Ciência Rural, Santa Maria, v.47: 06, e20160278, 2017 http://dx.doi.org/10.1590/0103-8478cr20160278

ISSNe 1678-4596

CROP PROTECTION

Agronomical indicators and incidence of insect borers of tomato fruits protected with non-woven fabric bags

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ABSTRACT: *Fruit bagging is an efficient mechanical control technique used in fruit growing. However, to date, few studies have evaluated the efficacy of bagging in the cultivation of vegetables, including tomato crops. The objective of this study was to evaluate the effectiveness of bagging of tomato flowers and/or fruits using a non-woven fabric (NWF) for the control of Helicoverpa spp., Neoleucinodes elegantalis, and Tuta absoluta, to evaluate the effect of this technique on the final yield, and determine the optimal period for bagging. Tests were conducted in a commercial crop of staked 'Valerin' tomato plants located in the municipality of Ubajara, Ceará State, Brazil. The experimental design was randomized blocks with a 2x4 factorial design (sprayed* versus *unsprayed plants, and both plant groups were bagged with NWF bags at different growth stages [flowers bagging, bagging of bunches of fruits with a diameter of 1.5cm, bagging of bunches of fruits with a diameter of 3.0cm, and unbagged bunches (control)], with five repetitions. We evaluated the number of fruits per bunch, number of bunches per plant, weight of each fruit, longitudinal and transverse diameter, percentage of bored fruits, yield loss caused by insect infestation, and final yield. Bagging of 'Valerin' tomato bunches with NWF bags was effective for the control of N. elegantalis, and productivity increased by 21.5% when bagging was done in bunches of fruits with a diameter of 1.5cm compared with unbagged fruits; therefore, this growth period was the most suitable for bagging.*

Key words: *Solanum lycopersicum, mechanical control, Neoleucinodes elegantalis, productivity.*

Indicadores agronômicos e incidência de insetos-broqueadores de frutos de tomateiro submetidos a ensacamento com tecido-não-tecido (TNT)

RESUMO: *O ensacamento de frutos é uma eficiente técnica de controle mecânico utilizado na fruticultura. No entanto, existem poucos estudos sobre sua eficiência em hortaliças como, por exemplo, o tomate. O objetivo deste trabalho foi avaliar a eficiência do ensacamento das flores e/ou frutos de tomate com sacos TNT para o controle de Helicoverpa spp., Neoleucinodes elegantalis e Tuta absoluta, avaliar o efeito dessa técnica sobre a produtividade obtida ao final do ciclo e determinar a melhor época para realização do ensacamento. O ensaio foi realizado em plantio comercial de tomateiro 'Valerin' estaqueado, localizado no município de Ubajara, CE. O delineamento experimental foi de blocos casualizados em esquema fatorial 2x4 (plantas pulverizadas* versus *não pulverizadas sendo que ambas receberam ensacamento com TNT em diferentes estágios fenológicos [ensacamento da flor, ensacamento do cacho com frutos de 1,5cm, ensacamento do cacho com frutos de 3,0cm, cachos não ensacados (Testemunha)], com cinco repetições. Avaliou-se: número de frutos/cacho, número de cachos/planta, peso/fruto, diâmetro longitudinal e transversal, porcentagem de frutos brocados, produtividade, perda provocada pelo ataque de pragas e ganho real obtido. O ensacamento dos cachos de tomate 'Valerin' com TNT foi eficaz para o controle de N. elegantalis e, quando o ensacamento foi realizado em cachos com frutos de 1,5cm de diâmetro, proporcionou incremento de 21,5% de produtividade em relação àqueles não ensacados sendo, portanto, o período mais indicado para o ensacamento.*

Palavras-chave: *Solanum lycopersicum, controle mecânico, Neoleucinodes elegantalis, produtividade.*

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L.) have high acceptability by consumers. This vegetable-fruit is widely consumed and is cultivated in almost all regions of Brazil as well as in other parts of the world. This crop plays a major role in the Brazilian economy by generating labor and revenue from the commercialization of products and services (SHIRAHIGE et al., 2010).

This crop is vulnerable to several arthropod pests, and pest infestations, which decrease productivity and/or lower the value of the crops, thus compromising their final quality. The main causes of damage and losses in tomato fruits are arthropods, including *Tuta absoluta* (Meyrick) (Lepidoptera:

Received 03.16.16 Approved 02.17.17 Returned by the author 04.03.17
CR-2016-0278.R2

Gelechiidae), *Neoleucinodes elegantalis* (Guinée) (Lepidoptera: Crambidae), *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), and *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) (LEITE et al., 2014; PRATISSOLI et al., 2015).

Feeding behavior of these insect species has given them the designation of borers because they cause external damage when penetrating the fruit, and internal damage by feeding on the pulp and forming galleries, which makes these fruits inadequate for consumption (GRAVENA & BENVENGA, 2003).

The primary method used for the control of insect pests in tomato crops is insecticide application. However, the constant, indiscriminate, and excessive use of insecticides may cause serious problems, including the poisoning of people and animals, environmental contamination, and, in some cases, promote the buildup of toxic residues in fruits (TOKAIRIN et al., 2014).

The changes in the profile of consumers and the increased social awareness about the impacts of the inappropriate use of these chemicals have increased the interest of the population in the acquisition of residue-free food products (WAMSER et al., 2008). This trend indicates the need to evaluate new pest control strategies.

Among these strategies, fruit bagging has proven to be an effective alternative for the control of arthropod pests in some cultures, especially in fruit growing. This technique is effective in preventing the infestation by insect borers of fruits of the soursop (*Annona crassiflora* Mart., Annonaceae) (LEITE et al., 2012), apple (*Malus domestica* Borkh., Rosaceae) (TEIXEIRA et al., 2011), guava (*Psidium guajava* L., Myrtaceae) (BILCK et al., 2011), abiu *Pouteria caimito* (Ruiz and Pavon) Radlk, Sapotaceae) (NASCIMENTO et al., 2011), and mango (*Mangifera indica* L., Anacardiaceae) (GRAAF, 2010).

Use of the bagging technique in vegetable crops requires the identification of materials that are suitable (durable and easy to apply) and economically viable. In addition to the viability of the material, another important factor is the identification of the most favorable season for effectively protecting the crops considering the size of the fruits. In the case of guava, fruit damage caused by fruit flies is decreased when fruit bagging is performed in the right season (SANTOS et al., 2013).

This study aimed to evaluate the efficacy of bagging of tomato flowers and/or fruits with NWF bags for the control of *H. zea*, *H. armigera*, *N. elegantalis*, and *T. absoluta*, evaluate the effect of this procedure on agronomic characteristics of the crop, and determine the optimal period for the implementation of this technique.

MATERIALS AND METHODS

The study was conducted in a commercial crop of ‘Valerin’ tomato plants, belonging to the salad group, with indeterminate growth in a staked system, in the Jaburuna district, Ubajara (3°51’16” S, 40°55’16” W, altitude: 819m), Ceará State, Brazil. The study was conducted from February to June 2015. Plants were distributed at a spacing of 1.2 x 0.6m. The staking method was vertical with string. All cultivation practices were conducted following the recommendations for this crop (GRAVENA & BENVENGA, 2003), and irrigation was performed by dripping.

The study was undertaken in two experimental areas, such that one area was treated with insecticides and the other area was not subjected to treatment, and the fruits in both areas were bagged with NWF bags at different growth stages. These experimental areas were located in a commercial staked tomato orchard. The experimental design was randomized blocks with a 2x4 factorial design and five repetitions. The variables evaluated were the use of insecticides [1- plants treated with insecticides (the use of chemicals and the spraying calendar were determined by the farmer, considering the common practice in that region), and 2- plants not treated with insecticides]; and the use of NWF bags for bagging tomato bunches [T1- bagging of flowers, T2- bagging of fruits with a diameter of 1.5cm, T3- bagging of fruits with a diameter of 3.0cm; unbagged bunches (control)]. The NWF bags used were white, with a length of 22cm, width of 18cm, mesh of 17g, and sealing with elastic bands. Each block was represented by a row of 20 plants (five plants from each treatment) for fruit bagging.

All flowers and/or fruit bunches were evaluated on a weekly basis for the identification of the growth stage of the bagged fruits and thus ensure the homogeneity of the harvest, i.e., that the fruits were in the same maturation stage. Three collections were made approximately 110 days after sowing on the 14, 21, and 28 of May 2015, as the fruits reached the same stage of maturation. Thirty fruits were harvested per block (10 fruits from each crop) to ensure adequate bagging, and this set of fruits was considered a sampling unit.

For the evaluation of the number of bunches per plant and the number of fruits per bunch, a direct count was made in the field in each plant from both study areas approximately 110 days after sowing. Longitudinal and transverse diameters were measured using a universal analog caliper (Vonder, PA 155) with capacity of 0-150mm (0-6 inches), graduation of 0.05mm (1/128 inches), and the fruits were weighed using a digital scale (TOLEDO, model Prix 3 Light/Prix 3 Light Bateria).

Percentage of infested fruits was calculated by the formula: (Number of bored fruits x 100)/10. This percentage was used to estimate the average losses at the end of the production cycle, considering that the infested fruits would be inadequate for commercialization. The formula used to estimate yield loss (t/ha) due to insect infestation was [Yield (t/ha) x Bored fruits (%)]/100.

Yield was estimated considering the number of bunches, number of fruits, and weight of fruits harvested in each experimental area. For quantification of the yield (t ha^{-1}), the data were extrapolated to 1ha. For this purpose, the following formula was used: (number of bunches per plant x number of fruits per bunch x weight of each fruit)/ number of plants in the study area. The total number of plants per hectare was 13,778 considering the spacing used in the study area.

The yield at the end of the production cycle (final yield, in t ha^{-1}) was also estimated. For this purpose, we considered the yield of the control area (unbagged fruits) in the sprayed area (absolute control) provided by the farmer. Then, we calculated (in percentage) the extent to which each treatment deviated from the actual crop yield using the following formula: [Yield (t ha^{-1}) of treatment x 100]/ yield (t ha^{-1}) of the absolute control].

The final yield was estimated using the formula: [Yield of treatment (%) x yield of the absolute control (t ha^{-1})]/100. The value obtained was used in the analyses. The actual yield was estimated by calculating the difference between the final yield and the loss caused by insect infestations. This value corresponded to the total yield (t ha^{-1}) that would be available for commercialization.

We also compared the costs of the use of NWF bags with those of using insecticides. For this purpose, the relationship (manual labor for spraying and cost of the products) x (manual labor for bagging and cost of the NWF bags) was considered. The result was expressed in R$ ha^{-1}.

Percentage of bored fruits was subjected to the Friedman test using the statistical software Paleontological Statistics version 2.16 (HAMMER et al., 2001) for comparison of the means because the data did not meet the normality and homogeneity assumptions. Other variables were subjected to analysis of variance (ANOVA) at a level of significance of 5% and, when significant, the means were compared using the Duncan test at a level of significance of 5% using the statistical software SASM-Agri version 8.2 (CANTERI et al., 2001). Data on losses were transformed into [(Root of (x + 0.5)] for inclusion in the analyses.

RESULTS AND DISCUSSION

The NWF bags resisted the changes in climate conditions and promoted an adequate protection of the crop until the harvest period. There was no interaction between the studied factors (presence and absence of spraying and bagging of fruits) for any of the evaluated variables, and thus the factors were analyzed separately. The means of the studied variables did not change significantly with the use of insecticides. Moreover, no significant differences in the number of bunches per plant and in the longitudinal and transverse diameters were observed between treatments (Table 1). These results demonstrated the standardization of the fruits obtained, i.e., bagging with NWF bags, in this study, maintained the commercialization standards of the bagged fruits compared with the unbagged fruits.

The bagging of 'Valerin' tomato fruits with NWF bags decreased the number of fruits per bunch regardless of the period in which bagging was performed (Table 1). When bagging was done at the flowering stage, in addition to the lower number of fruits per cluster, the weight of the fruits also decreased (Table 1).

This reduction in weight and number of fruits per bunch may be due to factors associated with the lack of or insufficient pollination. Tomato plants use autogamous pollination. However, the anthers only release the pollen after they vibrate, and vibration is primarily accomplished by bees (BUCHMANN & HURLEY, 1978). This increase in pollen deposition on the stigma, influenced by the action of pollinating insects, promotes an increase in the weight and number of fruits (CRUZ & CAMPOS, 2009). Cultivation of tomatoes together with bees in greenhouses yields heavier fruits compared with cultivations without bees (SANTOS et al., 2009).

The decreased number of fruits per bunch observed after bagging may also be attributed to changes in the microclimate inside the bag caused by the increase in temperature (WANG et al., 2007). Although, this variable was not evaluated in the present study, there may have been a difference in temperature between inside and outside of bags.

Table 1 - Agronomic characteristics of 'Valerin' tomato fruits protected with NWF bags at different growth stages, Ubajara, Ceará State, Brazil, 2015.

---------------------------Variables---------------------------		---------------------Treatments: bagging stage (mean ± standard error)---------------------			
		Flowering	1.5cm	3.0cm	Not bagged
Number of bunches per plant^{ns}	S^{1}	7.40±0.07	7.80±0.21	7.20±0.10	7.20±0.08
	NS^{2}	7.60±0.07	7.40±0.15	7.60±0.12	7.20±0.20
	Average	7.50±0.07	7.60±0.18	7.40±0.11	7.20±0.14
Number of fruits per bunch	S	3.40±0.35	3.60±0.15	3.80±0.37	4.00±0.34
	NS	3.00±0.25	4.00±0.16	3.60±0.3	4.20±0.36
	Average	3.20±0.3^{c}	3.80±0.15^{b}	3.70±0.33^{b}	4.10±0.35^{a}
Fruit weight (kg)^{ns}	S	0.15±0.00	0.16±0.00	0.16±0.01	0.15±0.01
	NS	0.15±0.01	0.16±0.00	0.17±0.01	0.16±0.01
	Average	0.15±0.00^{b}	0.16±0.00^{ab}	0.17±0.01^{a}	0.16±0.01^{ab}
Longitudinal diameter (cm)^{ns}	S	5.53±0.05	5.55±0.08	5.56±0.13	5.43±0.11
	NS	5.47±0.07	5.59±0.08	5.76±0.16	5.50±0.06
	Average	5.50±0.06	5.57±0.08	5.66±0.14	5.46±0.08
Transverse diameter (cm)^{ns}	S	6.93±0.06	6.99±0.04	7.03±0.16	6.76±0.17
	NS	6.93±0.10	7.04±0.08	7.05±0.13	6.96±0.03
	Average	6.93±0.08	7.02±0.06	7.04±0.14	6.86±0.10
Bored fruits^{3}(%)	S^{1}	3.33±1.47	7.33±2.24	13.33±2.78	16.66±3.05
	NS^{2}	1.99±1.15	5.33±1.84	7.33±2.14	26.66±3.62
	Average	2.66±1.31^{a}	6.33±2.04^{b}	10.33±2.46^{b}	21.66±3.34^{c}
Productivity (t/ha)	S^{1}	87.99±6.83	101.53±5.28	97.95±9.27	90.93±0.00
	NS^{2}	85.89±6.24	99.72±4.21	108.73±6.98	107.16±4.96
	Average	86.94±6.53^{b}	100.63±4.74^{a}	103.34±8.12^{a}	99.05±2.48^{a}
Loss (t ha^{-1})	S	2.88±1.24	7.58±2.53	13.41±3.52	15.16±3.83
	NS	1.79±0.75	5.56±2.64	7.83±1.47	28.13±4.09
	Average	2.33±0.99^{c}	6.57±2.58^{bc}	10.62±2.49^{b}	21.64±3.96^{a}
Final yield (t ha^{-1})	S	85.12±6.80	93.94±4.66	84.54±7.47	75.78±3.83
	NS	84.10±5.87	94.16±3.23	100.90±7.13	79.02±7.06
	Average	84.61±6.33^{ab}	94.05±3.94^{a}	92.72±7.30^{a}	77.40±5.44^{b}

[1]S = With insecticide spraying, [2]NS = without insecticide spraying. [ns]Not significant by the F test ($P<0.05$). Values with different superscripts in the same row are statistically different by the Duncan test ($P<0.05$). [3]Values with different superscripts in the same row are statistically different by the Friedman test ($P< 0.05$).

Accordingly, the bagging of apple fruits with NWF bags increased the temperature of the fruits' environment inside the bags by approximately 3.0°C compared with the temperature of unbagged fruits (TEIXEIRA et al., 2011). The increase in temperature causes abortion of flowers, reduces the viability of pollen, and ultimately reduces the number of tomato fruits (SILVA et al., 2000).

The presence of *T. absoluta*, *H. zea*, and *H. armigera* was not observed during the study period. Therefore, damage or loss due to the presence of these pests was not assessed in this study. Weather conditions, including rain, contributed to this phenomenon. The occurrence of these pests, especially *T. absoluta*, is favored by dry weather, and these pests practically disappear in the rainy season (MOURA, 2014). By contrast, *N. elegantalis* thrives in the rainy season (MOURA, 2014), and the presence of rainfall during the study period (February to June) favored the presence of this pest species in the study area.

The use of NWF for the bagging of tomato fruits decreased the rate of infestation by *N. elegantalis*, and this decrease was more pronounced when the plants were protected at the flowering stage (Table 1). Only 2.7% of the fruits bagged at the flowering stage were damaged by *N. elegantalis* whereas 21.7% of the unbagged fruits were damaged (Table 1).

Bagging decreased the incidence of *N. elegantalis*, indicating that NWF bags protected the fruits, serving as a mechanical control against insect infestations. Losses of up to 33% by infestations with *N. elegantalis* and 29% by infestations with *H. zea* were observed in unbagged tomato fruits (LEITE et al., 2014).

A lower productivity was observed when the bagging of fruit bunches was performed at the flowering stage. However, the productivity of unbagged fruits (control) and after bagging fruits with a diameter of 1.5cm and 3.0cm did not differ significantly (Table 1).

An increase in productivity was also observed in apple orchards when bagging was performed in fruits with a diameter of 2cm (SANTOS & WAMSER, 2006).

Although the number and weight of fruits bagged at the flowering stage decreased, this reduction was offset by the increased protection against insect infestations. Furthermore, the reduction in fruit weight observed when flowers were bagged was not sufficient to produce significant differences between the unbagged fruits and the fruits bagged at the flowering stage. Therefore, there was no significant difference in the final yield when bagging was performed in fruits with a diameter of up to 3.0cm. However, it is of note that *N. elegantalis* usually oviposits in young fruits (JAFFE et al., 2007) with diameters between 1.5 and 2.0cm, or even in flowers (GRAVENA & BENVENGA, 2003). Therefore, crop protection should be anticipated, during flowering or shortly after the emergence of the first fruits in the bunch to ensure the reduction of losses.

The highest percentages of fruit losses caused by *N. elegantalis* were reported in unbagged fruits (control), which reached a yield loss of 21.64t ha^{-1}, in contrast to the bagged fruits, with average yield losses of 6.5t ha^{-1} (Table 1). The actual yield obtained by the producer was higher than that of the control group when bunches of fruits with a diameter of 1.5 or 3.0cm were bagged (Table 1). However, the average yield of the fruits bagged at the flowering stage was similar to that of the other treatments (Table 1).

The estimated average cost for bagging fruits using NWF bags was 40.7% lower than the cost of chemical control. In the present study, this estimate would provide an average reduction in costs of R$11,236.00 per ha once in the conventional system the manual labor + insecticides would cost R$27,556.00 per ha and in the bagging system the manual labor + bagging with NWF bags would cost R$ 16,320.00[I]. Therefore, bagging is an economically viable method and, in addition to protecting the fruits against insect infestations, improves the quality of the products by reducing or eliminating the excessive application of pesticides, thus decreasing the risk of residues in fresh fruit (RUSIN et al., 2015). In this sense, bagging can also be a tool for the management of *N. elegantalis* in organic production systems.

In fruit growing, fruit bagging has been considered effective (GRASSI et al., 2011; NASCIMENTO et al., 2011; SANTOS et al., 2013). However, the greatest challenge is to use materials that are resistant enough to protect against pests, that do not require expensive labor, and that do not interfere with the development of e fruits. In this sense, the balance between protection, resistance, and ease application needs to be achieved. Bags made of paper and/or NWF or of other materials adapted to other crops have been used for tomato crops (LEITE et al., 2014). However, some of these materials have little durability, and the bagging process is compromised, requiring actions that often cannot be performed in field conditions.

The NWF bags used in the present study are easy to use for bagging fruit bunches because they are easily sealed with an elastic strap, a feature that improves crop protection in the field. Therefore, bagging with NWF is a viable alternative for the protection of fruits against insect infestations.

CONCLUSION

The bagging of 'Valerin' tomatoes with NWF bags is effective for the management of *N. elegantalis* when the crop is protected until the fruit reaches a diameter of 3.0cm. However, early protection produces better results. When bagging is performed in flowers and fruit bunches with a diameter of 1.5 and/or 3.0cm, it increases the final yield by approximately 21.5%. The use of NWF bags as a mechanical barrier against infestation with *N. elegantalis* reduced costs of crop production and did not negatively affect crop yield.

ACKNOWLEDGMENTS

We are grateful to the Fundação Cearense de Apoio ao Desenvolvimento Científico e Tecnológico (FUNCAP), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support and fellowships, and to Mario R. Mezzedimi from TNTEX Indústria e Comércio LTDA-ME.

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