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Effect of treatments with bunch bagging on production, fruit quality and damage by thrips of banana

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The effect of treatments of banana with blue polyethylene bag covering bunches on the production parameters at harvest, fruit quality during ripening and damage by thrips has been determined. Nine treatments with banana bunch blue polyethylene bags, including the control were evaluated. A complete randomized block design was used. Four replicates per treatment were used with five bunches each. Bunch weight, finger diameter, length and weight at harvest, external and internal fruit quality during ripening, and percentage of damages by thrips on banana fruit were assessed at harvest. Only the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) significantly increased the banana fruit diameter and weight (41.06 mm and 255.15 g, respectively) at harvest. Some treatments with blue polyethylene bag significantly improved the pulp weight, titratable acidity, and total soluble solid content, but did not improve the rest of the quality parameters at ripening stage. The fruit damage by red rust thrips was significantly reduced by the treatments with blue polyethylene bag. The blue polyethylene bags impregnated with chlorpyrifos did not improve the control of red rust thrips with respect to the blue polyethylene bags without impregnation with chlorpyrifos.

Key words: Fruit quality, fruit weight, fruit diameter, fruit firmness, thrips, chlorpyrifos, polyethylene bags, bunch bagging.

INTRODUCTION

Currently, there is an increasing demand of high-quality fresh fruits and particularly of banana fruits by national and international markets. This quality of banana fruits can be influenced by several factors, including pre-harvest agricultural practices (Muchui et al., 2010), among which the banana bunch bagging is commonly used. The banana bunch bagging constitutes a microclimate around the fruits (Sharma et al., 2014), which favors metabolic and physiological activities on the fruits (Jia et al., 2005). The effects of banana bunch bagging, particularly in the tropics, on fruit size, diameter, weight, length, color, and other quality parameters have been contradictory; which can be explained by the type of bag used, the age of the fruit at the moment of the bagging and cultivar (Amarante et al., 2002; Narayana et al., 2004; Muchui et al., 2010). Also banana bunch bagging provides protection to the fruit surface against pathogens, wind damage, leaf and petiole rubbing, dust,

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sunburn, bird feeding (Amani and Avagyan, 2014), peel coloration, damage by insect pest and mechanical damage (Santosh et al., 2017; Scribano et al., 2018) in pre-harvest. Likewise, countries such as Colombia, Ecuador, Costa Rica, Honduras and the Philippines use chlorpyrifos-impregnated blue polyethylene bags and they are kept over the ripening fruits for three months to protect the banana peel from damage caused by insects, primarily thrips (*Chaetanaphothrips orchidii* Moulton and *C. Signipennis* Bagnall, order Thysanoptera: Family Thripidae) (Altabtabaee et al., 2016). Kumar et al. (2015) reported that the fruit covered with transparent polyethylene bag significantly increased fruit length and weight. In another research work, organophosphorated insecticide-impregnated bunch polyethylene bags significantly reduced bunch yield and pulp diameter on ‘Prata Zulu’ cultivar, but these same bags increased fruit length on ‘Nanicao 2001 cultivar. Whereas bunch size and fruit thickness were not influenced by the bunch polyethylene bags impregnated with organophosphorated insecticide (Moreira, 2008). More recent findings revealed that fruits under white non-woven polypropylene cover registered highest total soluble solids (TSS, 22.84 °B) and lowest titratable acidity (AT, 0.23%) with respect to the control bunch (19.36 °B and 0.27%, respectively) on ‘Jahaji’ cultivar (Purnima et al., 2016). Likewise, Sarkar et al. (2016) found that bunches cover with non-woven polypropylene skirt bag significantly increased the fruit weight (105.79 g) when compared to the control bunch (96.64 g).

Although in Mexico and particularly at the banana growing area from Tabasco state the banana bunch bagging is a very common commercial agricultural practice, there is no or scarce study on the effect of the banana bunch bagging. The objectives of this research work were: i) to determine the effect of the bunch bagging on the production parameters of banana fruit at harvest, ii) to evaluate the effect of the bunch bagging on the fruit quality parameters of banana at ripening stage and iii) to evaluate the effect of the banana bunch bagging on the damage caused by thrips at harvest.

MATERIALS AND METHODS

Research site

The experiment was conducted with banana cv. ‘Enano Gigante’ in a commercial orchard located in the banana growing area from Teapa (geographic coordinates 17° 33´ 0´´ North 92° 57´ 0´´), Tabasco, Mexico from September to mid-November 2016. The banana planting density in the commercial orchard was 1600 plants per hectare.

Treatments and experimental design

Nine treatments with banana bunch polyethylene bags were evaluated: 1) micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 (aromatic essential oils, GAIA® Scent WG 300, Axipolymer Inc) at 3%, 2) normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3%, 3) micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6%, 4) normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6%, 5) micro-perforated blue polyethylene bag impregnated with conventional insecticide chlorpyrifos at 5%, 6) normal perforated blue polyethylene bag impregnated with conventional insecticide chlorpyrifos at 5%, 7) micro-perforated blue polyethylene bag, 8) normal perforated blue polyethylene bag and 9) control bunch (bunch without bagging). A complete randomized block design was used. Four replicates of five bunch each per treatment were used. The micro-perforated polyethylene bags had the following characteristics: hole of 5 mm in diameter, with 3 cm of distance among them in the same row and 6 cm of distance among rows. The normal perforated polyethylene bags had the following characteristics: hole of 10 mm in diameter, with 8 cm of distance among them in the same row and 12 cm of distance among rows.

Banana bunch bagging

Banana bunches were bagged when the hand fingers had started to curl upwards and the flower remnants had hardened and dried, on September 1st in 2016. Bags were slid up from the bottom of the stalk and securely tied to the peduncle above the first hand of the fruit. Bunch bags were left on bunches in field until the harvest (10 weeks after bunch bagging).

Production parameters at harvest

The effect of treatments with blue polyethylene bags on banana bunch was determined at harvest (green-mature stage: maturity stage 1). For each treatment with polyethylene bag forty fingers were taken of outer whorl from the second hand of the bunches (ten fingers for each replicate), and the followings quality parameters were measured:

Bunch weight (kg): Banana bunches were weighed with a hang electronic mini-balance (IPASA, OCS-L, Mexico city, Mexico).

Finger diameter (mm): The finger diameter was measured on the middle region of the banana fruit with a caliper (QA SUPPLIES, Virginia, USA).

Finger length (cm): The finger length was determined by measuring the outer curve of the fruit with a tape from the distal end to the proximal point where the pulp is judged to terminate.

Finger weight (g): The fingers were weighed with an electronic balance (Ohaus Corporation, USA).

Fruit peel color at harvest

The banana peel color was measured with a colorimeter (HunterLab, Virginia, USA) on the bottom, middle and top region of the finger.

External fruit quality during ripening

A lot constituted by the second hands of banana bunches at green mature stage bagged according to the treatments was treated with the recommended agrochemical products for banana in the packinghouse to prevent latex staining and to control anthracnose and crown rot diseases; it was then dried at room temperature. The banana fruit from this lot was ripened in a commercial ripening chamber at 18°C and 90-95% RH, using exogenous ethylene gas for 72 h located in the municipality of Cunduacán, Tabasco. After the commercial forced ripening period, forty banana fruits per treatment (ten fruits of each replicate) were selected to measure the following banana fruit quality parameters at three ripening stages (5, 6 and 7).

Pulp and peel thickness (mm): The fingers were peeled and then the banana pulp and peel thickness were measured using a caliper (QA SUPPLIES, Virginia, USA).

Pulp and peel weight (g): The banana fruit pulp and peel were individually separated and weighed with an electronic digital balance (Ohaus Corporation, USA).

Pulp to peel ratio: This fruit quality parameter was calculated by dividing the pulp between peel weights.

Fruit pulp firmness (kgf): The fruit pulp firmness was measured with a digital fruit penetrometer (model GY-4) with an 8 mm probe. The firmness was expressed as kilogram force (kgf).

Internal fruit quality during ripening

Determination of titratable acidity

Titratable acidity (TA) was determined during ripening at color stages 5, 6 and 7. Four samples per treatment were used and each sample consisted of 10 fingers from the second hand. 30 g of banana pulp tissue from the transverse section of the fruits in 90 ml of distilled water were blended for 2 min and then filtered through muslin cloth. 25 ml of the filtrate was transferred into a 125 ml flask and then 25 ml of distilled water was poured into it. Titratable acidity was determined by titration with 0.1N NaOH in the presence of phenolphthalein indicator and expressed as percent malic acid.

Determination of total soluble solids content

Total soluble solids content (TSSC) was determined during ripening at color stages 5, 6 and 7. Four samples per treatment were used and each sample consisted of 10 fingers from the second hand. 30 g of banana pulp tissue from the transverse section of the fruits in 90 ml of distilled water was blended for 2 min and then filtered through muslin cloth. Three drops of the filtrate were placed on the prism of a digital refractometer (ATAGO Pal-1, Japan). The TSSC was expressed in B°.

Damages by red rust and flower trips on banana fruit at harvest

For each treatment, four replications were used. Each replication consisted of 50 fingers taken randomly from five bunches per replication (It was taken from 10 fingers of the second hand per bunch). The banana red rust and flower trips damage was inspected, counted and recorded, and expressed as percent damage (%).

Statistical analysis

Data from fruit quality parameters, banana red rust damage and flower trips damage were analyzed by analysis of variance with statgraphics software (Statgraphics plus, version 5.1). Data on damage of banana red rust and flower trips were transformed to the arcsine of the square root of the proportion of damaged fruit to assure the homogeneity of variances. Statistical significance was judged at the level of $P \leq 0.05$. When appropriated, the Fisher's Protected Least Significant Difference (LSD) test was applied to separate means. Shown values are non-transformed data.

RESULTS

Effect of bunch bagging on the production at harvest

In general, all eight treatments with bunch cover bags evaluated in this research work did not significantly improve the yield parameters of banana at harvest, with the exception of the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) with respect to the control bunch. This treatment with bunch cover bag significantly increased the banana fruit diameter and weight with value of 41.06 mm and 255.15 g, respectively; while the control bunch had fruit diameter and weight of 39.69 mm and 229.40 g, respectively. Although the normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), and the micro-perforated blue polyethylene bag (T7) increased the fruit diameter and weight, with values of 40.14 and 39.73 mm, and 241.74 and 237.46 g, no significant differences with respect to the control bunch were observed (Table 1).

Effect of bunch bagging on fruit peel color at harvest (parameters L and a)

Overall, all eight treatments with banana bunch cover bag had no significant effect (p = 0.780) on lightness (L*) coordinate of the banana peel color when compared to the control bunch at harvest (Figure 1). Moreover, all treatments with banana bunch cover bag had no significant effect on **a*** coordinate (red/green; negative values of **a*** indicate green color and positive values of **a*** indicate red color) when compared to the control bunch. Irrespective of control bunch, significant differences among the treatments with blue polyethylene bag were observed. For instance, the greenest fruit peel color of banana (less ripened fruit after 10 weeks of bagging) was significantly obtained with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), with **a*** coordinate value of -11.94, followed by the normal perforated blue polyethylene (T8), with **a*** coordinate value of -11.83. In contrast, the least green fruit peel color of banana (more ripened fruit after 10 weeks of bagging) was significantly obtained with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1) and micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), with **a*** coordinate value of -11.36 for both treatments (Figure 1).

Table 1. Effect of bunch cover bags on yield parameters at harvest in banana cv. 'Enano Gigante'.

Treatment	Fruit diameter (mm)	Fruit length (cm)	Fruit weight (g)	Bunch weight (kg)
Control	39.69±0.28[a]	24.21±0.32[a]	229.4±2.06[a]	31.16±1.32[a]
Micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1)	39.85±0.29[a]	24.36±0.47[a]	232.72±3.66[a]	28.76±1.96[a]
Normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2)	39.63±0.37[a]	24.53±0.41[a]	229.66±5.19[a]	28.61±1.79[a]
Micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3)	39.61±0.26[a]	23.96±0.51[a]	230.34±4.89[a]	27.80±2.10[a]
Normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4)	39.71±0.65[a]	24.21±0.86[a]	235.71±12.85[a]	29.109±1.83[a]
Micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5)	41.06±0.30[b]	24.81±0.64[a]	255.16±6.07[b]	29.64±1.27[a]
Normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6)	40.14±0.24[ab]	24.51±0.72[a]	241.74±2.03[ab]	27.85±0.78[a]
Micro-perforated blue polyethylene bag (T7)	39.73±0.32[a]	24.73±0.37[a]	237.46±9.19[ab]	29.41±2.42[a]
Normal perforated blue polyethylene bag (T8)	39.30±0.21[a]	24.22±0.13[a]	227.55±5.26[a]	29.77±2.06[a]

Banana bunches were bagged when the hand fingers had started to curl upwards and the flower remnants had hardened and dried. Bunch bags were left on bunches in field until the harvest (10 weeks after bunch bagging). For each column, mean values followed by equal letters are not statically different (Fisher, 0.05).

Effect of bunch bagging on the external quality during ripening

Fruit peel and pulp thickness

No significant effect of treatments with bunch polyethylene bags was observed on the fruit peel thickness at the ripening stages 5, 6 and 7 on the 'Enano Gigante' banana. In general, the fruit peel thickness of banana ranged from 0.31-0.36, 0.30-0.35 and 0.28-0.32 mm at the ripening stage 5, 6 and 7, respectively (Figure 2).

Regarding the effect of bunch bagging on the fruit pulp thickness at ripening stage 5, the pulp thickness on the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) was significantly superior (pulp thickness of 3.19 cm) to the rest of the bagged treatments (pulp thickness of 3.02-3.06), except on the control bunch (pulp thickness of 3.11 cm) and the micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3; pulp thickness of 3.10 cm). At ripening stage 6, the highest fruit pulp thickness was obtained in bunches covered with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) and normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), with a fruit pulp thickness of 3.21 and 3.17 cm, respectively (Figure 2). At ripening stage 7, the highest fruit pulp thickness was recorded in bunches covered with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) and normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), with a fruit pulp thickness of 3.23 and 3.17 cm, respectively (Figure 2).

Banana fruit peel and pulp weight

At ripening stage 5, the fruit peel weight (ranged of 70.62-77.06 g) of banana fruit was not significantly affected by the treatments with blue polyethylene bags covering bunches with respect to the control bunch (fruit peel weight of 73.71 g), with the exception of the bunches covered with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), in which the peel weight of fruit was 81.79 g.

At ripening stage 6, among the tested blue polyethylene bags, only the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) and the normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4) resulted in a higher peel weight (75.85 and 73.73 g of peel weight, respectively) compared with the control bunch (70.40 g of peel weight; Figure 3).

At ripening stage 7, highest fruit peel weight was significantly obtained by bunches covered with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) and by normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), with a fruit peel weight of 71.28 and 69.17 g, respectively, with respect to the control bunch (Figure 3).

No significant effect of bunch bagging was observed on the fruit pulp weight at ripening stage 5. The fruit pulp

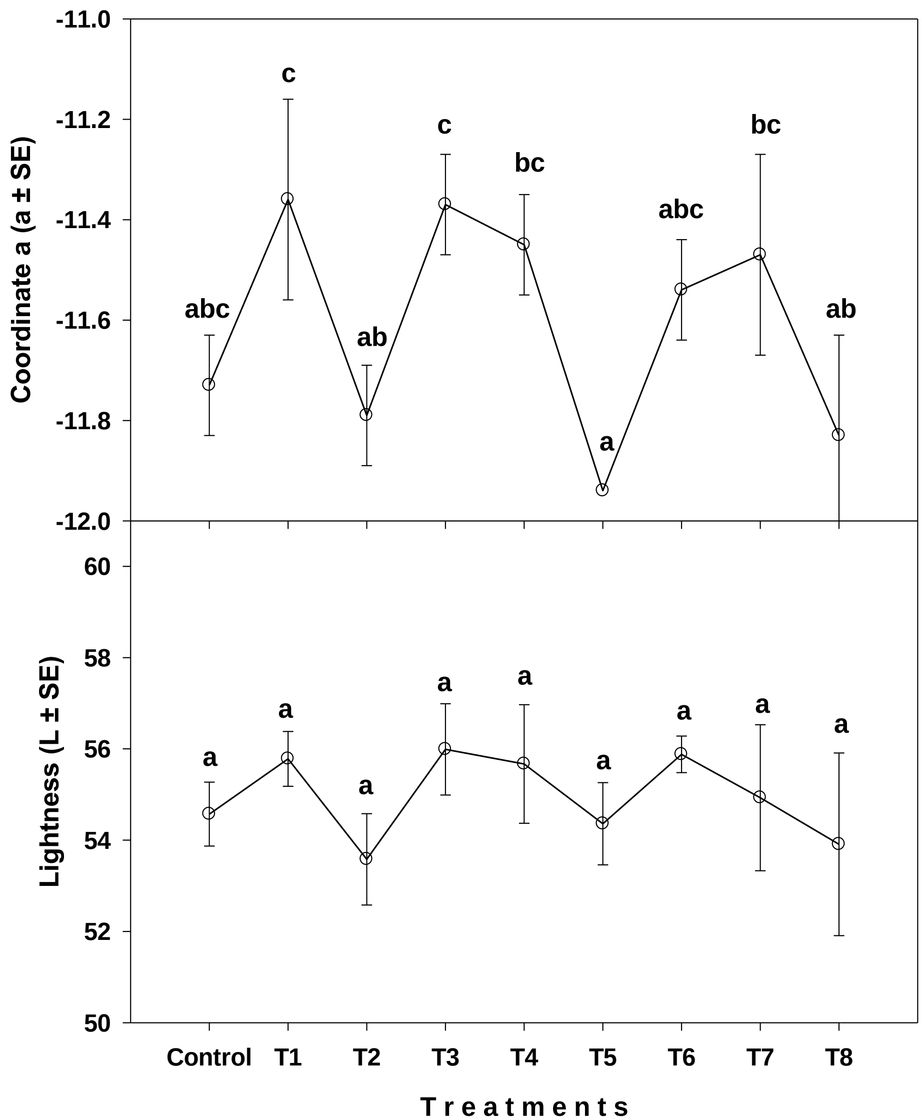

Figure 1. Effect of treatments with bunch bag on coordinate a and L of the fruit peel color in banana cv. 'Enano Gigante' at harvest. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). Means with equal letters are not statically different (Fisher, 0.05).

weight ranged from 127.85-137.15 g of banana fruit on the treatments with blue polyethylene bags covering bunches with respect to the control bunch (fruit pulp weight of 127.00 g); the bunches covered with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) was exempted, in which the peel weight of fruit was of 146.90 g. At ripening stage 6, among the tested blue polyethylene bags, only the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) improved the pulp weight of fruit compared with the control bunch, with values of fruit pulp weight of 148.46 and 129.60 g, respectively (Figure 3). At ripening stage 7, the fruit pulp weight was consistently superior in

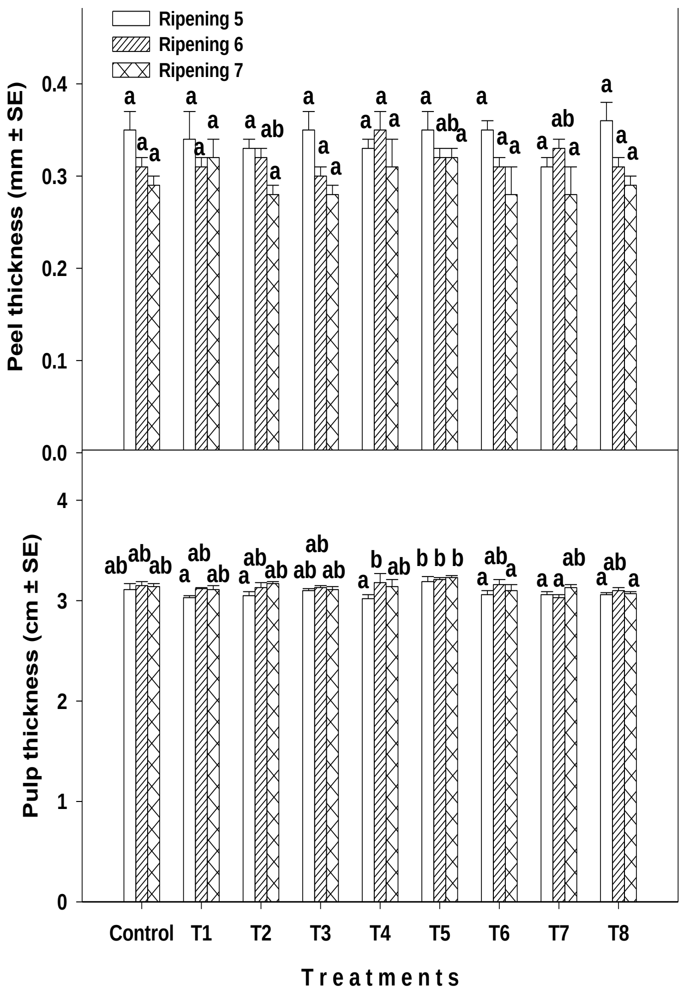

Figure 2. Effect of treatments with bunch bag on fruit peel and pulp thickness in banana cv. 'Enano Gigante'. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). For each ripening stage, bars with equal letters are not statically different (Fisher, 0.05).

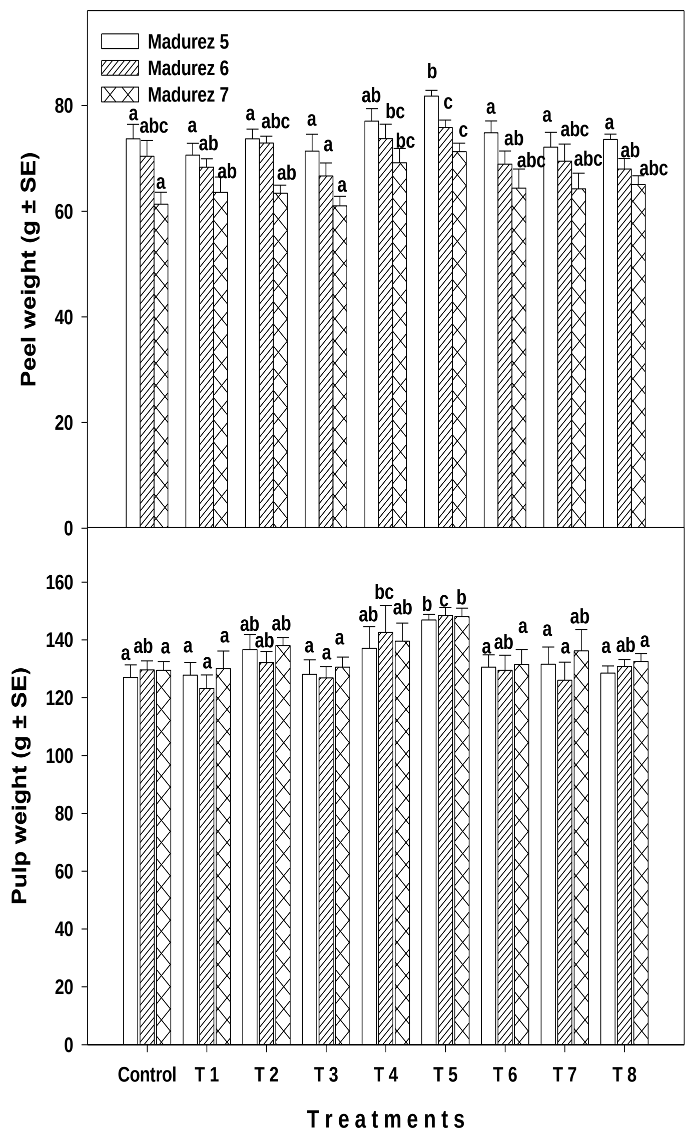

Figure 3. Effect of treatments with bunch bag on fruit peel and pulp weight in banana cv. 'Enano Gigante'. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). For each ripening stage, bars with equal letters are not statically different (Fisher, 0.05).

bunches covered with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) to those obtained on the control bunch, with a fruit pulp weight of 148.03 and 129.60 g, respectively (Figure 3).

Fruit pulp to peel weight ratio

Overall, all eight treatments with bunch polyethylene bag had no significant effect ($p > 0.05$) on the pulp to peel weight ratio of fruits with respect to the control bunch of cv. 'Enano Gigante' at three ripening stages (Figure 4). Irrespective of the control, at ripening 6, bunch the micro-perforated blue polyethylene bag impregnated with

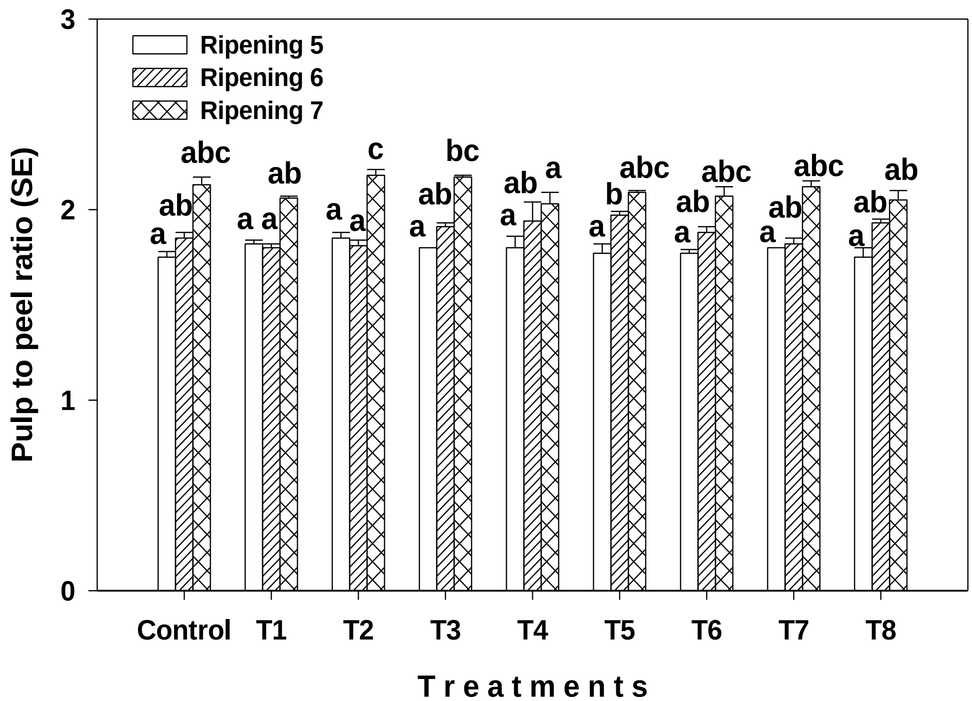

Figure 4. Effect of treatments with bunch bag on fruit pulp to peel weight ratio in banana cv. 'Enano Gigante'. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). For each ripening stage, bars with equal letters are not statically different (Fisher, 0.05).

insecticide chlorpyrifos at 5% (T5) significantly increased the pulp to peel ratio (1.97) when compared with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1; 1.85) and the normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2; 1.80). Likewise, at ripening stage 7, among the tested blue polyethylene bags, the normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2) was significantly superior in increasing the pulp to peel ratio (2.18) to the other bunch bagging treatments, except the micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3; 2.17).

Pulp firmness

In general, all eight treatments with blue polyethylene bags covering banana bunches significantly affected or did not affect the pulp firmness of 'Enano Gigante' banana fruit in respect to the control bunch at harvest and during ripening. At harvest, pulp firmness of banana fruit was significantly decreased from 3.65 kgf on the control bunch to a range of 3.51-3.30 kgf on the treatments with bunch blue polyethylene bags.

Likewise, irrespective of the pulp firmness of banana fruit on the control bunch, the fruit pulp of bunches covered with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) was significantly the most firm, with a value of pulp firmness of 3.51 kgf. This is followed by the treatment with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3) and the treatment with the micro-perforated blue polyethylene bag (T7), with values of pulp firmness of 3.44 and 3.42 kgf, respectively (Figure 5).

At ripening stage 5, irrespective of the pulp firmness on the control bunch, the fruit pulp more firm was obtained on the treatment with micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) and the micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), with a firmness of 0.75 kgf for both treatments, but

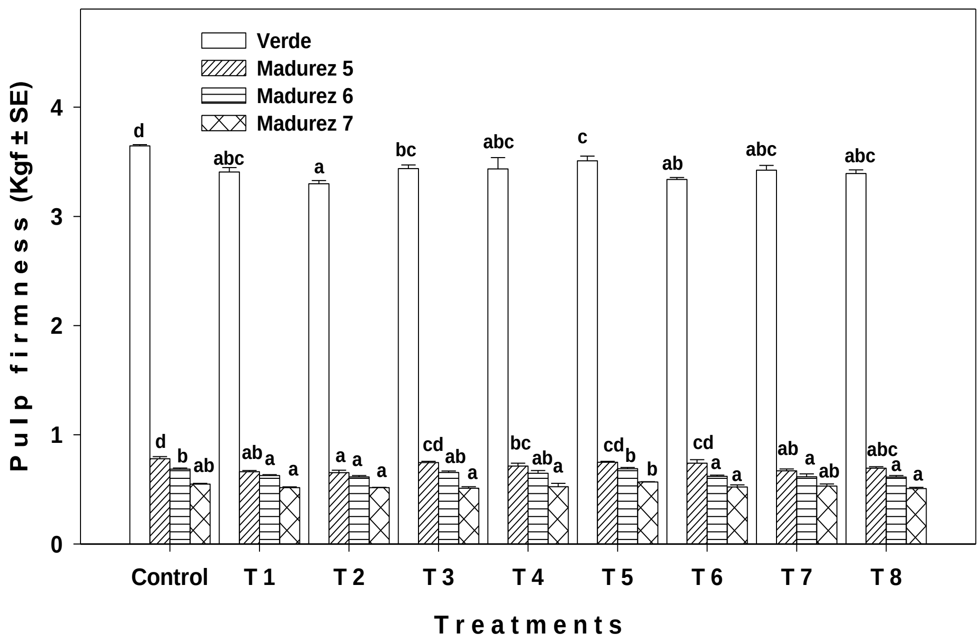

Figure 5. Effect of treatments with bunch bag on pulp firmness in banana cv. 'Enano Gigante'. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). For each ripening stage, bars with equal letters are not statically different (Fisher, 0.05).

without significant differences between both (Figure 5).

At ripening stage 6, irrespective of the pulp firmness (pulp firmness of 0.69 kgf) on the control bunch, the fruit pulp more firm was observed on the treatment with micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), on the treatment with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3) and the treatment with normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), with firmness of 0.69, 0.65 and 0.65 kgf, respectively (Figure 5).

At ripening stage 7, the treatments with blue polyethylene bag on banana bunches had no significant effect on pulp firmness of fruit when compared to the control bunch. Irrespective of the control bunch, the pulp firmness (0.57 kgf of pulp firmness) of banana fruit with the treatment with micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) was significantly superior to those obtained by the rest of the treatments (0.51-0.52 kgf of pulp firmness); blue polyethylene bags cover the bunches, except the treatment with micro-perforated blue polyethylene bag (T7; Figure 5).

Effect of bunch bagging on the internal quality during ripening

Titratable acidity

At ripening stage 5, all eight treatments with blue polyethylene bag tested in this research work had no significant effect on the titratable acidity of banana fruit cv. 'Enano Gigante'. At ripening stage 6, among the treatments tested with blue polyethylene bags, the treatments with the micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), the normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), and the normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6) significantly reduced the titratable acidity, with values of 0.23, 0.23 and 0.23% of malic acid, with respect to the control bunch (0.26% of malic acid). Irrespective of the control bunch, blue polyethylene bags covering banana bunches did not affect the titratable acidity of fruit (Figure 6). At ripening stage 7, the treatments with the normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), the micro-

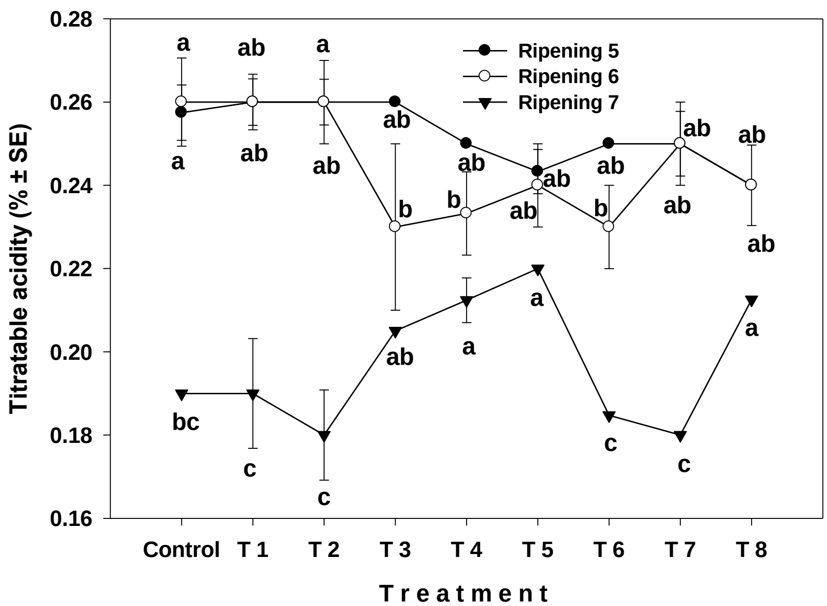

Figure 6. Effect of treatments with bunch bag on titratable acidity in three ripening stages on banana fruit cv. 'Enano Gigante'. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). For each ripening stage, means with equal letters are not statically different (Fisher, 0.05).

perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) and normal perforated blue polyethylene bag (T8) significantly increased the titratable acidity, with respect to the control bunch, with values of 0.21, 0.22, 0.21 and 0.19% of malic acid, respectively (Figure 6).

Total soluble solid content

At ripening stage 5, the banana fruit with higher total soluble solid content were obtained by the treatments with the micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1) and with normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), with respect to the control bunch (total soluble solid content of 11.1 °B), with a total soluble solid content of 11.9 and 12.05 %, respectively (Figure 7). In contrast, the treatments with micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) and the normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), had a detrimental effect on the total soluble solid content of banana fruit. Whereas the rest of the treatments had no significant effect on soluble total solid content of banana fruit cv. 'Enao Gigante' (Figure 7). At ripening stages 6 and 7, all eight treatments with blue polyethylene bag had no statistically significant effect on the total soluble solid content of the banana fruit cv. 'Enano Gigante' (Figure 7).

Effect of bunch bagging on fruit damages by red rust and flower thrips

All treatments with blue polyethylene bag covering the bunch consistently reduced fruit damage by red rust thrips with respect to the control bunch. The fruit damage by red rust thrips was significantly reduced from 27.8% on the control to 3-5.8% on the treatments with blue polyethylene bag. No significant differences were observed among the treatments with blue polyethylene bag. The treatments with micro-perforated blue polyethylene bag (T7) and with normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4) were the most effective to reduce the

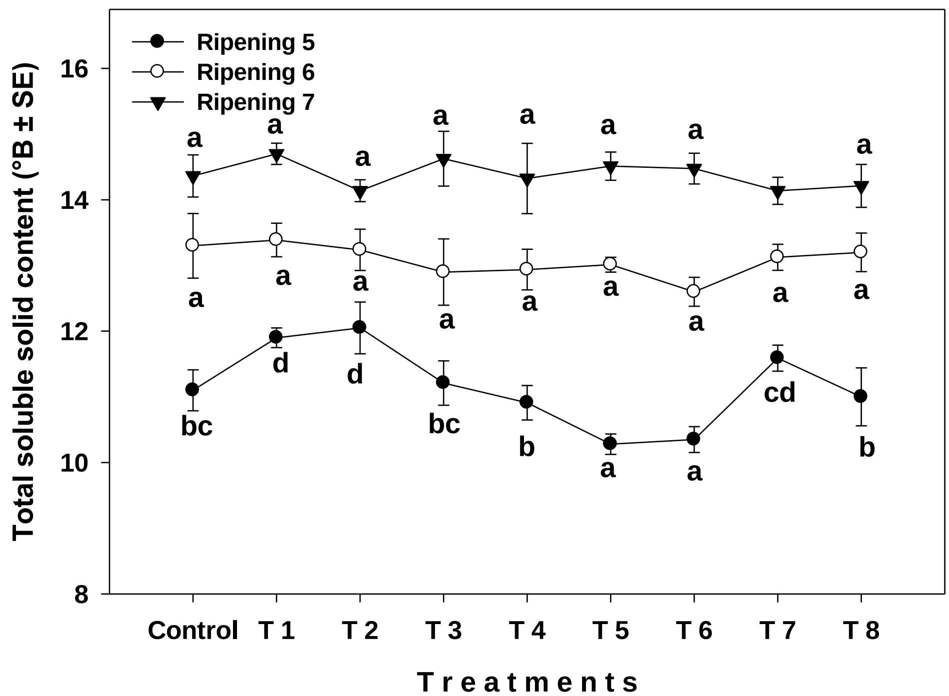

Figure 7. Effect of treatments with bunch bag on total soluble solid content in three ripening stages on banana fruit cv. 'Enano Gigante'. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). For each ripening stage, means with equal letters are not statically different (Fisher, 0.05).

fruit damage by red rust, with damage values of 3.0 and 4.1% (Figure 8).

DISCUSSION

In this research work the effect of treatments with blue polyethylene bag covering bunches on the production parameters at harvest, fruit peel color at harvest, fruit quality during ripening and damage by trips of banana cv. 'Enano Gigante' has been determined. According to our results only the treatment with the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) was capable of increasing the production parameters: banana fruit diameter (41.06 mm) and weight (255.16 g) at harvest. These results differed from those reported by Muchui et al. (2010) on 'Williams' bananas or Patil and Jagadeesh (2016) on 'Grand Naine' bananas in which bunch bagging with polyethylene covers did not affect fruit diameter. Likewise, our results were similar to those reported by Patil and Jagadeesh (2016) in which bunch bagging with polyethylene covers significantly increased the fruit weight with respect to the control bunch on 'Grand Naine' bananas. Additionally, Sarkar et al. (2016) revealed that banana bunches covered with nonwoven polypropylene skirt bag significantly increased fruit weight in comparison to the control bunch on 'Malbhog' bananas. However, an earlier study reported that polyethylene covers had no significant effect on banana fruit weight (Rodrigues et al., 2001). On the other hand, in this study, all eight treatments with blue polyethylene bag covering 'Enano Gigante' banana bunches had no significant effect on fruit length or bunch weight at harvest. Moreover, similar results were obtained by Muchui et al. (2010) with respect to the control bunch on 'Williams' banana fruit when banana bunches were bagged with perforated dull and shiny blue bunch covers. Similarly, bunch bagging with polyethylene covers did not affect the fruit length or bunch weight on 'Prata Aña (Rodrigues et al., 2001) and 'Grand Naine' bananas (Patil and Jagadeesh, 2016). In contrast, Moreira (2008) revealed that bunches covered with bag

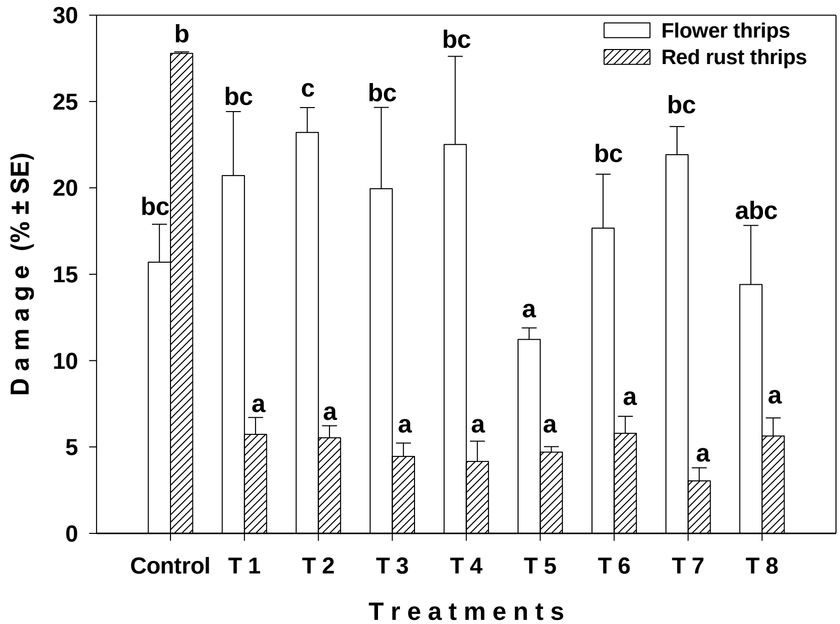

Figure 8. Effect of treatments with bunch bag on red rust and flower trip damages in banana cv. 'Enano Gigante'. Banana bunches were bagged with micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T1), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 3% (T2), micro-perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T3), normal perforated blue polyethylene bag impregnated with organic insecticide WG 300 at 6% (T4), micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5), normal perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T6), micro-perforated blue polyethylene bag (T7), normal perforated blue polyethylene bag (T8), and bunch without bagging (control). For each pest, means with equal letters are not statically different (Fisher, 0.05).

impregnated with organophosphorated insecticide significantly increased fruit length on 'Nanicao' bananas. Regarding the effect of bunch bagging on the fruit peel color at harvest, in this work and in general, the treatments with blue polyethylene bag did not influence neither the **L*** nor **a*** coordinate of the fruit peel color with respect to the control bunch (non-bagged bunch). These findings differed from those reported by Patil and Jagadeesh (2016) in which bunches polyethylene covers significantly increased **L*** of fruit peel color on 'Grand Naine' bananas with respect to the non-bagged bunch. In an earlier research work it was found that transparent bags covering bunches of 'Williams' banana significantly increased the **L*** coordinate of the fruit peel color compared to that of blue bags (Vargas-Calvo and Valle-Ruíz, 2011). Moreover, our results could be due to the fact that all the polyethylene bags used as covers on banana bunches in this study were of the same color (blue); they did not result in a substantial change of bag internal atmosphere to diminish chlorophyll accumulation and thus the **L*** coordinate of fruit peel color was unaffected. In general, the difference in effects on **L*** and a* coordinate here shown among different researchers may also be dependent on the kind of bag, duration of bagging and cultivar.

Regarding the effect of bunch bagging on the external fruit quality during ripening, the fruit pulp to peel ratio was not affected by the bunch bagging treatments in comparison with the control bunch. These results are in agreement with those reported by Kumar et al. (2015) on 'red' bananas, Muchui et al. (2010) on 'William' bananas or Purnima et al. (2016) on 'Jahaji' bananas. In this work, the bunch bagging had a detrimental effect on the fruit firmness at harvest, reducing it. This result differs from that obtained by Muchui et al. (2010), in which the bunch bagging had no significant effect on the fruit firmness on 'William' bananas. Likewise, in this work and in general, the bunch bagging significantly reduced fruit firmness during ripening. Moreover, Muchui et al. (2010) found that bunch bagging had no effect on fruit firmness. While Santosh et al. (2017) reported that the bunch bagging significantly reduced the fruit firmness of bananas. Logically, the fruit firmness decreased in a gradual manner during ripening.

In general, the effect of bunch bagging on the titratable acidity varied depending on the ripening stages. For instance the bunch bagging did not influence the fruit acidity at ripening stage 5 with respect to the control bunch; while, some treatments (T3, T4 and T6) with bunch bagging significantly reduced the fruit acidity compared to the control bunch at ripening stage 6. Finally, at ripening stage 7, the bunch bagging did not influence or had a detrimental effect (T4, T5 and T8) on the fruit acidity, increasing the titratable acidity on 'Enano Gigante' bananas. Our results at ripening stage 6 coincided with those reported by Purnima et al. (2016) in which white non-woven polypropylene bag, blue non-woven polypropylene, transparent polyethylene bags significantly reduced the titratable acidity on 'Jahaji bananas. Likewise, our results at ripening 5, are in agreement with those obtained by Kumar et al. (2015) in which different types of bag did not affect the titratable acidity on 'Red' bananas or Muchui et al. (2010) on 'Williams' bananas. It is known that the fruit acidity is due to the presence of organic acids mainly malic and citric acids (Seymour et al., 1993). The organic acid content of the pulp of fruits is affected by environmental factors and agricultural practices such as temperature, light intensity, cultivar, mineral nutrition, water availability or fruit load/pruning (Etienne et al., 2013). Temperature on fruit in growth and development affects the titratable acidity of it (Famiani et al., 2015), and it is believed that high temperatures during ripening decrease titratable acidity (Trad et al., 2013).

In general, the bunch bagging had no significant effect on the total soluble solid content at ripening stages 6 and 7 on 'Enano Gigante' bananas. Normally, the banana fruit is generally eaten by the consumer at ripening stage 6 and in some cases at ripening stage 7. These results are in agreement with those reported by Muchui et al. (2010) and Patil and Jagadeesh (2016) on 'Williams' and 'Grand Naine' bananas when banana bunches were bagged in which no significant effect was observed on TSSC. On the other hand, our findings differed with those reported by Purnima et al. (2016) in which the TSSC was increased by white non-woven polypropylene cover on 'Jahaji' bananas. Likewise, Santosh et al. (2017) mention that the bunch bagging significantly increased the TSSC of bananas.

In general, our findings on the effect of bunch bagging on production parameters and fruit quality are controversial because our results coincided or differed to those obtained by other authors. This can be due to the different materials of bagging used for covering bunch, the fruit age when covered, the climatic conditions, cultivar response, presence and size of holes on bag and bag color (Amarante et al., 2002).

In this research work, in general, all treatments with blue polyethylene bag covering the bunch consistently reduced fruit damage by red rust thrips with respect to the control bunch. These results coincided with those reported by Robinson and Sauco (2010) where the red rust thrips is controlled by the banana bunch bagging. Likewise, Stover (1972) revealed that banana thrips (*C. sorchidii*) has been controlled with bunch cover in 2-3 weeks after formation of fruits. Also our results indicated that no significant difference was found among the impregnated blue polyethylene bags with chlorpyrifos and the non-impregnated blue polyethylene bags with chlorpyrifos. This finding might be explained because of the fact that the chlorpyrifos contained in the bunch bags was lost in a 90% within the first 10 days after bagging (Altabtabaee et al., 2016). This finding could be taken into account by the growers of banana to select the bag type to cover the banana bunches, which could influence the benefit-cost relation. These results differed with those found by Pinese (1987) who reported that the bags covering banana bunch impregnated with insecticide chlorpyrifos were consistently effective to control the red rust thrips.

Conclusions

It is concluded in this research work that only the micro-perforated blue polyethylene bag impregnated with insecticide chlorpyrifos at 5% (T5) was capable of increasing the banana fruit diameter and weight at harvest under the environmental conditions of humid tropic from the Mexican Southeast in the autumn season. However, the results could vary according to bag type, cultivar, and timing of bagging or season of the year. Moreover, we can confirm, in this study, that the bunch bagging reduces the damage of banana fruit by red rust thrips. Likewise the treatments with blue polyethylene bags impregnated with chlorpyrifos did not guarantee the control of red rust thrips on 'Enano Gigante' banana fruit.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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