

Banana bunch cover: evaluation of promising bag materials

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Abstract

Now days there has been an increase in the consumers demand for great food, produced in environmentally cost-effective and friendly processes, being increasingly necessary new cultivation techniques able to ensure the required standards for banana growers and consumers. Therefore, the research aimed to evaluate the effects of bunch cover materials on development and quality of 'BRS Platina' banana fruits. The experimental design was in randomized blocks, with six treatments, four replications and four plants per plot, being the treatments: WB – without bagging; BBTK – black polypropylene bag (TNT) + kraft paper; BBPK - black polyethylene bag + kraft paper; KP – kraft paper; WBT – non-woven polypropylene white bag (TNT) and WBP - white polyethylene plastic bag. The 'BRS Platina' banana bunches cover improved fruits quality and the treatment polyethylene white bag (WBP) can be an advantageous option for the banana growers because of its effectiveness on the reduction of damages caused by flowers thrips (*Frankliniella* spp), providing a good agronomic performance and also does not delay the harvesting.

Keywords: bunches physical protection, kraft paper, *Musa* spp, polyethylene, polypropylene

Introduction

Banana (*Musa* spp.) is one of the most important fruit species economically produced in the world, cultivated in regions with tropical and subtropical climate. It is present in more than 130 countries, reaching more than 116 million tons produced worldwide (Amah et al., 2019; FAOSTAT, 2021). Its success and high consumer demand are due both to the versatility, in terms of modality of use (processed, fried, boiled, *in natura*), and to the attributes related to flavor, smell, nutritional value, price, hygiene and ease of consumption (Bolfarini et al., 2016). Additionally, it can be produced throughout the year, what makes it a more attractive species for producers.

Although it is a successful crop, its production in major cultivation regions is commonly affected by a complex of biotic and abiotic stresses and by problems in the production chain, which results in a drop in the

fruit's quality and price. In addition, consumers growing demand for food produced in a cost-effective and sustainable manner is also a strong appeal for the use of an important integrated system of techniques, from planting to marketing, aiming to overcome issues related to the high fragility and perishability level of this kind of product.

Due to this high perishability, banana is one of the fruits with higher loss during the production stages. Among some factors, insects attack before the harvest stands out, such as flowers thrips attack (*Frankliniella brevicaulis*). Producers in areas with high insect infestation have difficulties to produce fruits free from stains, which results in significant quality losses and harms the trading (Santosh et al., 2017). Also, wounds caused by the thrips ease the proliferation of fungi that originate rots in post-harvest (Brown et al., 2013).

Practices like male inflorescence removal and

deflower reduce the population of these insects, but are not enough to reduce the damages effectively, being necessary the application of chemical pesticides. However, the practice of banana bunch bagging has become a promising and safe alternative for these damages' reduction, especially nowadays, since consumers are more aware of food and environmental safety (Santosh et al., 2017).

The fruits bagging technique has been a recommended practice for many years to improve production quality, and it is already used for some banana producers in large scale productions. Besides protection against insects attack, this technique contributes to improve agronomic and commercial characteristics of the crop, as reduction in the interval between inflorescence emission and harvest, increase of the bunches and fruits masses, beyond providing protections against cold and leaves abrasive action (Buthelezi et al., 2021).

Although this technique encumbers production costs, it allows the reuse of packages from a cycle to another, depending on the material used and, despite the advantages, the recommendations of usage and the expected benefits does not always agree in literature, especially due to its interference caused by climate conditions found in the various spots analyzed and types of used materials.

The most appropriate type of material for fruits bagging has been the subject for many researchers' studies in different cultures and knowing that there are lots of types of materials that can be used and promote various effects on fruits growth and ripening, the present study aimed to evaluate the influence of materials for bunches bagging in the development and quality of 'BRS Platina' banana tree fruits.

Material and Methods

Location and characterization of the experimental layout

The research was conducted in Lageado Experimental Farm, which belongs to São Paulo State University "UNESP", Faculty of Agricultural Sciences, Botucatu Campus, in Botucatu municipality/ state of São Paulo, situated at 22° 51' 55" S and 48° 26' 22" W and at 810 m altitude.

Weather in Botucatu/SP municipality is classified as Cwa (Köppen, 1948), humid subtropical with drought in winter period and rain from November to April, being 1433 mm the annual rainfall average, the relative humidity of the air is 71% and temperature is 19.3° C. During the experiment period it was observed rainfall average of 112.98, relative humidity of the air of 70.57% and temperature of 21.74° C (Figure 1).

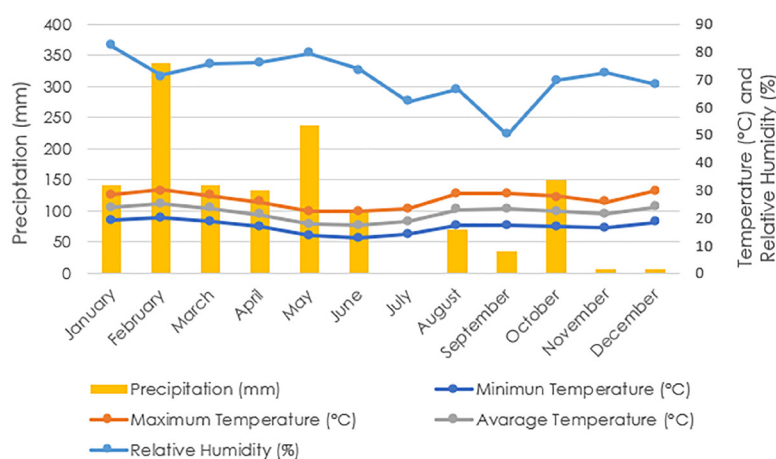


Figure 1. Climate data of Botucatu municipality in the research period. Source: Department of Natural Resources, Environmental Sciences/FCA UNESP – Botucatu-SP.

Experimental design, experiment's installation and conduction

The experiment was carried out in the experimental design in randomized blocks, composed by four blocks with six treatments and four plants per plot, amounting 96 plants. 'BRS Platina' banana plants were used, with two years old in the second production cycle, originated from micropropagated seedlings transplanted in experimental area spaced out at 2 x 2,5 m.

Bagging was performed at the moment plants sent the inflorescences out, tying up the bags' superior part to the stems. (Figure 2A). The bags used presented dimensions of 85 x 120 x 0.05cm (diameter x length x thickness), hollow cylindrical shape, with openings on its ends and drillings along the extension, in order to facilitate the gas exchanges.



Figure 2. Inflorescence without bagging (A) and with polypropylene black bag (TNT) + kraft paper (B); polyethylene black bag + kraft paper (C); kraft paper (D); polypropylene white bag (E) and polyethylene white bag (F).

The bags that composed the treatments were: WB – without bagging (Figure 2A); BBTk – polypropylene black bag (TNT) + kraft paper (Figure 2B); BBPK – polyethylene black bag + kraft paper (Figure 2C); KP – kraft paper (Figure 2D); WBT – non-woven polypropylene white bag (TNT) (Figure 2E) and WBP – polyethylene plastic white bag (Figure 2F).

Plants cultivation management was carried out when necessary, performing cubs thinning, defoliation, male inflorescence removal (“heart”), invasive plants control and maintenance fertilization. This maintenance fertilization was held based on soil analysis and recommendations for cultivation, applying fertilizer pellet

NPK in the dosage 20-05-20. Phytosanitary management, when necessary, was carried out according to recommendations for the crop.

Evaluated variables

Phenological characteristics

Fruits fruiting period was evaluated, corresponding to days between bagging and harvesting. Bunches harvest was performed from the observation of fruits visual parameters, considering the corners angularity and the total green color of the peel, matching stage I of ripening in Von Loesecke scale (CEAGESP, 2006) (Figure 3A).

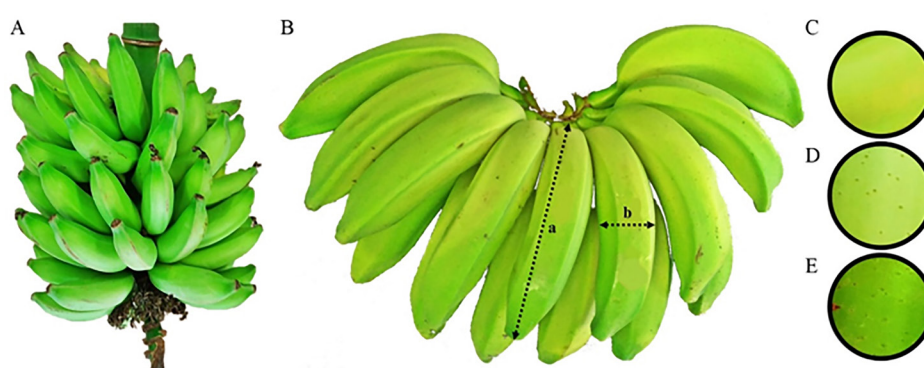


Figure 3. Bunch harvesting point (A); second hand and fruits (B), being length (a) and fruit diameter (b); fruits without injuries caused by thrips (C), with minor injuries (D) and severe injuries (E).

Productive agronomic performance and postharvest quality

Productive agronomic performance counted the number of hands per bunch (NH); bunch mass (kg) (BM) and productivity ($t\ ha^{-1}$) (PROD), considering the bunch mass and a stand of 2,000 plants ha^{-1} .

The second hand of each bunch (Figure 3B), considering the representative, was selected for the performance of physicochemical evaluations, being determined: fruits in the hand (FH), by counting; hand mass (kg) (HM), carried out with the help of an analytical balance with a precision of 0.01g; fruit length (cm) (FL) (Figure 3B, a), corresponding to the distance between

the ends of five central fruits measured with measuring tape; and fruit diameter (mm) (Figure 3B, b) measured in the central region of five fruits from the second hand, with the help of a digital pachymeter.

It was visually evaluated the presence of damages or injuries in the fruits (%) (DAM) per bunch, considering damages that affected the fruits' appearance, which can have physiological, entomological, pathological or mechanical origin.

For the thrips (*Frankliniella brevicaulis*) attack measurement, grades were assigned in terms of the number of scores in a circular area of 2.85 cm^2 . These scores were classified as without damage (under 5

scores) (Figure 3C), light damages (5 to 14 scores) (Figure 3D) and severe damages (more than 15 scores) (Figure 3E), as stated in the Banana Classification Rules of the Fruit Integrated Program proposed by CEAGESP (2006).

Subsequently, the hands were kept in ambient temperature (approximately 25°C), under balcony, until their complete maturation (ripening stage VI), according to Von Loesecke scale (CEAGESP, 2006). When they were ripe fruits, evaluations of pulp:peel⁻¹ (g) (PPR) relation were performed, soluble solids (°Brix) (SS), titratable acidity (TA) (Instituto Adolfo Lutz, 2005) and ripening rate (SS/TA) in the five central fruits of each second hand.

Statistical analysis

The data were analyzed and the normality

hypothesis was tested by Shapiro-Wilk test. The F test was used in the variance analysis to detect the difference between the factors. When a substantial difference for the variation source was found, the Scott-Knott test was used to compare the treatments averages for each variable. All statistical tests were performed at 5% probability using the SISVAR 5.6 software.

Results and Discussion

Phenological characteristics

The fruiting period and also 'BRS Platina' banana tree's productivity were influenced by the bunch bagging technique, presenting statistic difference between treatments (Table 1).

Table 1. Variance analysis for fruiting period, productivity of 'BRS Platina' banana bunches bagged with different materials.

Variation Sources	Fruiting Period (days)	Productivity (t ha ⁻¹)
	Medium Squares	
Block	4286.8971*	16.1281 ^{NS}
Treatment	1795.9288*	200.3278*
C.V. (%)	11.26	22.74
Treatments	Averages	
WB	171.25 ± 13.50 _{B**}	25.12 ± 0.35 _B
BBTK	197.50 ± 1.47 _A	36.41 ± 4.67 _A
BBPK	196.91 ± 1.38 _A	36.92 ± 1.46 _A
KP	195.50 ± 1.82 _A	37.32 ± 1.45 _A
WBT	168.00 ± 11.63 _B	28.82 ± 1.07 _B
WBP	168.88 ± 14.17 _B	33.24 ± 3.56 _A
Overall Average	183.01 ± 4.13	32.97 ± 1.20

(*) Significant and (NS) not significant at 5% of probability through F test. (**) Equal capital letters on the column (between lines) do not differ with each other through Scott-Knott test at 5% of probability. C.V. (%): coefficient of variation. WB – without bagging; BBTK – polypropylene black bag (TNT) + kraft paper; BBPK – polyethylene black bag + kraft paper; KP – kraft paper; WBT – non-woven polypropylene white bag (TNT) and WBP – polyethylene plastic white bag.

Treatments WB, WBT and WBP indicated shorter fruiting period with 171.25; 168.00; e 168.88 days, respectively. In literature, there are conflicts related to the cv. banana 'BRS Platina' development cycle, which can vary according to soil and climate conditions of the production locations, management techniques and banana plantation area's age. Considering that the shorter the fruiting period, the faster the fruits growth and, consequently, the fruits harvest, it can be said that using WBT e WBP constitutes feasible treatments. Even though they did not reduce the fruiting period, they did not cause delays in the harvest either.

Johns and Scott (1989) cite that the formation of a microclimate capable of rising the temperature and change the O₂ and CO₂ levels inside the bags on bagged bunches can reduce the fruiting period between 4 to 14 days, depending on the material type and external environmental conditions. During the present study, did not occur temperatures under 12°C in Botucatu municipality (Figure 1), which, in turn, increases the production cycle and causes physiological disorders such

as "chilling" on banana tree cultivation. That indicates that the obtained results suffered influences mainly of the applied treatments.

In all other treatments (SPTK, SPPK e PK) that caused an increase in the fruiting period related to the bunch without bagging (WB) (Table 1), it was used the kraft paper in their composition. This material might have contributed to a more intense modification in the microclimate of the environment around the bunch when compared to the other treatments. That is possibly because it is a less porous material, so lead to a reduction in the gas exchanges efficiency in such a way that the fruits morphophysiological development was delayed and, consequently, the values for this variable raised.

The crop final productivity was boosted by the treatments BBTK, BBPK, KP and WBP, that reached averages of 36.40; 36.92; 37.32 and 33.24 t ha⁻¹, respectively. Among this, WBT is what represents the shortest fruiting period, that is, the shortest development cycle time until harvest, the KP treatment is the one that represents the greatest productivity increase, providing

a 12.2 t ha⁻¹ rise when compared to WB bunch without bagging (Table 1).

It can be noticed that, in this case, treatments with greater productivity and that present kraft paper in their composition are the ones that took more time for the harvest. It can be said that these fruits received nutrients and photo-assimilated for a longer period when compared to the others, obtaining higher bunch and hand weight and productivity, therefore. As mentioned, the paper kraft material can favor a microclimate creation inside the bags because of its reduced porosity, as well as plastic bags materials such as WBP, when compared to only fabric-non-fabric bags (WBT), for example, which, in turn, allow better fruits breathe.

Similar result was found by Sarkar et al. (2016) that verified productivity 1.88 t ha⁻¹ higher in bunches bagged with polypropylene, comparing to the control, in agreement with what was found in the present study,

when it was used black polypropylene (BBTK), which provided an increase of 11.29 t ha⁻¹.

Productive agronomic performance and postharvest quality

In relation to the agronomic performance, there is no significant influence in the number of hands per bunch and fruits in the hand (Table 2). These variables presented on average 7.44 hands per bunch and 12.94 fruits in the second 'BRS Platina' banana hand, respectively. According to Moreira (1987), the number of hands, as well as the number of fruits per hand are parameters defined in the shift from the apical meristem vegetative development stage to the flower stage, around three or four months before inflorescence emerging in the plants peak. They are very much driven, especially, by genetic aspects of each cultivar.

Table 2. Variance analysis for number of hands, fruits in hand, hand mass and bunch mass of 'BRS Platina' banana bunches bagged with different materials.

Variation Sources	Number of Bunches	Fruits in Bunches	Hand Mass (kg)	Bunch Mass (kg)
Medium Square				
Block	0.2431 ^{NS}	2.1863*	0.0440 ^{NS}	3.2059 ^{NS}
Treatment	1.5375 ^{NS}	0.5299 ^{NS}	0.7440*	49.9288*
C.V. (%)	11.67	6.53	19.29	22.73
Treatments		Averages		
WB	6.88 ± 0.30	12.57 ± 0.14	1.96 ± 0.09 _{B**}	12.56 ± 0.18 _B
BBTK	7.63 ± 0.42	12.91 ± 0.30	2.60 ± 0.20 _A	18.20 ± 2.33 _A
BBPK	7.75 ± 0.31	13.19 ± 0.54	2.58 ± 0.14 _A	18.46 ± 0.73 _A
KP	8.00 ± 0.27	12.98 ± 0.24	2.63 ± 0.16 _A	18.66 ± 0.72 _A
WBT	7.38 ± 0.18	13.24 ± 0.32	2.01 ± 0.09 _B	14.60 ± 0.50 _B
WBP	7.00 ± 0.27	12.75 ± 0.22	2.30 ± 0.21 _A	16.62 ± 1.78 _A
Overall Average	7.44 ± 0.13	12.94 ± 0.13	2.35 ± 0.07	16.50 ± 0.60

(*) Significant and (^{NS}) not significant at 5% of probability through F test. (**) Equal capital letters on the column (between lines) do not differ with each other through Scott-Knott test at 5% of probability. C.V. (%): coefficient of variation. WB – without bagging; BBTK – polypropylene black bag (TNT) + kraft paper; BBPK – polyethylene black bag + kraft paper; KP – kraft paper; WBT – non-woven polypropylene white bag (TNT) and WBP – polyethylene plastic white bag.

One notices that there was a significant influence of bagging on hand and bunch masses of 'BRS Platina' banana. The banana hands presented higher masses on treatments BBTK (2.59 kg), BBPK (2.58 kg), KP (2.63 kg) and WBP (2.30 kg), being these values statistically equal. The bunch mass is also higher in treatments BBTK (18.20 kg), BBPK (18.46 kg), KP (18.66 kg) and WBP (16.62 kg), which did not differ from each other (Table 2).

Considering the composition of the materials used in the mentioned treatments above, the obtained results can be explained just as said previously for the productivity variable. That is, the treatments possibly entailed a microclimate formation inside the bags that reduced the gas exchanges efficiency among the fruits and the external environment. This way the fruits demanded more time for their complete development. Consequently, in function of the higher period until

the harvest, these fruits received nutrients and photo-assimilated at more time, ensuring greater mass gain.

Fruits' size is a physical characteristic associated to the species or cultivars. Although, it is used as a quality attribute for the selection and classification of the products, according to the consuming market's convenience (Schreiner et al., 2013). The types of bags, however, did not affect fruits length and diameter, as well as the pulp:peel relation. The experiment's overall averages for these variables were respectively 21.01±0.36 cm, 39.87±0.60 mm e 2.14±0.07 (Table 3).

In relation to the damages and injuries percentage, it can be noticed that the WB treatment presented the higher percentage of damages in fruits (10%), differing from the other treatments with bagged bunches and showing that the use of bagging was effective for this variable. Besides, the BBPK and WBT

bags reduced significantly the damages percentage, staying with average of 2% of damages in fruits (Table 4). The main damages observed were mechanic damages, caused primarily by the harvest, and in the case of without bagging bunches (WB), also damages caused by leaves abrasion, wind and rain.

It can be said that bunches bagging interfered on the incidence of the plague attack in fruits, once bagged bunches reduced injuries to light level,

independent of the treatment (Table 4). This emphasized that pesticides needn't be used for the plague control when the bagging technique is applied. According to Sarkar et al. (2016) the reduction in the percentage of fruits damages and injuries to the detriment of bagging make them more attractive for consumers, consequently elevating the market price and net profit of producer's sale, when compared to fruits without bagging.

Table 3. Variance analysis for length, diameter and pulp:peel relation of the fruits in the second hand of 'BRS Platina' banana bunches bagged with different materials.

Variation Sources	Fruits Length (cm)	Fruits Diameter (mm)	Pulp:Peel Relation
		Medium Square	
Block	2.6480 ^{NS}	11.3625 ^{NS}	0.3283 ^{NS}
Treatment	5.8890 ^{NS}	35.4225 ^{NS}	0.3114 ^{NS}
C.V. (%)	12.00	9.78	22.38
Treatments		Averages	
WB	19.64 ± 0.77	39.40 ± 0.92	2.15 ± 0.27
BBTK	20.84 ± 0.57	40.74 ± 0.97	2.01 ± 0.14
BBPK	22.33 ± 0.32	42.79 ± 0.61	2.19 ± 0.15
KP	21.01 ± 1.68	36.32 ± 2.70	1.90 ± 0.08
WBT	21.15 ± 0.43	39.88 ± 1.12	2.09 ± 0.11
WBP	21.09 ± 0.73	40.05 ± 0.70	2.48 ± 0.21
Overall Average	21.01 ± 0.36	39.87 ± 0.60	2.14 ± 0.07

(^{NS}) not significant at 5% of probability through F test. C.V. (%): coefficient of variation. WB – without bagging; BBTK – polypropylene black bag (TNT) + kraft paper; BBPK – polyethylene black bag + kraft paper; KP – kraft paper; WBT – non-woven polypropylene white bag (TNT) and WBP – polyethylene plastic white bag.

Table 4. Variance analysis for damages or injuries and classification of damages caused by thrips of 'BRS Platina' banana bunches bagged with different materials.

Variation Sources	Damages or Injuries (%)	Classification of Damages by Thrips
Block	0.0374*	
Treatment	73.4412*	
C.V. (%)	1.93	
Treatments		Averages
WB	10.00 ^{A**}	Severe
BBTK	3.00 ^C	Light
BBPK	2.00 ^D	Light
KP	4.00 ^B	Light
WBT	2.00 ^D	Light
WBP	3.00 ^C	Light
Overall Average	4.00	-

(*): Significant at 5% of probability through F test. (**): Equal capital letters on the column (between lines) do not differ with each other through Scott-Knott test at 5% of probability. C.V. (%): coefficient of variation. WB – without bagging; BBTK – polypropylene black bag (TNT) + kraft paper; BBPK – polyethylene black bag + kraft paper; KP – kraft paper; WBT – non-woven polypropylene white bag (TNT) and WBP – polyethylene plastic white bag.

In this work, all treatments that received bagging significantly reduced the percentages for this variable (Table 4), corroborating with other studies carried out with bananas and other fruit species. To Sarkar et al. (2016) cv. Malbhorg banana fruits bagged with polypropylene presented only 5% of damages or injuries, compared to the bunch without bagging (no protection), in which the rate was superior to 50%. Tran et al. (2015) in a work with three cultivars of red pitaya. They pointed out that the total percentage of damaged and defective fruits with bagging was significantly smaller than the ones without bagging on the three cultivars, regardless of the

type of bag that was used. Costa et al. (2017) verified that red pitaya fruits packed with polypropylene were not damaged during the cycle. While 54.40% of the fruits without bagging presented some kind of damage or injury.

Damages caused by the flowers thrips (*Frankliniella brevicaulis*) can be easily visualized after fruits growth, from the appearance of small brown and rough points on touch on the fruits peel (Figures 3C, 3D e 3E). These points are reactions of the tissue to the oviposition made by the female thrips that, despite not interfering in the pulp quality, reduces the commercial

value of the product (PROMUSA, 2018).

As mentioned before in this study, treatments with bagged bunches reduced the damage caused by thrips to light, while non-bagged bunches (WB) showed severe damage. These results are in line with what was found by Martins et al. (2020), who concluded that bunches bagging is efficient for flower thrips control. Sharma et al. (2014), in studies with 'Royal Gala' apples, also observed that protecting fruits through field bagging is an effective

technique against pathogens and plagues.

Soluble solids contents, titratable acidity, ripeness index and pH are attributes that best define the quality of banana fruits (Sanæifar et al., 2016). Among fruits chemical evaluation, pH was the only which did not present difference between the accomplishment or not of bagging, being the pH of fruits pulp around 53 ± 0.05 (Table 5).

Table 5. Analysis of variance for pH, soluble solids, titratable acidity and ripening index of fruits from the second hand of 'BRS Platina' banana bunches bagged with different materials.

Variance Sources	pH	Soluble Solids (°Brix)	Titratable Acidity (g malic acid 100 g pulp ⁻¹)	Ripening Index
Medium Square				
Block	0.1524 ^{NS}	0.6058 ^{NS}	0.0113 ^{NS}	19.7902 ^{NS}
Treatment	0.1355 ^{NS}	5.0168*	0.0505*	181.7590*
C.V. (%)	8.24	4.09	17.47	15.80
Treatments	Averages			
WB	4.33 ± 0.26	23.39 ± 0.13 _{B**}	0.50 ± 0.03 _B	48.27 ± 2.66 _A
BBTK	4.55 ± 0.09	24.88 ± 0.26 _A	0.71 ± 0.05 _A	36.09 ± 2.25 _B
BBPK	4.59 ± 0.05	23.84 ± 0.41 _B	0.64 ± 0.02 _A	37.86 ± 1.15 _B
KP	4.48 ± 0.09	24.98 ± 0.53 _A	0.69 ± 0.03 _A	36.67 ± 0.75 _B
WBT	4.49 ± 0.13	23.79 ± 0.21 _B	0.57 ± 0.04 _B	43.38 ± 3.38 _A
WBP	4.72 ± 0.02	23.01 ± 0.36 _B	0.59 ± 0.05 _B	38.33 ± 1.88 _B
Overall Average	4.53 ± 0.05	23.98 ± 0.17	0.61 ± 0.02	40.10 ± 1.06

(*) Significant and (NS) not significant at 5% of probability through F test. (**) Equal capital letters on the column (between lines) do not differ with each other through Scott-Knott test at 5% of probability. C.V. (%): coefficient of variation. WB – without bagging; BBTK – polypropylene black bag (TNT) + kraft paper; BBPK – polyethylene black bag + kraft paper; KP – kraft paper; WBT – non-woven polypropylene white bag

The pH is a parameter that indicates on the whole the fruit acidity and, the less the value, more acid is the fruit. On banana crop most of hybrids present pH reduction according to their ripening. Although, some hybrids may not demonstrate changes (Dadzie & Orcard, 1997), as happened in the present study. It can be noticed that the overall average for 'BRS Platina' is in accordance with what was found Oliveira et al. (2013), that observed pH of 4.75 in work carried out with the same cultivar in bunches not bagged.

Soluble solids values were higher in BBTK e KP bags, with values at 24.88 and 24.98 °Brix, which differed from the other treatments. The same treatments also presented the highest averages for titratable acidity, followed by BBPK treatment with, respectively, 0.71; 0.69 and 0.64 g malic acid 100 g pulp⁻¹, and differing significantly from the other treatments (Table 5).

Soluble solids (SS) and titratable acidity (TA) contents are directly connected to the fruits breathe metabolic processes during ripening. Bananas are starchy fruits when unripe and, as far as the ripening goes, these compounds are broken into sugars to be used in the fruits breathe. Organic acids, in the case of bananas and differently from other vegetable species, are not used in this process and because of that it is common, in

these fruits ripening, to occur its accumulation in ripe fruits (Thakur et al., 2019).

Possibly the increase of internal temperature of some bag materials raised the 'BRS Platina' fruits respiration rate, intensifying the accumulation of SS and TA (Chitarra & Chitarra, 2005). Another aspect that should be considered consists in the act that the BBTK, BBPK and KP treatments took more time to grow until harvest, according to what was shown previously on Table 1, with more time for the TA to accumulate in fruits, when compared to treatments harvested prematurely. That way, since banana is a climate fruit and continues its ripening after harvest, the TA of these fruits continued to accumulate until evaluations moment (stage 6), when it was obtained, therefore, greater values than the ones provided by the other treatments harvested with lower TA. Different results were reported by Fernandes et al. (2019) that did not observe significant difference for SS and TA in terms of the use of the technique in banana 'Prata-anã'.

Relation between SS and AT expresses the fruits ripening index and is one of the ways most commonly used to evaluate fruits taste, and there should be a balance among components (Chitarra & Chitarra, 2005). WB and WBT treatments produced the best averages for

this variable, with 48.27 and 43.38 rates, respectively, and were statistically different from others (Table 5). This result makes evident that bagging with WBT, besides improving agronomic variables, also provides fruits with sensory quality, such as obtained when the technique is not used, not being unfavorable in the acquisition of such results for the producer. It is worth observing that in treatments with BBTk, BBPK and KP, the lower values occurred due to a greater accumulation of organic acids.

According to Sharma et al. (2014), ripe banana has the high relation SS:TA as an outstanding characteristic. That is, the fruit presents in this case greater soluble solids contents in relation to acidity. According to Chitarra and Chitarra (1984) the standard ripening index for ripe bananas from the Prata group must be around 39.29. That way, may be said that WB and WBT treatments provide fruits with ripening index more adequate for consumption (48.27 e 43.38, respectively) when compared to others that, in turn, present suboptimal values considered by the authors mentioned above. Similar result was verified by Oliveira et al. (2013) in studies with 'BRS Platina' not bagged fruits, where it was observed index of 46.99.

Therefore, it can be observed by the results obtained in this experiment and in the works previously mentioned that bunches bagging provides the formation of a microclimate inside the bags that shall affect production and postharvest variables of 'BRS Platina' banana. Although, it is important that in future works this information is confirmed through temperature measurement and gases composition inside the bags, for better comprehension of the results. It is worth mentioning that, although the technique shall increase the production costs, depending on the material used, it is possible to make the reuse from a cycle to another, leading to savings for the producer.

Conclusions

'BRS Platina' banana bunches cover consists on a technique capable of improving fruits quality, being the bagging with white polyethylene (WBP) bag an advantageous option for the banana growers, because it is effective in the reduction of damages caused by flowers thripes (*Frankliniella spp*), providing a good agronomic performance, and also do not cause delays to the harvest.

Acknowledgments

Authors would thank the Coordination of Improvement of Higher Education Personnel (CAPES) for granting a master's degree to the first author, also to the National Research Council (CNPq) for providing financial

support (Process 304455/2017-2).

References

- Amah D., Biljon, A. Van., Brown, A., Perkins-Veazie, P., Swennen, S., Labuschagne, M. 2019. Recent advances in banana (*Musa spp.*) biofortification to alleviate vitamin A deficiency, *Critical Reviews in Food Science and Nutrition* 59: 3498-3510.
- Bolfarini, A.C.B., Leonel, S., Leonel, M., Tecchio, M.A., Silva, M.S., Souza, J.M. A. 2016. Growth, yield and fruit quality of 'Maçã' banana under different rates of phosphorus fertilization. *Australian Journal of Crop Science* 10:1368– 1374.
- Brown P.R., McWilliam A., Khamphoukeo K. 2013. Post-harvest damage to stored grain by rodents in village environments in Laos. *International Biodeterioration & Biodegradation* 82: 104-109.
- Buthlezi, N., Mafeo, T., Mathaba, N. 2021. Preharvest Bagging as an Alternative Technique for Enhancing Fruit Quality: A Review, *HortTechnology hortte* 4-31: 13.
- CEAGESP. Companhia De Entrepósitos E Armazéns Gerais De São Paulo. 2006. Programa Brasileiro Para a Modernização da Horticultura e Produção Integrada de Frutas. *Normas de Classificação de Banana*. São Paulo, SP: CEAGESP. <http://www.ceagesp.gov.br/wp-content/uploads/2015/07/banana.pdf> <Retrieved on Nov 27, 2020>
- Chitarra, M.I.F, Chitarra, A.B. 2005. *Pós-colheita de frutas e hortaliças: fisiologia e manuseio*. Lavras, MG: UFLA.
- Chitarra A.R., Chitarra M.I.F. 1984. Manejo pós-colheita e amadurecimento comercial de banana. *Pesquisa Agropecuária Brasileira* 19: 761-771.
- Costa A.C., Ramos J.D., Menezes T.P., Laredo R.R., Duarte M.M. 2017. Quality of pitaya fruits submitted to field bagging. *Revista Brasileira de Fruticultura* 39: e-377.
- Dadzie, B.K., Orchard, J.E. 1997. *Evaluación rutinaria postcosecha de híbridos de bananos y plátanos: criterios e métodos*. Roma: CIRPAC, IPGRI.
- FAO. Food and Agricultural Organization. 2019. <http://www.fao.org/faostat/en/#home> <Retrieved on March 10, 2021>
- Fernandes, M.B., Mizobutsi E.H., Rodrigues M.L.M., Ribeiro R.C.F., Mizobutsi G.P., Pinho, D.B. 2019. Bagging time of 'Prata-anã' banana regarding anthracnose control. *Revista Brasileira de Fruticultura* 41: e-066.
- Instituto Adolfo Lutz. 2005. *Métodos físico-químicos para análise de alimentos*. São Paulo, SP: Instituto Adolfo Lutz.
- Johns G.G., Scott K.J. 1989. Delayed harvesting of bananas with 'sealed' covers on bunches modified atmosphere and microclimate inside sealed covers. *Australian Journal Experimental Agriculture* 29: 719-726.
- Köppen, W. 1948. *Climatología conune studio de los climas de la Tierra*. México: Fondo de Cultura Económica, 478p.

Martins R.C., Leonel S., Souza J.M.A., Silva M.S., Ferreira R.B., Züge P.G.U., Lorenzetti E.R., Bueno R.C.O.F. 2020. Yield, seasonality and plant health care of banana 'BRS Conquista' covered with different coloured polyethylene bags. *Semina: Ciências Agrárias*. 41: 2977-2990.

Moreira R.S. 1987. *Banana: teoria e prática de cultivo*. Campinas, SP: Fundação Cargill.

Oliveira, C.G., Donato, S.L.R., Mizobitsi, G.P., Silva, J.M., Mizobitsi, E.H. 2013. Característica pós-colheita de bananas 'Prata-anã' e 'BRS Platina' armazenadas sob refrigeração. *Revista Brasileira de Fruticultura* 35: 891–897.

PROMUSA (2018). Bagging/News, knowledge and information on bananas from. <http://www.promusa.org/Bagging> <Retrieved on March 10, 2021>.

Sanaeifar, A., Bakhshipour, A., Guardia, M.L. 2016. Prediction of banana quality indices from color features using support vector regression *Talanta* 148: 54–61.

Santosh D.T., Tiwari K. N., Gopala R.R. 2017. Banana bunch covers for quality banana production - A Review. *International Journal of current microbiology and applied sciences* 7: 1275-1291.

Sarkar, S., Das, G., Sarkar, S., Saha, S., Biswas, S. 2016. Frontline demonstration on effect of bunch cover in banana for quality production of banana fruits. *International Journal of Green Pharmacy* 10: S261.

Schreiner, M., Korna, M., Stenger, M., Holzgrevea, L., Altman, M. 2013. Current understanding and use of quality characteristics of horticulture products. *Scientia Horticulturae* 163: 63–69.

Sharma R.R., Reddy S.V.R., Jhalegar M.J. 2014. Pre-harvest fruit bagging: A useful approach for plant protection and improved post-harvest fruit quality – A review. *Journal of Horticultural Science and Biotechnology* 89: 101–113.

Thakur, R., Pristijono, P., Bowye,r M., Singh, S.P., Scarlett, C.J., Stathopoulos, C.E., Vuong, Q.V. 2019. A starch edible surface coating delays banana fruit ripening. *LWT - Food Science and Technology* 100: 341–347.

Tran, D., Yen, C., Chen, Y.H. 2015. Effects of bagging on fruit characteristics and physical fruit protection in red pitaya (*Hylocereus* spp.). *Biological Agriculture & Horticulture: An International Journal for Sustainable Production Systems* 31: 158-166.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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