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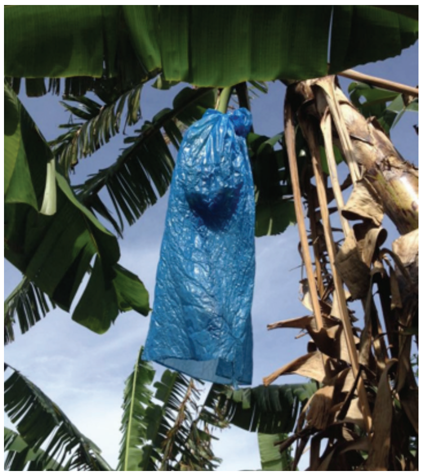
Production and quality of banana 'BRS Conquista' bagged with different colored polypropylene bags

Producción y calidad de frutos del banano 'BRS Conquista' empacados en bolsas con polipropileno de diferentes colores



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'BRS Conquista' banana bunch bagged with blue polyethylene.

Photo: R.C. Martins

ABSTRACT

Worldwide, the second most traded fruit is banana, which is highly appreciated by Brazilian consumers. Moreover, new technologies have been used to improve fruit quality during cultivation. This study aimed to assess the influence of plastic bag colors on the production and quality of banana 'BRS Conquista'. The treatments consisted of the use of commercial polypropylene bags e colored white, black, red or blue, in addition to the control (non-bagged). This study used a randomized complete block design with five treatments, four replicates and four plants per plot, totalling 80 plants. The assessments consisted of bunch mass; rachis mass; fruit total mass; mean cluster mass; number of fruits per bunch and per cluster; and fruit length and diameter; along with fruits physicochemical traits, such as soluble solids, titratable acidity, pulp/peel ratio and maturation index. The results indicated that no interference was obtained from the different plastic bag colors in the productive variables. However, a greater content of soluble solids was observed in the non-bagged bunches.

Additional key words: *Musa* sp.; bunch cover; yield; postharvest.

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RESUMEN

La banano es la segunda fruta con mayor volumen comercializado en el mundo. Por el hecho de ser una fruta muy apreciada por el consumidor brasileño, en los últimos años surgieron diversas tecnologías que ayudan al cultivo del plátano, principalmente relacionadas a la calidad de los frutos. En este contexto, el trabajo tuvo como objetivo evaluar la influencia de la coloración de las bolsas plásticas empleadas en el embolsado de racimos del banano 'BRS Conquista' sobre la producción y calidad de los frutos. Los tratamientos consistieron en el uso de bolsas de polietileno comerciales, en los colores blanco, negro, rojo y azul, además del testigo (sin embolsado). El diseño experimental fue en bloques casualizados, con cinco tratamientos, cuatro repeticiones y cuatro plantas por parcela, totalizando 80 plantas. Se evaluó la masa del racimo, masa de la raquis, masa del los frutos, número de frutos por racimo, número de pencas por racimo, masa de las pencas, número, longitud y diámetro de frutos de la segunda penca, y las características físico-químicas de los frutos, como sólidos solubles, acidez titulable, relación pulpa/cáscara e índice de maduración. Se verificó que el embolsado de los racimos con bolsas plásticas de diferentes colores no interfirió en las variables productivas. Sin embargo, en los racimos que no recibieron embolsado se observaron mayores contenidos de sólidos solubles que en los racimos empacados.

Palabras clave adicionales: *Musa* sp.; ensacado de racimos; productividad; poscosecha.

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INTRODUCTION

The banana tree belongs to the Musaceae family and is considered one of the main crops of economic interest in the fruit market. Also, banana is the second most traded fruit in the world (Perrier *et al*., 2011) and is grown in 80 tropical countries, with a production of 106 million tons. India, China, the Philippines and Brazil are the largest producers. The largest exporting countries are Costa Rica and Ecuador, with Ecuador accounting for 30% of world trade (FAO, 2017).

Since it is a highly appreciated fruit, innovations and technologies have appeared to optimize the productive process in recent years, mainly related to the improvement of fruit quality.

However, research on the quality aspects of banana fruits is of extreme importance because they are mainly destined for direct consumption.

Considered an ecological practice, fruit bagging is a very effective and old technique for protecting fruits from attack by pests and diseases (Teixeira *et al*., 2011). In banana cultures, in addition to phytosanitary factors, studies have indicated that bagging can improve fruit quality. Thus, in temperate areas, it is common to cover. The fruits, while they are growing, improve yield and fruit quality. However, this technique is also used in warmer countries during the coldest seasons to protect fruits (Sakai, 2015).

Although it is an expensive technique, it protects the bunches from physical damage, such as wind action, low temperatures, fruit contact with the leaves, diseases and hail (Alves *et al*., 1999; Rodrigues *et al*., 2001; Costa *et al*., 2002; Silva Filho and Moreira, 2005; Moreira, 2008; Euleuterio *et al.*, 2010; Sakai, 2015).

The method of bagging fruits is a cultural practice adopted by large-scale banana growers. Questions that have not been resolved refer to the existence of differences in the types of materials used for bagging bunches, along with bag color here are differences between fruit bagging recommendations around the world, based on preferences for color and material (Surajit *et al*, 2016; Santos *et al*., 2017).

There is a need for studies on bagging materials (Azevedo *et al*., 2016; Coelho *et al*., 2008) information and on how to perform bagging in different situations (Costa *et al*., 2002). Sarkar *et al*. (2016), in an experiment in India, evaluated the use of polypropylene bags and found that bagged fruits presented less insect damage and higher mass. However, Kutinyu (2014), in a study with different cluster protection materials, found that bagging did not provide significant results for fruit weight in Grande Naine. Sakai (2015) obtained similar results, evaluating the physical protection of 'Nanicão' bunches, and observed that the bunch mass, second bunch mass, fruit density and pulp pH were not influenced by bagging.

Therefore, studies that evaluate the effect of color of the plastic used to cover banana bunches are crucial since they can subsidize information for the productive sector to demystify and elucidate the role of this method in the production and quality of fruits. This study aimed to assess the influence of plastic bag colors on the production and quality of banana 'BRS Conquista'.

MATERIAL AND METHODS

The current study took place at the Sao Paulo State University (Unesp), School of Agriculture, Botucatu, São Paulo, Brazil. According to the Köppen classification, mesothermic temperate type (Cfa) was the predominant climate in the region, that is, humid and with a mean temperature of the hottest month close to 22ºC (Cunha and Martins, 2009). The soil of the experimental area was classified as Red Nitosol (Santos *et al*., 2018).

Prior to the experiment installation, a soil analysis was performed with soil samples at depths of 0-20 cm and 20-40 cm. Based on this analysis, liming and fertilization were performed according to Raij *et al*. (1999), i.e. using 1.89 t ha^{-1} of dolomitic limestone, 300 g/plant of urea and 241.5 g/plant of potassium chloride. During the experiment, other cultural treatments were carried out in the orchard according to the technical recommendations for the crop.

Two-year-old banana 'BRS Conquista' plants were spaced at 2 x 2.5 m and evaluated in an agricultural cycle in 2017.

The treatments consisted of polypropylene bags with different colors (i.e. white, black, red and blue), plus a control (non-bagged bunches). The bag dimensions were 150×75 cm, open at the ends, with lateral perforations of 0.5 cm to allow gas exchange between the fruits and the outside air. The experiment design used randomized blocks, with five treatments, four replications and four plants per plot, totalling 80 plants.

The bagging was done shortly after the inflorescence issued, before the opening of the bracts. The bags were tied at the top.

Starting with the second cycle, cluster emission is not simultaneous among plants; therefore, fruit development occurs under different conditions between plants. To standardize the harvest point, the bunches were harvested when they reached the thermal accumulation degree-days of 3,200.33°C after inflorescence emission. To assess this thermal accumulation pattern, non-useful plants in the area were previously selected, and the thermal accumulation between inflorescence emission and harvest was calculated; the basal temperature was lower than 15°C and higher than 37ºC, according to Figueiredo *et al.* (2006).

The evaluations of plant productive performance was done right after harvesting, when the fruits presented a completely green peel (PBMH and PIF, 2006). The variables included production or bunch mass (kg), rachis mass (kg), fruit total mass (kg) and mean cluster mass (kg), which were measured in scale; number of fruits per bunch and per cluster; and yield (t ha^{-1}), for which the cluster mass was considered with a stand of 2,000 plants/ha.

The evaluations of yield performance considered five fruits from the second cluster of the bunch. The following variables were evaluated: fruit number per length and length (cm) and diameter (mm) of the fruits; the latter was measured using a digital caliper for evaluations of the physical and physicochemical characteristics of the ripe fruits. The leaves were kept on shelves at room temperature until they were completely yellow (PBMH and PIF, 2006). The following variables were evaluated: fruit number per cluster; fruit length (cm) and fruit diameter (mm); the latter was measured using a digital calliper.

For the physical and physicochemical characteristics of the ripe fruits, clusters were kept on shelves at room temperature until they were completely yellow (PBMH and PIF, 2006). The following evaluations were carried out on the five fruits of the second ripen cluster: pulp/peel ratio, with the fruits and peels weighed on a semi-analytical balance. The fruit mass was determined with the peel divided by peel mass; the values were expressed in grams. The titratable acidity (TA) was obtained according to the analytical standards of Instituto Adolfo Lutz (Lutz, 2005), titrated with sodium hydroxide (NaOH) to 0.1 N, using 5 g of homogenized pulp, diluted in 100 mL of distilled water and 0.3 mL of phenolphthalein. The content of soluble solids (SS) was measured with the aid of a digital refractometer (Atago 3405 PR-32a Palette), expressed in °Brix. The maturation index (SS/TA) was calculated with the ratio of the soluble solids and the titratable acidity.

The data were submitted to analysis of variance, and, when there was significance, the means were compared with the Scott-Knot test at 5% probability level. All analyses were performed in the program SISVAR 5.0 - Program of Statistical Analysis and Planning of Experiments of the Federal University of Lavras (Ferreira, 2011).

RESULTS AND DISCUSSION

In terms of productive performance, the analysis of variance did not detect any significant effect of treatments on the variables (Tab. 1).

The fact that there was no difference between the color of the polypropylene bags for bunch mass indirectly resulted in the absence of effect on the rachis and fruits mass since bunch mass is composed of rachis and fruit mass. Moreira (2008) evaluated banana bunch mass in the presence and absence of bagging in the State of Amazonia and did not found any significance in the variation of the treatments for cultivars Prata Zulu, FHIA 18, Nanicão 2001 and Thap Maeo.

In an experiment using blue plastic bags to cover banana bunches, cv. Williams did not present any significant effect on bunch mass, according to Muchui *et al*. (2010). Also, Sakai (2015) evaluated bagging in two fruit development seasons (i.e. summer and winter) and did not notice any statistical difference for bunch mass.

The mean cluster mass was also unaffected by fruit bagging, regardless of color (Tab. 1). These results corroborate with those found by Rodrigues *et al.* (2001), who aimed to verify the influence of bagging banana bunches on the production of cv. 'Prata-anã' and did not verify statistical differences for cluster mass, fruit mass and number of clusters. Sakai (2015) evaluated bagging bananas in two fruit development seasons (i.e. Summer and Winter) did not report any statistical difference for cluster mass.

It was evident that the environmental conditions of Botucatu, State of Sao Paulo, the microclimate of the treatments, did not impact the productive aspects.

Fruit bagging only changes the amount of radiation, humidity and temperature within the cluster area. All other parts of the plants, i.e. leaves, are still exposed to environmental conditions and variations. Nevertheless, it is worth emphasizing that leaves are the main photosynthetic organs that produce carbohydrates that will later be translocated to fruits; also, photosynthesis is not efficient enough in green fruits. Thus, these traits may have resulted in the absence of effects of bagging bunches on the productive factors.

However, Costa *et al.* (2002) studied bagged bunches during winter, summer and autumn seasons and reported an increase in bunch mass of cv. Grand Naine bagged in the summer. Soto (2015) verified an increase in bunch yield, as a function of bagging in the summer. The highest yield of the bunches was attributed to the increase in temperature inside the bags, which created a more uniform microclimate (Alves, 1999). Another relevant aspect is the banana's ability to emit leaves more frequently in the summer, which leads to a greater photosynthetically active area and, consequently, greater production.

Table 1. Values of the F test, degrees of freedom (DF), coefficients of variation (CV) and mean bunch, rachis mass, fruit mass, hand mass, number of fruits per clusters and number of clusters per bunch of banana 'BRS Conquista' in Botucatu, State of Sao Paulo, 2018.

F test	DF	Bunch mass (kg)	Rachis mass (kg)	Fruit mass (kg)	Hand mass (kg)	Fruit number per clusters	Cluster number per bunch	Yield (t ha^{-1})
Block	3	4.99*	3.43*	4.55*	1.44^{NS}	2.02^{NS}	2.78^{NS}	4.99*
Treatment	4	1.15^{NS}	0.91^{NS}	1.21^{NS}	0.96^{NS}	2.72^{NS}	0.61^{NS}	1.15^{NS}
CV (%)		12.12	14.29	12.72	14.10	12.23	6.77	12.12
Mean		19.26	1.56	17.71	1.34	22.15	13.18	19.26

^{NS} = not significant; * = significant at $P \leq 0.05$.

For the number of fruits, cluster and yield, the color of the polypropylene bags showed no differences, indicating that any of the evaluated colors could be recommended for bagging banana bunches in the field. Costa *et al.* (2002) did not find any significant difference for the yield of bagged and non-bagged bunches in a study on cv. Prata-anã and Grande Naine.

In an experiment on banana bunches covered with polyethylene bags, Moreira (2008) found that the bags did not affect the number of fruits or clusters; also, the differences were only observed in the cultivars. Plant behaviour related to the number of fruits and clusters and the productive capacity is mainly due to genetic and edaphoclimatic factors.

Another important factor is the moment of floral differentiation since any disturbances, such as unfavourable climatic conditions, may reflect on bunch formation and development (Karamura *et al.,* 2011).

When the physical characteristics were evaluated in the second cluster with green fruits, no significant difference was observed for the number, length and diameter of the fruits (Tab. 2).

Table 2. Values of F test, degrees of freedom (DF), coefficients of variation (CV) and mean fruit number, length and diameter of fruits of the second cluster of banana 'BRS Conquista' in Botucatu, State of Sao Paulo, 2018.

F test	DF	Fruit number	Length (cm)	Diameter (cm)
Block	3	1.03^{NS}	1.03^{NS}	0.10^{NS}
Treatment	4	1.06^{NS}	0.18^{NS}	1.36^{NS}
CV (%)		24.08	8.46	6.91
Mean		23.80	14.15	34.77

^{NS} = not significant at $P<0.01$ and $P\leq0.05$ by F test.

The values found for fruit length and diameter were similar to those found by Rodrigues *et al.* (2001). Likewise, similar values were found by Aquino *et al*. (2017), who observed length and diameter values of approximately 14.00 and 38 cm in plants of the 'Prata' group, respectively. An experiment in Kenya evaluated the effect of blue-colored polyethylene bags and of non-bagging on cv. Williams, Muchui *et al*. (2010) and did not find any significant differences for length. Rodrigues *et al.* (2001) also did not obtain statistical difference for fruit length and diameter for bagged bunches in cv. Prata anã.

According to the classification proposed for cv. Prata by Abanorte by the Fruit Growers' Central Association of North Minas Gerais - (MI *et al*., 2000), the fruits from 'BRS Conquista' fit the best quality type since they presented values higher than 14 cm in length and larger than 32 mm in diameter. Independent of the bag color, the fruits presented within the stated size range for 'Prata' in the current study. Therefore, the bunch bagging method did not impair fruit development.

It is noteworthy that length, diameter and fruit number are not only related to the bunch bagging method but also to abiotic factors during floral differentiation to bunch harvest and to cultivar genetic characteristics.

For the post-harvest characteristics of the ripe fruits, there was no statistical difference between the treatments for pulp/peel ratio, acidity, and maturation index time (Tab. 3), but there was a significant effect for soluble solids (Tab. 4).

The pulp/peel ratio is linked to the genetic characteristics of the cultivar and fruit ripening phase; therefore, during the maturation process, there was an increase in pulp mass and, consequently, a decrease in peel mass because of the osmotic transfer of moisture from the peel to the pulp and water loss from the peel to the environment. Thus, there are two factors that may interfere in the pulp/peel ratio that did not occur in the current study (Payasi and Sanwl, 2005).

Table 3. Values of F test, degrees of freedom (DF), coefficients of variation (CV) and means of pulp/peel ratio, acidity, soluble solids and maturation index of 'BRS Conquista' in Botucatu, State of Sao Paulo, 2018.

F test	DF	Pulp/peel ratio	Acidity (%)	Soluble solids (ºBrix)	Maturation index
Block	3	0.54^{NS}	0.24^{NS}	2.26^{NS}	0.24^{NS}
Treatment	4	2.24^{NS}	1.20^{NS}	5.99**	1.49^{NS}
CV (%)		19.02	13.97	2.89	15.91
Mean		100.72	0.66	23.24	36.15

^{NS} = not significant; ** = significant at $P<0.01$ by F test.

Silva Filho and Moreira (2005) also verified that bagged or non-bagged bunches in different types of cultivars did not alter the pulp/peel ratio. Muchui *et al*. (2010) did not find any significant relationship between the pulp/peel ratio of cv. Williams in an experiment with different bag colors and perforation sizes.

These authors also found no statistical differences for titratable acidity in fruits, as observed by Silva Filho and Moreira (2005) in an experiment with several varieties using the bunch bagging method in the State of Amazonia.

For the fruit maturation index, there was no significant difference between the treatments. The maturation index is the most widely used method to evaluate fruit flavor, which is the most representative isolated measurement of acidity and sugars (Chitarra and Chitarra, 2005). A ripe banana is a great example of a high SS/TA ratio because it has high levels of sugar and a low acid content.

There was a difference in the content of soluble solids in the fruits. The non-bagged fruits presented the highest average, 24.65° Brix (Tab. 4). Green bananas have high levels of starch; however, as a fruit ripens, starch is broken down into sugars to be used in the respiratory process, consequently increasing the soluble solid contents in the pulp (Chitarra and Chitarra, 2005). This result can be related to the fact that the non-bagged fruits were more exposed to radiation, which, even in small proportions, may have allowed greater photosynthesis and sugar production.

Table 4. Soluble solids values of the second cluster of the bunch of 'BRS Conquista' submitted to different polypropylene bag colors in Botucatu, State of Sao Paulo, 2018.

Treatment	Soluble solids (°Brix)
Non-bagged	24.65 a
White polypropylene	22.94 b
Black polypropylene	22.73 b
Red polypropylene	23.24 b
Blue polypropylene	22.64 b
CV (%)	2.89

Means with different letters indicate significant differences according to the Scott-Knot test ($P \leq 0.05$).

The non-bagged fruits may have presented a lower respiration rate than the bagged ones because, inside the bags, the mean temperature was much higher that outside, which in turn promoted an increased respiratory rate and, therefore, an increased sugar consumption.

During the respiratory process, substrates are consumed but mainly organic acids, sugars and starch are consumed (Chitarra and Chitarra, 2005), so the lower the respiration rate, the lower the substance consumption, causing higher soluble solids contents, as observed in the non-bagged fruits. Costa *et al*. (2002) observed a low soluble solids content in bagged bunches in cv. Nanicão, in Tietê, State of Sao Paulo. Likewise, Silva Filho and Moreira (2005) found higher soluble solids in non-bagged bunches than in bagged ones.

CONCLUSIONS

Regardless of the bag color, the banana bunch bagging method for 'BRS Conquista' did not promote changes in the plant productive performance.

The non-bagged fruits presented a higher soluble solids content than the bagged ones although the maturation index and the other physicochemical traits were not affected.

Conflict of interests: this manuscript was prepared and reviewed with the participation of the authors, who declare that there is no exists conflict of interest that puts the validity of the presented results at risk.

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