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Strobilurin and boscalid in the quality of net melon fruits

Estrobirulinas e boscalida na qualidade de frutos de melão rendilhado

Ana Claudia Macedo^{1*}; Amanda Cristina Esteves Amaro¹; Anamaria Ribeiro Pereira Ramos¹; Elizabeth Orika Ono²; João Domingos Rodrigues³

Abstract

Until recently, fungicides were used exclusively for disease control; however observations of physiological effects brought a new concept to the use of these products. Strobilurins have positive physiological effects on crop yield, due to the increase of liquid photosynthesis and better hormonal balance. However, boscalid complements the action of these fungicides, applied alternately or together. The aim of this study was to evaluate the effect of strobilurins (azoxystrobin and pyraclostrobin), boscalid and the mixture of these on the physical-chemical quality of net melon fruits (*Cucumis melo* var. *Reticulatus*). The experiment was conducted in the municipality of São Manuel (SP), using the hybrid of Cantaloupe M2-308 net melon, the experimental design was in randomized blocks with five replicates. The treatments used were: T1 – control; T2 – azoxystrobin 60g ha⁻¹ of active principle (a.p.); T3 – boscalid 75g ha⁻¹ of the a.p.; T4 – pyraclostrobin 50g ha⁻¹ of the a.p.; T5 – boscalid (37,5g ha⁻¹) of the a.p. + pyraclostrobin (25g ha⁻¹) of the a.p. The first application of the treatments was carried out at fourteen days after the transplanting of the seedlings and the others at seven day intervals, totaling eight applications throughout the cycle. Two fruits of each plot were collected, which were identified for analysis in the laboratory. The following characteristics were evaluated: fresh fruit mass; mesocarp thickness, pulp texture, peel trajectory, pH, titratable acidity, soluble solids and the ratio. The results were submitted to analysis of variance and the averages compared by the Tukey test at 5% probability using the SISVAR program. The fruits of the plants treated with boscalid 75g ha⁻¹ were the ones that showed higher concentration of soluble solids and low titratable acidity, resulting in a better ratio. Despite the lower value, the fruits of the plants treated with pyraclostrobin 50g ha⁻¹ showed a high ratio value, besides presenting higher value for pulp texture. The mixture of boscalid (37.5g ha⁻¹) + pyraclostrobin (25g ha⁻¹) also showed high values of soluble solids which resulted in a good “ratio” value.

Key words: *Cucumis melo* var. *reticulatus*. Post-harvest. Soluble solids. “Ratio”.

Resumo

Os fungicidas até pouco tempo eram utilizados exclusivamente para o controle de doença, no entanto observações de efeitos fisiológicos trouxeram um novo conceito para o uso desses produtos. As estrobilurinas possuem efeitos fisiológicos positivos no rendimento das culturas, devido ao aumento da fotossíntese líquida e melhor balanço hormonal. Já o boscalida complementa a ação desses fungicidas, aplicado alternadamente ou em conjunto. O trabalho teve como objetivo avaliar o efeito da aplicação de estrobilurinas (azoxistrobina e piraclostrobina), boscalida e a mistura destes na qualidade físico-

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química de frutos de melão rendilhado (*Cucumis melo* var. *reticulatus*). O experimento foi conduzido no município de São Manuel (SP), utilizando-se o híbrido de melão rendilhado Cantaloupe M2-308, o delineamento experimental foi em blocos ao acaso com cinco repetições. Os tratamentos utilizados foram: T1 – testemunha; T2 – azoxistrobina 60g ha⁻¹ do princípio ativo (p.a.); T3 – boscalida 75g ha⁻¹ do p.a.; T4 – piraclostrobina 50g ha⁻¹ do p.a.; T5 – boscalida (37,5g ha⁻¹) do p.a. + piraclostrobina (25g ha⁻¹) do p.a. A primeira aplicação dos tratamentos foi realizada aos 14 dias após o transplante das mudas e as demais a intervalos de sete dias, totalizando oito aplicações ao longo do ciclo. Foram colhidos 2 frutos de cada parcela, os quais foram identificados para as análises no laboratório. Foram avaliadas as seguintes características: massa fresca do fruto; espessura do mesocarpo, textura de polpa, rendilhamento da casca, pH, acidez titulável, sólidos solúveis e o “ratio”. Os resultados foram submetidos à análise de variância e as médias comparadas pelo teste Tukey a 5% de probabilidade com auxílio do programa SISVAR. Os frutos provenientes das plantas tratadas com boscalida 75g ha⁻¹ foram os que apresentaram maior concentração de sólidos solúveis e baixa acidez titulável, resultando em melhor “ratio”. Apesar do valor ser menor, os frutos das plantas tratadas com piraclostrobina 50g ha⁻¹ apresentaram alto valor de “ratio”, além de apresentarem maior valor para textura de polpa. A mistura do boscalida (37,5g ha⁻¹) + piraclostrobina (25g ha⁻¹) também apresentou altos valores de sólidos solúveis o que acabou resultando em um bom valor de “ratio”

Palavras-chave: *Cucumis melo* var. *reticulatus*, Pós-colheita. Sólidos solúveis. “Ratio”.

Introduction

The cultivation of melon (*Cucumis melo* L.) in Brazil has increased considerably in recent years; it is a fruit of great importance for the domestic market and for exportation in terms of monetary value (IBRAF, 2009). Approximately 199 thousand tons of melon fruit were shipped between August 2014 and March 2015, generating US\$148.3 million, 6.1% higher than the value obtained in the previous harvest. The dollar appreciation and the good quality of the national fruit favored exports (CEPEA, 2014).

Brazil is among the leading producers of fresh fruits in the world, getting behind only of China and India. Among the Brazilian states, Minas Gerais stands out, it is only behind the states of São Paulo and Bahia in quantity produced in the country. The melon is considered one of the main fruits, because it leads in export volume and has significant revenues (ANUÁRIO BRASILEIRO DA FRUTICULTURA, 2013).

The first record of melon cultivation in Brazil, for commercial purposes, was in 1986, by *Cooperativa Agrícola de Cotia*, with seeds imported from Japan. The fruit has net surface, round-oval shape, striking aroma, soluble solids around 10° Brix and pulp

color ranging from light green to salmon (RIZZO, 1999). The net melon is characterized to present very branched herbaceous stem and producing fruits of approximately 900g, with a net and rough surface. Its pulp is salmon, but it can also be green, with a musky aroma (COELHO et al., 2003).

Most of the large melon producers dominate the technology required to obtain good quality product, such as the use of cold chambers. However, small producers are not able to adopt a cold chambers structure and they are forced to store their fruits in ambient conditions for relatively long periods until the commercialization (MENDONÇA et al., 2004).

Due to this, it is necessary to delay the ripening and senescence and to provide a firmer texture of the fruits, giving them greater resistance to the physiological, microbial and mechanical damages (BRACKMANN et al., 2009).

In studies carried out with fungicides several beneficial physiological effects were evidenced, such as increased rate of liquid CO₂ assimilation, increased activity of nitrate reductase enzymes and antioxidants, and effects on fruit quality improvement at post-harvest (AMARO, 2011; MACEDO, 2012; RAMOS et al., 2013). The beginning of studies of these fungicides occurred in the 1980s when the

fungus *Strobiluros tenacellus* produced a substance called strobilurin, which had antifungal action. The use of this substance as fungicide, the molecules acted positively on the physiology of plants, through the reduction of respiration and ethylene production (KÖHLE et al., 1994).

The boscalid has also been used for physiological effects. It is a fungicide that belongs to the family of carboxamides and annelids (TÖFOLI, 2004), and, it has the same physiological effects of strobilurin, besides providing the preventive antifungal protection of the plant (VENTURE, 2006). In grafted and non-grafted Japanese cucumber plants, strobilurin and boscalid had positive physiological effects, and these effects were more evident in grafted plants, in which fungicides increased fruit production, nitrate reductase enzyme activity (at the beginning of the development), besides of the antioxidative system activity and the chlorophyll index. Regarding the production components, number of fruits and productivity (kg/m^2), the application of the mixture of pyraclostrobin and boscalid was the only treatment that increased in both total and commercial production of the non-grafted plants (free-standing); this represented 17% and 16% more of total and commercial fruits, respectively (AMARO, 2011).

The internal and external markets seek fruit with good appearance, desired size, absence of defects, firmness to transport and adequate sensorial characteristics, so this study evaluated the effects of the application of strobilurin, boscalid and the mixture of them in the physical-chemical quality of net melon fruits (*Cucumis melo* var. *Reticulatus*) cultivated in a protected environment.

Materials and Method

The experiment was carried out in São Manuel Teaching, Research and Production Farm, located at São Manuel, São Paulo, Brazil, at the Faculty of Agronomic Sciences of the São Paulo State University – UNESP, Campus of Botucatu-SP.

A protected arc environment was used, with the following characteristics: 30 m of length, 7 m of width and 3 m high ceiling, covered with 150 μm low density polyethylene film, and closed at the sides with a 75% shading screen.

The Cantaloupe M2-308 melon hybrid was seeded in 128-cell expanded polystyrene trays, planting one seed per cell, using the commercial substrate Carolina Soil® II composed of Sphagno peat, expanded vermiculite, class A agroindustrial organic waste, dolomitic limestone, agricultural gypsum and traces of NPK fertilizers, pH 5.5 ± 0.5 , EC $0.4 \pm 0.3 \text{ mScm}^{-1}$ and density of 155 kg m^{-3} .

The sowing was carried out on September 7 and transplantation on October 4, 2010, with one plant per pit with a spacing of $1.0 \times 0.5 \text{ m}$. Each plot had a height of 0.20 m above ground level, each served by an irrigation and fertigation line.

The experimental design was randomized block design with five replicates, containing one control and four fungicide treatments with five replicates, consisting of seven plants per plot, considering five useful plants.

The treatments used were: T1 – control; T2 – azoxystrobin 60 g ha^{-1} of the active principle (a.p.); T3 – boscalid 75 g ha^{-1} of the a.p.; T4 – pyraclostrobin 50 g ha^{-1} of the a.p.; T5 – boscalid (37.5 g ha^{-1}) of the a.p. + pyraclostrobin (25 g ha^{-1}) of the a.p.

As the source of azoxystrobin (strobilurin), the Amistar® product, containing 500 g kg^{-1} of the a.p. made by Syngenta was used; for boscalid the Cantus® product, containing 500 g kg^{-1} of the a.p.; for pyraclostrobin (strobilurin) the Comet® product, containing 250 g L^{-1} of the a.p., and for the mixture of boscalid and pyraclostrobin, Cantus® plus Comet® made from BASF S.A.

The first application of the treatments was performed at 14 days after transplanting (DAT), when the plants were with six leaves completely expanded, on October 28, 2010, and the others at seven day intervals, totaling eight applications. The

applications were carried out through foliar spray with the use of a pressurized CO₂ manual sprayer with 0.3 kgf/cm², conical nozzles, using a plastic curtain between treatments to avoid drift.

The seedlings were individually tutored and conducted with a stem, to not impair the production and quality of the fruits, being removed the buds and eliminated the shoots and flowers until the 11th node. In the 12th, 13th and 14th nodes the secondary branches were left, because in these appeared the hermaphrodite flowers, future fruits. From the 15th node, the buds were eliminated again and the internodes 21st, 22nd and 23rd were left. The left internodes were emerged shortly after the fruit and the apical pruning carried out in the 24th node.

The pollination, in addition to the one done by insects, was also done manually, thus ensuring greater safety in fertilization, which consisted of the removal of the male flower and placing it in contact with the stigma of the female flower in the morning. The plants were carried out with 5 or 6 fruits according to the crop treatments, and the thinning of part of these fruits was carried out as soon as they reached 3 cm, leaving only two fruits per plant, which were carried with mesh and wire.

The fruits were harvested on December 23rd, 2010. Two fruits were collected from each plot. In the laboratory, the fresh fruit mass (FFM) was evaluated, with the aid of a digital scale, in grams; the mesocarp thickness on both sides of the fruit (MT) was measured with digital caliper in mm, and the netting of the peel (PP), using a scale of grades based on the Rizzo (2004) methodology, grade 1 for fruits with intense netting, 2 for fruits with medium netting and 3 for fruits with weak netting.

The fruit texture was measured in two whole fruits with peel, at two central points of each fruit, using STEURENS-LFRA texture analyzes, with penetration distance of 10 mm and speed of 2.0

mm s⁻¹, using dTA 9/1000 pointer. The results were expressed in gram-force (gf cm⁻²).

The titratable acidity was expressed in grams of citric acid per 100 g of pulp obtained by titration of 5 g of homogenized pulp and diluted to 100 mL of distilled water, with standard solution of sodium hydroxide at 0.1 N, using the phenolphthalein as an indicator, as recommended by the Adolfo Lutz Institute (PREGNOLATTO, W.; PREGNOLATTO, N. P, 1985)

The soluble solids content was determined using a Palette PR – 32 digital refractometer, ATAGO brand, with automatic temperature compensation (AOAC, 1992) and the results expressed in ° Brix. The relation between the soluble solids content and the titratable acidity determined the ratio (TRESSLER; JOSLYN, 1961).

The pH was determined by direct reading in homogenized pulp solution using a potentiometer (Digital DMPH⁻²), according to the technique described by Pregnolato and Pregnolato (1985).

The results were submitted to analysis of variance and the averages compared by the Tukey test at 5% probability, using the SISVAR program.

Results and Discussion

The fresh mass of the net melon fruits was positively influenced by the treatments when they were compared to the fruits from the control. The plants treated with boscalid 75g ha⁻¹ were those that showed the highest value of fruit fresh mass, 881.44g. Along with the boscalid 75g ha⁻¹, the plants treated with pyraclostrobin 50g ha⁻¹ and the mixture of boscalid (37.5g ha⁻¹) + pyraclostrobin (25g ha⁻¹) also showed high values for this characteristic, 821.34g and 853.44g, respectively, and these three treatments did not differ statistically from each other (Table 1).

Table 1. Average values of fresh fruit mass (g), mesocarp thickness (mm), pulp texture (gf cm⁻²) and netting of the peel in net melon fruits in function of treatments. Botucatu, SP. 2011.

	Fresh fruit mass (g)		Mesocarp thickness (mm)		Pulp texture (gf cm ⁻²)		Netting of the peel	
Control	719.39	C	32.42	A	113.23	B	2.26	A
Azoxystrobin 60g ha ⁻¹	686.35	BC	30.07	A	114.30	B	2.01	A
Boscalid 75g ha ⁻¹	881.44	A	32.45	A	116.18	B	2.18	A
Pyraclostrobin 50g ha ⁻¹	821.34	ABC	32.94	A	146.00	A	1.65	A
Boscalid 37.5g ha ⁻¹ + Pyraclostrobin 25g ha ⁻¹	853.44	AB	29.74	A	120.15	B	2.11	A
CV (%)	10.13		6.93		9.70		24.16	

Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability.

Sirtoli (2011) studied the application of doses of boscalid in grafted and non-grafted Japanese cucumber, where productivity results did not show significant statistical differences; however, grafted plants produced 11.58% more than non-grafted plants, which in practice is considerable to the producer. These results were also found in the production of grafted and non-grafted Japanese cucumber, in which the treatment with boscalid was the second best in the increase of fruit production, reaching 40% in relation to the control (AMARO, 2011).

The mesocarp thickness did not show statistical difference when the treatments were compared (Table 1). However, the fruits treated with boscalid 75g ha⁻¹ were those that showed the greatest thickness, 32.45mm. The mesocarp thickness (MT), together with the locule transverse diameter, the locule longitudinal diameter and the locule shape index determine the use of pulp in the fruits, and are usually inherent to the genotype (MELO et al., 2014). Even if these characteristics are inherent to the genotype, the submission of net melon plants to treatments may influence the mesocarp thickness. When studying substrates in the productivity of different hybrids of net melon, it was verified that fruits of the Fantasy hybrid have better use of the pulp, independent of the substrate used, which did not occur with other hybrids (MELO et al., 2012).

Costa and Pinto (1977) assure that the ideal fruit should have thick pulp and small internal cavity,

attributes that confer to the fruit better resistance to transport and greater post-harvest durability. The greater thickness of the pulp is desirable because it increases the weight and the edible part, improving the quality of the fruit (COELHO et al., 2003).

There was a statistical difference for the pulp texture, so the plants treated with pyraclostrobin 50g ha⁻¹ showed the highest value, 146.00gf cm⁻² (Table 1). The texture is one of the attributes of most important quality and is related to the flavor of the fruits. In the fruits, in general, the texture is dictated by the softness or firmness of the pulp and is related to the force necessary for the product to reach a given deformation (CHITARRA; CHITARRA, 2005).

The pulp texture is also an attribute of maturity and fruit quality; giving an idea of the transformations in the cellular structure, cell cohesion and biochemical alterations, responsible for the texture of the product (YAMAGUCHI et al., 1977). The decrease in firmness is normal during the storage period; this characteristic varies depending on the cultivar, and may change due to regional climatic conditions, fruit position in the plant, degree of maturation, size of product and improper use of manual equipment during its measurement (CHITARRA; CHITARRA, 2005). Ramos et al. (2013) verified that the treatment with the mixture of pyraclostrobin and boscalid showed higher values of texture, indicating firmer fruit and with better post-harvest conservation.

For the netting of the peel, there was no statistical difference between treatments, with values varying from 1.65 to 2.26 (Table 1). The external appearance of the melon fruit is an attribute of quality (MENEZES et al., 2001), and commercially melons with high intensity of netting are desired because it is an attractive to the consumer (GORGATTI NETO et al., 1994). The netting of the peel of the melon fruits is not influenced by the cultivar factor, but becomes a significant factor in the cultivation system, since fruits cultivated in substrate show more intense netting than those cultivated in soil

(VARGAS et al., 2008). Cultivars of net melon studied in greenhouse had most of the fruits with intense netting, a desirable feature when dealing with net melon (RIZZO; BRAZ, 2001).

The pH values of the melon fruits ranged from 6.33 to 6.49, showing no statistical difference between the treatments (Table 2). In a study developed with 'Giuliana' tomatoes and the same fungicides, this characteristic was not also influenced by the treatments, and the pH ranged from 4.27 to 4.37 (RAMOS et al., 2013).

Table 2. Average values of pH, soluble solids (SS, °Brix), titratable acidity (TA, g of citric acid 100 g of pulp⁻¹) and SS/TA relation in net melon fruits in function of treatments. Botucatu, SP. 2011.

	pH	Soluble solids		Titratable acidity			SS/TA	
Control	6.36	A	8.7	B	0.200	A	43.85	B
Azoxystrobin 60g ha ⁻¹	6.33	A	9.1	BC	0.174	AB	52.28	AB
Boscalid 75g ha ⁻¹	6.44	A	11.6	A	0.173	AB	69.55	A
Pyraclostrobin 50g ha ⁻¹	6.45	A	10.1	AB	0.153	B	67.60	A
Boscalid 37.5g ha ⁻¹ + Pyraclostrobin 25g ha ⁻¹	6.49	A	10.7	AB	0.194	AB	55.32	AB
CV (%)	2.04		10.53		12.59		17.57	

Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability.

On the other hand, the titratable acidity (TA) of the melon fruits showed a statistically significant difference when the treatments were compared, and the control plants had the highest value for this characteristic, 0.200 g of citric acid 100 g of pulp⁻¹, plants treated with pyraclostrobin 50g ha⁻¹ showed the lowest value, 0.153 g of citric acid 100 g of pulp⁻¹. The organic acid contents in fruits are influenced by several factors, among them maturation stage, nutrition and climatic conditions. After the maturity, during the harvest and storage, the amount of organic acids tends to fall, in function of respiratory processes, because oxidation and conversion to sugars occur (CHITARRA; CHITARRA, 2005).

For the soluble solids (SS), there was a statistical difference between the treatments, the plants treated with boscalid 75g ha⁻¹ were those with the highest

value, 11.6 °Brix, followed by plants treated with pyraclostrobin, 50g ha⁻¹ and the mixture of boscalid 37.5g ha⁻¹ + pyraclostrobin 25g ha⁻¹, 10.1 and 10.7 °Brix, respectively.

The soluble solids content indicates the amount of the solids that are dissolved in the fruit juice or pulp, which unit is represented as °Brix. They have a tendency to increase throughout maturity and are mainly composed of sugars, varying according to species, cultivar, stage of maturation and climate. Thus, the soluble solids content (SS) are used as a direct measure of the sugar content, since it increases the value as these contents are accumulated in the fruit (CHITARRA; CHITARRA, 2005).

The fruits of the treatments that showed the highest values of soluble solids meet the quality standards for commercialization, both for the

domestic market and for the external market, since, for the European market, fruits with soluble solids content below 9 °Brix are considered unfit, fruits between 9 and 12 °Brix are acceptable, and those with values above 12 °Brix are considered optimal for commercialization (CHARLO et al., 2009).

The SS/TA ratio relation is one of the most used forms for the evaluation of the flavor, giving a correlation of equilibrium between sugars and acids of the fruits, being more representative than the isolated measurement of sugars or the acidity (CHITARRA; CHITARRA, 2005). The SS/TA ratio values are described in Table 2, showing that the treatment boscalid 75g ha⁻¹ has the highest ratio. These results come from fruits with high soluble solids and low titratable acidity, allowing a more pleasant taste to consumers.

Conclusion

In the conditions, which the experiment was conducted, the results allowed to conclude that the application of the treatments positively influenced the physical-chemical characteristics of the net melon fruits. The most significant treatment was boscalid 75g ha⁻¹, which provided a higher concentration of soluble solids and low titratable acidity, resulting in a better ratio of fruits. In addition, the fruits of the plants treated with pyraclostrobin 50g ha⁻¹ and with the mixture of boscalid (37.5g ha⁻¹) + pyraclostrobin (25g ha⁻¹) also showed high values of soluble solids which resulted in excellent values of ratio. The highest value for pulp texture was from plants treated with pyraclostrobin 50g ha⁻¹.

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