rust like blemishes become roughened and occasionally cracked. Most species are controlled by the use of banana bunch covers especially using the early bagging system which is just after bunch emergence. Other pests such as beetles can also cause at a later stage of bunch development but are also controlled by bunch covers (Robinson and Sauco, 2010). In further investigations on the control of Hercinothrips bicintus (Bagn.) and Tetranychus lombardini on bananas in South Africa, triazophos and chlorpyrifos adequately controlled both pests on uncovered fruit when applied at intervals of 6 weeks in August- January during fruit development after flower bracts dropping. A single application to young bunches before covering them with plastic bags (a practice that became common in the winter of 1978) controlled the pests until harvest. In addition, a segment of dichlorvous strip measuring 2x1.5cm controlled both pests when placed in young bunches that were then covered with a bag (Choudhury et al, 1996b). The mite Calacarus citrifolii Keifer was observed for the first timer as a pest on the experimental site where it occurred more on covered bunches than on uncovered ones and was not adequately controlled by Dichlorvos; over-mature bunches were particularly prone to damage and correct timing of harvesting is recommended in preference to the application of the acaricides against C. citrifolii (Jones, 1979). In field studies conducted in India, the 24influence of bunch cover treatments on infestation of fruit scarring beetle and crop duration in Dwarf Cavendish banana. The lowest number (10.67) of banana fingers per bunch infected by Basilepta subcostatum was obtained using a white polyethylene bunch cover treatment (Kimani et al. 2010). This was 7.50% of the total number of fingers per bunch compared with 54.67 (52.91% of total fingers per bunch) in untreated controls. Crop duration days from plant to flower development and flowering to physiological maturity and production per day was significantly influenced by different bunch cover treatments (Kimani et al, 2010). Plants 28 treated with white polyethylene cover and a soil application of mustard oil cake matured earlier (430 days) compared to untreated control (142 days) (Choudhury et al, 1996b). This treatment had highest production of fruit (157.63 kg/ha per day) which was equal to the white polyethylene bunch cover treated plants (153.73 kg/ha per day) (Choudhury et al, 1996b). The authors also suggested that the bunch cover treatments with polyethylene were effective and economical for controlling damage caused by B. subcostatum and this avoided the use of insecticides which eventually gave higher yields. 29 SUMMARY The uses of banana bunch covers improve fruit peel quality, reduce bunch emergence to yield periods, protect the fruit from insect and pest damage. The two yield parameters important for optimum banana production are bunch weight and cycle times, which are evidently, influenced by the environment and management practices done commercial farmers. The management practise of using fruit protection (bunch cover) bags during certain stages of bunch development has positively impacted the production of bananas. The export quality of banana can only be achieved by producing a blemish fruit. Post- harvest shelf life is significantly influenced as banana bunch covers effectively reduce 8both physical and insect damage to the peel. The advantages such as increased yield with larger 10fruit, more uniform fullness of the fruit within the bunch the protection from mechanical damage while the fruit is hanging in the plantation and in the transportation to the packing houses. Fruit appearance is better under bunch covers which is what a consumer needs as the impression of a blemish free fruit is one of the major factors of influencing a buyer for the fruit. Physical and biochemical properties of the banana fruits are not affected by bunch covers. Fruit under covers is clean compared to that which is grown uncovered which implies reduced water usage during post-harvest preparation of the fruits. Bunch covers can be used non-perforated during the cooler months and perforated during the warm months to avoid any sunburn to the fruit. However bunch covers alone without proper post-harvest handling procedures to ensure that the clean, visually appealing fruits are not bruised during the post-harvest period. This will help enhance the bunch cover effect on the fruit as all this fruit will be for export markets such as Europe, Middle East and Asian markets. The study also shows that the use of bunch covers increase profits for the banana grower due to improved quality, increased yields and better profit margins due to harvesting export quality fruit. 30 28CHAPTER 3 3.0 MATERIAL AND METHODS 3.1 Experimental site, bunch harvesting, processing and stem diagnostics: This trial was conducted at Metocheria Farm, Mozambique located at a Latitude South (14.88˚ S), Longitude East (40.04˚ E), and Altitude (139m) and 235 metres above sea level). Banana flowers of the same uniform plant health were marked and fruit was protected on a weekly basis using the different fruit protection bags. The study was out over two consecutive season's i.e. 2012 and 2013, respectively. Temperature data was recorded using data logger. The experimental site average temperatures were 24.9 ˚C and 23.7 ˚C for 2012 and 2013 growing seasons Table 1 and Table 2. Table 1 Average temperature (˚C) in Grain Nain banana bunch covers for 2012 and 2013 season 2012 2013 Min Max Ave Min Max Ave Control 13.4 44.7 27.5 13.1 45.1 27.9 Blue perforated 14.1 42.2 27.9 14.8 41.8 28.3 Green non perforated 13.2 41.6 28.1 14.2 43.0 31.0 White non perforated 15.1 41.6 27.8 15.8 42.6 29.5 Blue non perforated 14.5 43.3 29.6 15.5 43.8 30.6 White perforated 13.9 42.5 28.8 14.0 40.5 29.3 Green perforated 14.4 38.0 26.9 15.2 41.3 28.1 Cheese cloth 15.6 44.4 28.5 15.0 43.8 29.1 Table 2 Average temperature (˚C) in Williams's banana bunch covers for 2012 and 2013 season 2012 2013 Min Max Ave Min Max Ave Control 12.1 Blue perforated 13.1 Green non perforated 13.0 White non perforated Blue non perforated White perforated Green perforated Cheese cloth 14.7 13.8 12.7 13.4 14.8 42.1 41.4 42.8 43.0 40.8 41.5 41.8 43.4 28.1 27.7 27.3 28.2 28.6 27.6 25.7 29.6 12.9 13.6 14.4 14.2 14.5 13.8 14.6 14.3 44.8 41.0 42.6 44.4 43.9 39.5 41.8 44.8 28.8 29.2 30.1 30.5 28.1 28.2 26.5 29.9 31 Banana plants were clearly marked and bunch were marked using different colour ribbons which coincide with the same colours as the rest of the farm for age grade control. (a) (b) Figure 1.0 (a) Green polyethylene bag (b) Blue polyethylene bag Typical banana bunch covers of different colours. Selection procedures 3.2.1 Selection and marking of 5 uniform plants and flowers per variety (Williams and Grand Nain) per treatment per week for 8 consecutive weeks. A total of 320 bunches were selected with a total of 256 bunches of Williams and 64 bunches of Grand Nain. 3.2.2 The bunches were selected as follows, for example the first bunch selected was 33Treatment 1, the second one Treatment 2, the third one Treatment 3, and so forth until all treatments are completed (Banana flowers randomly emerge, they do not all appear 32 next to each other in the same row during the same week, which cause treatments to be applied randomly). The trial was a completely random block design method. Plants were marked with stickers and ribbons FIGURE 2.0 3.2.3 Plants from or near plantation borders, drainage canals, cable way and roads were not selected as these areas affect fruit quality and yield. 3.2.4 All the covers were applied using the early bagging system which means once the bunch emerges and the bell drop; bunch protection covers were applied (early bagging practice). Early bagging method, bunch cover applied. Tree bag application was done before the bracts open FIGURE 3.0 33 3.2.5 All bunches were de-handed, false +2 which is the normal standard operational procedure for the farms at Metocheria farm. 3.2.6 Harvesting was done using age grade control, using colour ribbons and calibration. 3.2.7 Weighing scales used a dial Avery type with maximum weight of 50 kgs. 3.2.8 Calliper used was the Hecho En type. Ranges from 28/32 to 60/32. 3.2.9 Measuring fruit was done using a Dole International flexible tape calibrated in both inches and centimetres. 3.3 Experimental Design and Treatments Completely randomized block design (CRBD) with 8 treatments replicated five (5) times treatment were used for the study in both seasons (indicate) per week for 8 consecutive weeks were used for the study. 15Formatted: Font: (Default) Times New Roman, Complex Script Font: Times New Roman Formatted: Normal, Left 34 Table 3 Treatments were arranged as follows. Treatments Description Pictures 1 Control – No bag 2 Blue Polyethylene bag, perforated 3 Green Polyethylene bag, non-perforated 35 4 White Polyethylene bag, non-perforated 5 Blue Polyethylene bag, non-perforated 6 White Polyethylene bag, perforated 7 Green Polyethylene bag, perforated 36 8 Cheese Cloth 37 3.4 Variables evaluated Bunch covers were 8applied after the bracts covering the hands have fallen when the fingers were curling upwards, and the floral remnants have hardened. Covers were slided up from the bottom of the stalk and secured tired 8to the bunch stalk above the first hand of the fruit. Covers were left on bunches until harvest. Temperature loggers were placed in for all treatments up to day of harvesting (Tables 4 and 5). Table 4 Average temperature (˚C) in Grain Nain banana bunch covers for 2012 and 2013 season 2012 2013 Min Max Ave Min Max Ave Control 13.4 44.7 27.5 13.1 45.1 27.9 Blue perforated 14.1 42.2 27.9 14.8 41.8 28.3 Green non perforated 13.2 41.6 28.1 14.2 43.0 31.0 White non perforated 15.1 41.6 27.8 15.8 42.6 29.5 Blue non perforated 14.5 43.3 29.6 15.5 43.8 30.6 White perforated 13.9 42.5 28.8 14.0 40.5 29.3 Green perforated 14.4 38.0 26.9 15.2 41.3 28.1 Cheese cloth 15.6 44.4 28.5 15.0 43.8 29.1 Table 5 Average temperature (˚C) in Williams's banana bunch covers for 2012 and 2013 season 2012 2013 Min Max Ave Min Max Ave Control 12.1 Blue perforated 13.1 Green non perforated 13.0 White non perforated Blue non perforated White perforated Green perforated Cheese cloth 14.7 13.8 12.7 13.4 14.8 42.1 41.4 42.8 43.0 40.8 41.5 41.8 43.4 28.1 27.7 27.3 28.2 28.6 27.6 25.7 29.6 12.9 13.6 14.4 14.2 14.5 13.8 14.6 14.3 44.8 41.0 42.6 44.4 43.9 39.5 41.8 44.8 28.8 29.2 30.1 30.5 28.1 28.2 26.5 29.9 38 At harvest, data were recorded on several yield parameters; including weight hands, box stem ratio, yield and marketability. Justifications of these variables measured Formatted: English (South Africa) 3.4.1 Total bunch weight The bunch weight was evaluated so that after processing the bunch we were able to evaluate actual marketable weight which has an effect on yield and income. 3.4.2 Marketable fruit (%) per bunch The marketable fruit is one of the key elements to determine exportable quantities; the marketable fruit can be affected by banana bunch sleeve quality which can affect yield and fruit quality. 3.4.3 Defects The total defects which affect yield and quality. 3.5 BSR (Box/stem/ratio) The Box to Stem Ratio is the true reflection of yield and quality. This is the actual packed fruit after processing the bunch. This indicates the actually achieved yield per bunch. 3.6 Statistical Analysis Data collected was analysed using the General Linear Model (GLM) procedure and variance analysis using SAS version 8.0 2003 (SAS Institute Inc., 2003) and 38Duncan Multiple range test (DMRT) was used to separate the means. 39 CHAPTER 4 4.1. RESULTS During 2012/2013, bagging treatments did not significantly improve weight in hands, banana finger weight, total fruit weight, marketable weight, and percentage marketable fruit weight and box stem ratio (BSR) of Grain Nain (Table 6 and 7). However, there was significant reduction of fruit defects in all bagging treatments compared to control (no bags). Again, bagging treatments significantly increased Grand Nain yield per ton in both seasons. Table 6 Effects of bunch covers on yield performance of Grand Nain banana variety in 2012 Treatment Weight Defects Weight in Total Marketable Marketabl Box Yield/ ton Tree bags hands (kg) Kilos (kg) Fruit Weight e stems (kg) (kg) Weight (kg) Percentag ratio (kg) e (BSR) (%) Control 3.13 a 4.66 a 1.90 a 17.63 a 13.67 a 77.90 a 1.03 a 32.75 b Green 3.21 a 4.01 b 2.13 a 17.88 a 13.86 a 76.35 a 1.04 a 39.81 a perforated Green non 2.86 a 3.13 b 1.88 a 17.33 a 14.01 a 81.54 a 1.05 a 39.25 a perforated White 2.48 a 2.23 b 1.98 a 16.63 a 11.40 a 72.93 a 0.85 a 39.77 a perforated White non 3.04 a 2.33 b 1.79 a 17.21 a 14.89 a 86.78 a 1.10 a 41.68 a perforated Blue 2.88 a 3.61 b 1.90 a 16.71 a 13.10 a 77.28 a 0.96 a 36.68 a perforated Blue non 3.18 a 3.96 b 1.81 a 16.36 a 11.70 a 69.79 a 0.86 a 38.29 a perforated Cheese 2.95 a 2.64 b 1.81 a 17.63 a 13.95 a 84.53 a 1.03 a 39.05 a Cloth Means in a 5column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT) 40 Table 7 Effects of bunch covers on yield performance of Grand Nain banana variety in 2013 Treatment Weigh Defects Weight Total Marketab Marketab Box Yield/ ton Tree bags t (kg) in Kilos Fruit le Weight le stems hands (kg) Weight (kg Percenta ratio (kg) (kg) ge (BSR) (%) Control 2.95 a 13.88 a 1.65 a 15.94 a 9.43 a 59.98 a 0.68 a 26.40 b Green perforated Green non perforated White perforated White non perforated Blue perforated Blue non perforated Cheese Cloth 3.33 a 3.15 40a 2. 95 a 2. 81 a 3.06 a 2. 94 a 3.12 a 5.03 b 3.95 b 5.13 42b 4. 22 b 4. 59 b 3. 33 b 4.09 b 1.70 a 2.03 a 1 11.85 a 1. 84 a 1. 25 a 1. 61 a 1. 51 a 17.70 a 17.09 a 15.68 a 16.94 a 17.00 a 16.66 a 15.74 a 12.66 a 13.14 a 10.54 a 12.71 a 12.41 a 13.34 a 11.65 a 70.76 a 76.24 a 64.51 a 75.40 a 80.19 a 71.13 a 71.45 a 0.95 11a 0. 98 a 0. 78 a 0. 96 a 0. 93 a 0. 99 a 0. 86 a 35.50 a 36.80 a 29.51 a 35.61 a 34.75 a 37.35 a 32.63 a Means in 5a column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT) Table 8 Effects of bunch covers on yield performance of Williams's banana variety in 2012 Bagging treatment Weigh t hands (kg) Defects Weight (kg) in Kilos (kg) Total Fruit Weight (kg) Marketab le Weight (kg) Marketable Percentage (%) Box stems ratio (BSR) Yield/ ton (kg) Control 3.09 a 3.48 b 1.75 b 16.37 a 12.05 b 73.93 a 0.89 b 31.02 b Green perforated Green non perforated White perforated White non perforated Blue perforated Blue non perforated Cheese Cloth 3.09 a 4.32 a 2.90 a 5.11 50a 3. 07 a 3. 72 a 3. 01 a 3. 60 a 2.94 47a 4. 47 a 3 .13 a 4.10 a 3. 12 a 3.35 b 1.90 a 16.47 a 3.07 a 15.75 a 2.40 a 17.13 a 2.00 a 17.33 a 2.54 a 15.47 a 1.84 a 17.04 a 1.96 a 17.34 a 12.99 b 79.30 a 20.75 a 64.42 b 13.41 b 79.88 a 13.74 b 79.44 a 17.66 a 71.89 a 12.88 b 73.21 a 13.98 b 80.85 a 0.97 b 4.25 a 1.00 b 1.02 48b 3. 55 a 0. 92 b 1.03 b 36.37 a 33.75 a 37.55 a 38.46 a 32.16 a 34.97 a 39.14 a Means in 5a column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT) 41 Table 9 Effects of bunch covers on yield performance of Williams's banana variety in 2013 Treatment Tree bags Weight hands (kg) Defects (kg) Weight (kg) Total Fruit Weight (kg) Marketabl e Weight (kg) Marketable Percentage (%) Box stems ratio (BSR) Yield/ton (kg) Control 2.30 b 6.19 a 1.45 b 15.94 a 9.75 a 60.71 a 0.72 a 27.29 b Green perforated Green non perforated White perforated White non perforated Blue perforated Blue non perforated Cheese Cloth 2.73 a 4.99 b 3.02 a 5.03 b 2.75 a 4.70 ab 2.79 a 6.46 a 2.70 a 4.53 b 2.68 a 4.65 b 2.81 a 4.42 b 1.55 a 15.89 a 1.47 a 15.77 41a 1.62 a 16.20 a 1. 53 a 16.24 a 1. 47 a 15.13 a 1.63 a 15.80 a 1.71 a 15.51 a 10.90 a 67.93 a 10.75 a 67.23 a 11.50 a 70.28 a 9.78 a 59.19 a 10.61 a 69.76 a 11.15 a 68.55 a 11.09 a 70.68 a 0.80 11a 0. 79 a 0. 85 a 0. 72 a 0. 78 a 0. 83 a 0. 82 a 30.52 a 30.07 a 32.18 a 32.19 a 29.71 a 31.22 a 31.06 23a Means in a column followed by the same letter are not significantly different (P>0.05) using Duncan Multiple Range Test (DMRT) In William banana cultivar, bagging treatment tended to be inconsistent in the two seasons (Table 8 and 9).

During 2013 bagging, treatments significantly improved weight, whereas no significance differences were observed on weight of hands during 2012. Move table 8 and 9 Bagging of banana bunches reduces defects in both seasons, though no significant response were shown in marketability percentage. In 2012/2013, marketable weight tended to be inconsistent with blue perforated cloth and green non-perforated significantly increasing marketable weight. However, no significant differences were observed during 2013. Both green and blue perforated bags significantly improved box stem ration (BSR). However, no significant differences were observed during 2013. Bagging treatments significantly increased William's cultivar yield per ton in both seasons (Table 8 and 9). 42 This should not form ChapterCHAPTER 6 DISCUSSIONS Results shown from the trials indicate that yield and quality performance of bunch covered banana fruits is dependent on a number of factors, including type of cover, season and cultivar. Bunch cover application resulted in increase in yield even though inconsistent results were drawn from other parameters. These could be due to interaction between different light intensity and temperature. Such temperatures fluctuations inside the bunch covers due to weather patterns and bunch cover designs were shown in banana production across regions (Cuneen and McEntye, 1988; Johns and Scott, 1989). The average temperatures inside the bags in both banana cultivars were higher than the outside air temperature. The blue and green non perforated bags resulted in the highest temperature increase than the other bag types. In studies done by Cuneen and McEntye (1988), 27no significant differences in yields and quality were found for the different coloured bags, although yields were highest for bunches inside the clear silver bags. In some instances in the tropics benefits are related more to blemish control and reduction of pest damage (Anon., 2003). In winter, even the use double bunch covers improved the yield of bananas (Johns, 1996). Use of bunch covers to control against chilling temperature, would also reduce incidences of under peel discolouration (Snowden, 2010). Bunch covers can also increase the marketability of banana fruits through increase in size and quality. The use of different bunch cover combinations during summer in South Africa resulted in low proportion of clean fingers (9-12%) with however a relatively high relative humidity in polyethylene bags resulting in the highest percentages of soft rots (15%) and uneven ripening (Robinson and Nel, 1982). Building up of high relative 43 humidity inside the banana bags can however be reduced with use of perforated bags (Anon., 2003, Muchui et al, 2010), ultimately preventing multiplication of fungi. Sizes of the holes should also vary with climatic conditions within production areas. Besides effect of presence of holes on changes in humidity and temperature inside bunch covers, colour of the covers also plays a role in micro environment characteristics. Muchui et al, (2010) reported that using perforated dull and shiny blue bunch covers resulted in higher quality and yields of bananas. Bunch appearance and size of hands was also affected by colour of the bunch covers and polyethylene density in banana produced in the Caribbean (Vargas et al, 2010). Crop duration, particularly days taken from flowering to physiological maturity and production per day can also be influenced by different bunch cover treatments (Vargas et al, 2010). The use of covers of various colours may also be depended on seasons (Stevenson, 1976). Bunch covers performed the same in summer but in winter the use of transparent material speeded up the filling and harvesting of banana bunches (Johns, 1996, Johns and Scott, 1989; Stevenson, 1976). The use of various colours in different seasons, climate or regions has shown their different performance capabilities towards banana physiological growth. Photo synthetically Active Radiation (PAR) which is responsible for light intensity required in growth and development becomes filtered through various bunch cover colour designs. Transparent covers let in more light than blue of green covers. However, banana production regions mostly use blue covers as they let in heat without causing sun scald (Muchui et al, 2010), because it blocks UV rays. Transparent covers can further be treated to block ultraviolet and infrared rays. These transparent bunch covers with specific UV and IR permeability properties were found to allow better light and temperature conditions for banana growth (Jannoyer and Chillet, 1998). 44 Fruit Length 2012 4.1.22 Fruit Calliper and Fruit Length No 46significant differences were noticed between treatments and control in both the year 2012 and 2013. (i) (ii) FIGURE 4.0 (i) Unbagged (ii) Bagged Visual appearance of banana cultivar Grand Nain at harvest 45 A few of the covered fruits suffered sunburn, which adversely affected fruit quality (Figure 5). This affected bunches which the leaves did cover during growth. Top hand was mainly affected especially for bunches covered with dull blue covers probably due to more heat absorbed inside the cover compared to the shiny blue covers which may have reflected some heat away. Elsewhere, bagging of bananas resulted in sun scorching of the fruits irrespective of the colour of the bunch covers (Weerasinghe and Ruwapathirana, 2002). This is overcomed by 10maintaining enough leaves on the plant to shade the plant and by using reflective blue covers (Anon, 2003). Pulling leaves over the covered bunches may also reduce/prevent sunburn. In addition, inserting a newspaper on the inside of the bunch cover to cover a top hand to prevent them from sun scorch has been found to work (Linbing et al., 2004). The blue polyethylene covers has shown to absorb more blue-green and ultraviolet lights, which may cause sunburn to banana fruits (ShihChao et al., 2004). Economic model 8Bunch covers are highly specialised items available from a few companies which are found mainly in areas and countries of commercial banana production. The costs of bunch covers are as follows: The additional cost of using a bunch cover averages $0.13. The data using the economic model of 2,000 bunches per hectare at 1.4 cycles per year for bagged gives an annual carton 2,800 per year (13.5kg cartons). However data for the control or non-bagged bunches show that at 2,000 bunches per hectare per year at 1.2 cycles per year gives an annual carton of 13.5kgs of 2,400 per year. The trial resulted in the following: Williams: Over the 2012 and 2013 46 Control season's average BSR was 0.81 0.81 x 2000 x 1.2 = 1,944 cartons per hectare per year Green Perforated Bags seasons average BSR was 0.90. 0.90 x 2000 x 1.4 = 2,520 cartons per hectare per year Blue Perforated Bags seasons average BSR was 2.19 2.19 x 2000 x 1.4 = 6,132 cartons per hectare per year White perforated bags seasons average BST was 0.93 0.93 x 2000 x 1.4 = 2,604 cartons per hectare per year Cheese cloth seasons average BSR was 0.93 0.93 x 2000 x 1.4 = 2,604 cartons per hectare per year These results show that it is more economical to use bunch covers in Williams as this in increased yields making it more profitable. The positive benefits achieved from using bunch covers makes the price of 40.13 per bunch cover very reasonable can results in improved profit margins. Gran Nain: Over the 2012 and 2013 Control season's average BSR was 0.86 0.86 x 2000 x 1.2 = 2,064 cartons per hectare per year Green perforated bags season average BSR 0.995 47 0.995 X 2000 X 1.4 = 2,786 cartons per hectare per year Blue perforated bags season average BSR was 0.945 0.945 x 2000 x 1.4 = 2,646 cartons per hectare per year White perforated bags season average BSR was 0.82 0.82 x 2000 x 1.4 = 2.296 cartons per hectare per year Cheese Cloth season average BSR was 0.96 0.96 x 2000 x 1.4 = 2,688 cartons per hectare per year The above data shows that it is cheaper to use tree bags as these results in increased yields per hectare per year in both varieties. The physical appearance of the peel is especially important in the export market. Buyers in these markets require consistent supplies of uniform coloured fruit with blemish free peels. This help retain customers and fruit can receive premium prices. Conclusions, the studies conducted are evident that bagging treatments significantly increased yield per tonne of Grain Nain and William's cultivars with significant reductions of fruit defects. Therefore, bagging treatments are recommended in marginal climatic conditions of Namialo in Northern Mozambique. REFERENCES Amarante, C., Banks, N.H., and Max, S. 2002. Effect of pre harvest bagging on fruit quality and post-harvest physiology of pears (Pyrus communis). New Zealand Crop and Horticulture Science Journal 30, pp. 99-107. 48 Anon., 2003. Bunch covers for improving plantain and banana peel quality. National Agriculture Research Institute. Technical Bulletin no 4. www.agrinetguyana.org.gymoa. Choudhury, H., Chandra, K., and Baruah, K.1996a. Effect of bunch cover on morphological parameters and yield of banana. 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978689 Source DF Type I SS Mean Square F Value Pr > F TRT 7 REP 7 2.60342603 0.37191800 1.39 1.44865365 0.20695052 0.77 0.2335 0.6136 52 Weight in kilograms Source 9Sum of DF Squares Mean Square F Value Pr > F Model 14 3.93750435 0. 28125031 2.33 0. 0157 Error 46 5.54183991 0. 12047478 Corrected Total 60 9.47934426 R-Square Coeff Var Root MSE wghtkilos Mean 0. 415377 18.29972 0. 347095 1. 896721 Source DF Type I SS Mean Square F Value Pr > F TRT 7 REP 7 0.67476093 3.26274342 0.09639442 0.80 0.5913 0.46610620 3.87 0.0022 53 Total Fruit weight Source 17Sum of DF Squares Mean Square F Value Pr > F Model 14 145.8184262 10. 4156019 0.92 0. 5419 Error 46 519.0740328 11.2842181 Corrected Total 60 664.8924590 3R-Square Coeff Var Root MSE Totfruitwt Mean 0. 219311 20.05394 3. 359199 16.75082 Source DF Type I SS Mean Square F Value Pr > F TRT 7 REP 7 79.58983997 66.22858625 11.36997714 1.01 0.4384 9.46122661 0.84 0.5613 54 Fruit Defects 34Formatted: Border: Bottom: (Single solid line, Auto, 0.5 pt Line width)18Source DF Sum of Squares Mean Square F Value Pr > F Model 14 102.6568116 7.3326294 1.31 0.2398 Error 46 257.9300737 5.6071755 Corrected Total 60 360.5868852 6R-Square Coeff Var Root MSE defects Mean 0. 284694 70.25525 2. 367948 3.370492 Source DF Type I SS Mean Square F Value Pr > F TRT 7 REP 7 40.35765906 62.29915254 5.76537987 1.03 0.4247 8.89987893 1.59 0.1632 55 Marketable Weight in kilograms 9Sum of Source DF Squares Mean Square F Value Pr > F Model 14 233.9324732 16.7094624 1.24 0.2795 Error 46 618.7039202 13.4500852 Corrected Total 60 852.6363934 3R-Square Coeff Var Root MSE Mktwgtkilos Mean 0. 274364 27.40916 3. 667436 13.38033 Source DF Type I SS Mean Square F Value Pr > F TRT 7

73.1658577 10.4522654 0.78 0.6096 REP 7 160.7666155 22.9666594 1.71 0.1308 Marketable Percentage 19Source Sum of DF Squares Mean Square F Value Pr > F Model 14 5996.43954 428.31711 1.38 0.1990 56 Error 46 14226.93849 309.28127 Corrected Total 60 20223.37803 2R-Square Coeff Var Root MSE makerperc Mean 0. 296510 22.38202 17. 58639 78.57377 Source DF Type I SS Mean Square F Value Pr > F TRT 7 1756.138449 250.876921 0.81 0.5826 REP 7 4240.301088 605.757298 1.96 0.0817 Box Stems Ratio Source 12Sum of DF Squares Mean Square F Value Pr > F Model 14 1.26621807 0. 09044415 1.20 0. 3088 Error 46 3.47115898 0. 07545998 Corrected Total 60 4. 73737705 57 R-Square Coeff Var Root MSE bsr Mean 0. 267283 27.65130 0. 274700 0.993443 Source DF Type I SS Mean Square F Value Pr > F TRT 7 REP 7 0.41684133 0.84937674 0.05954876 0.79 0.6000 0.12133953 1.61 0.1572 Yield per tonne 19Source Sum of DF Squares Mean Square F Value Pr > F Model 14 1743.817890 124.558421 1.25 0.2762 Error 46 4593.053585 99.848991 14Corrected Total 60 6336.871475 R-Square Coeff Var Root MSE Yieldperton Mean 0. 275186 26.61395 9.992447 37.54590 58 13Source DF Type I SS Mean Square F Value Pr > F TRT 7 REP 7 521.510821 74.501546 0.75 0.001 1222.307069 174.615296 1.75 0.1212 59 APPENDIX 2 Williams : Evaluation of banana bunch protections materials for optimum fruit and quality . Dependent Variable: Weight per hand Source 2Sum of DF Squares Mean Square F Value Pr > F Model 38 15.02004249 0. 39526428 1. 57 0. 0256 Error 203 51.10458560 0. 25174673 Corrected Total 241 66.12462810 R-Square Coeff Var Root MSE Whand Mean 0. 227147 16.44393 0. 501744 3.051240 Source DF Type I SS Mean Square F Value Pr > F TRT REP 31 13.60729666 0.43894505 1.74 0.0126 7 1.41274583 0.20182083 0.80 0.5867 60 Dependent Variable: Fruit Defects Source 17Sum of DF Squares Mean Square F Value Pr > F Model 38 713.282668 18. 770597 2.71 <.0001 Error 203 1408.456712 6.938210 Corrected Total 241 2121.739380 6R-Square Coeff Var Root MSE defects Mean 0. 336178 66.09017 2. 634048 3.985537 Source DF Type I SS Mean Square F Value Pr > F TRT REP 31 643.0275431 7 70.2551246 10.0364464 20.7428240 1.45 0.1885 2.99 <.0001 Dependent Variable: Weight in kilograms 30Sum of Source DF Squares Mean Square F

Value Pr > F 61 Model 38 190.802355 5. 021115 0.96 0. 5361 Error 202 1052.732084 5.211545 Corrected Total 240 1243.534440 6R-Square Coeff Var Root MSE wghtkilos Mean 0. 153436 105.3570 2. 282881 2.166805 Source DF Type I SS Mean Square F Value Pr > F TRT 7 39.2005606 5.6000801 1.07 0.001 REP 31 151.6017949 4.8903805 0.94 0.5650 Dependent Variable: Total fruit weight Source 18Sum of DF Squares Mean Square F Value Pr > F Model 38 843.609098 22. 200239 1.79 0. 0057 Error 202 2507.272894 12.412242 Corrected Total 240 3350.881992 62 3R-Square Coeff Var Root MSE Totfruitwt Mean 0. 251757 21.16161 3. 523101 16.64855 Source DF Type I SS Mean Square F Value Pr > F TRT 7 106.0451873 15.1493125 REP 31 737.5639109 23.7923842 1.22 0.2929 1.92 0.0042 Dependent Variable: Marketable Weight in kilograms Source 3Sum of DF Squares Mean Square F Value Pr > F Model 38 5246.22491 138.05855 1.15 0.2632 Error 204 24433.96036 119.77432 Corrected Total 242 29680.18527 2R-Square Coeff Var Root MSE Mktwgtkilos Mean 0. 176758 75.33362 10.94415 14.52757 63 13Source DF Type I SS Mean Square F Value Pr > F TRT 7 1707.108514 REP 31 3539.116398 243.872645 114.165045 2.04 0.0522 0.95 0.5427 Dependent Variable: Marketable percentage Source 3Sum of DF Squares Mean Square F Value Pr > F Model 38 26431.41355 695.56351 2.43 <.0001 Error 204 58390.52678 286.22807 Corrected Total 242 84821.94033 2R-Square Coeff Var Root MSE makerperc Mean 0. 311611 22. 34377 16.91828 75.71811 13Source DF Type I SS Mean Square F Value Pr > F TRT 7 6280.33902 897.19129 3.13 0.0036 REP 31 20151.07453 650.03466 2.27 0.0004 64 Dependent Variable: Box Stems Ratio Source 3Sum of DF Squares Mean Square F Value Pr > F Model 38 1109.536290 29.198323 1.12 0.3080 Error 206 5389.189669 26.161115 Corrected Total 244 6498.725959 14R-Square Coeff Var Root MSE bsr Mean 0. 170731 311.9553 5. 114794 1.639592 Source DF Type I SS Mean Square F Value Pr > F TRT REP 31 735.2957951 23.7192192 0.91 0.6129 7 374.2404948 53.4629278 2.04 0.0502 65 Dependent Variable: Yield per tonne Source 3Sum of DF Squares Mean Square F Value Pr > F Model 38 7007.50923 184.40814 2.02 0.0010 Error 206 18823.50277 91.37623 Corrected Total 244 25831.01200 22R-Square Coeff Var Root MSE Yieldperton Mean 0. 271283 26.87727 9. 559091 35.56571 Source DF Type I SS Mean Square F Value Pr > F TRT REP 31 5168.813208 166.735910 1.82 0.0075 7 1838.696024 262.670861 2.87 0.0069 Formatted: Border: Bottom: (No border) 66 67

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Dear Dr. Mudau,

We wish to acknowledge receipt of the signed Copyright Transfer Agreement. Also, the paper is scheduled to be published in 2014 Volume 91, No.3 which is expected to be in print by July 2014.

We thank you for choosing *Tropical Agriculture* to publish your work.

Regards,

Sarojini Ragbir

Managing Editor

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Florida,

South Africa

11 September 2012

Re: Letter of Confirmation for Trials being conducted by Rodrick Kutinyu

Dear all,

This letter serves to confirm that Rodrick Kutinyu, student number 43554377 doing his Msc Agriculture with UNISA is conducting his trials here at Metocheria Farm, Namialo, and Nampula being Matanuska Mozambqiue Lda.

His topic of Research being : **THE EVALUATION OF DIFFERENT BANANA BUNCH PROTECTION MATERIALS ON SELECTED BANANA CULTIVARS FOR OPTIMUM FRUIT PRODUCTION AND QUALITY IN NAMPULA PROVINCE, MOZAMBIQUE.**

Thank you.

Yours,

MATANUSKA MOÇAMBIQUE LIMITADA NUIT: 400176590

Mrs. C. Fraser

Head: Technical Services

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SECTION F: DECLARATION

The applicant/researcher(s) undertakes to treat all that has been stated in this application will be undertaken in a manner that is respectful of the rights and integrity of all research subjects, as stipulated in the UNISA Research Ethics Policy.

The applicant/researcher(s) undertakes to notify the Ethics Committee of the College of Agriculture and Environmental Sciences at Unisa if changes to the aforementioned protocol are affected.

Mr. Rodrick Kutinyu_
Name of applicant (Title, Full Names & Surname)

______________________________ ___10 September 2012_
Signature Date

Prof. Mudau Fhatuwani
____
Name of Supervisor if applicant is a student in CAES
(Title, Full Names & Surname)

N/A
______________________________ ______________________________
Signature Date

Dr Kayoka Prudence
____
Name of COD (Title, Full Names & Surname)

______________________________ ______________________________
Signature Date

____
Name of Post Graduate Research Coordinator
(Title, Full Names & Surname)

_______________N/A_______________________ ______________________________
Signature Date

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Mr R Kutinyu
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EDEN GLEN EXT 4
1609

2014-11-07

Dear Mr Kutinyu

I have pleasure in informing you that your dissertation has been accepted for the degree of **MSc in Agriculture**. You obtained a mark of 58% for the dissertation.

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The evaluation of different banana bunch protection materials on selected banana cultivars for optimum fruit production and quality in Nampula Province, Mozambique

ABSTRACT

Mozambique has potential to boost its banana exports. To fully realise this, agronomic practices in production should be fully developed to combat physiological disorders associated with banana within the region. Currently, lower temperatures are being experienced in some production sites, consequently affecting yield and quality. The objective of this study was to evaluate use of bunch protection covers on banana cultivars Grand Nain and Williams banana cultivars, for performance under different fruit protection materials to determine best fruit protection bag suitable for Metocheria, Nampula. Plants were not selected near plantation borders, drainage canals, cable way and roads, as this would influence the growth pattern of plants and fruit development.

Treatments consisted of control (no bag on bunches), white perforated polyethylene, white non-perforated polyethylene, blue perforated polyethylene, blue non perforated polyethylene, green perforated polyethylene, green polyethylene non perforated and cheese cloth bags arranged in a complete randomised block designed CRBD with 26 plants replicated eight times.

During 2012/2013, bagging treatments did not considerably improve weight in hands, banana finger weight, total fruit weight, marketable weight and percentage marketable fruit weight and box stem ratio (BSR) of Grand Nain. However there was reduction of fruit defects in all bagging treatments compared to control (no bags). In Williams during the 2013 season bagging treatments improved weight but no significant differences were observed on weight of hands in 2012. Bagging of banana bunches reduce defects in both seasons. Both green and blue perforated bags improved box stem ratio. Bagging treatments increased Williams's cultivar yield (per ton) in both seasons.

Keywords: *banana bunch cover, early bagging, de-handing.*

Student number: 43554377

I declare that **THE EVALUATION OF DIFFERENT BANANA BUNCH PROTECTION MATERIALS ON SELECTED BANANA CULTIVARS FOR OPTIMUM FRUIT PRODUCTION AND QUALITY IN NAMPULA PROVINCE, MOZAMBIQUE** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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