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Tools to modify cherries harvest time in Alto Valle de Río Negro and Neuquén, Argentina

VIII Encuentro Latinoamericano Prunus sin Fronteras

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Herramientas para regular el momento de cosecha en cerezas en el Alto Valle de Río Negro y Neuquén, Argentina

Ferramentas para regular o tempo de colheita em cerejas no Alto Valle de Río Negro e Neuquén, Argentina

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Abstract

Cherry production is characterized by a very short fruit development period that covers an average of 80 days from flowering to harvest. Although there are varieties with different cycles, the harvest in Alto Valle de Río Negro and Neuquén, Argentina, is highly concentrated. The possibility of extending the harvest period allows to improve logistics, decongest packing work and regulate to a certain extent the supply of cherries on the market. Fruit cherries are highly perishable non-climacteric fruits and have low supply in counter season, which determines an unsaturated foreign market and the possibility to obtain good prices. The highest prices on the market depend on the fruit size and fruit quality and the harvest time (early and late). The aim of this work was to evaluate the feasibility of using different growth regulators and bio-stimulants to extend the sweet cherries harvest period. The use of hydrogen cyanamide (HC) in early varieties to advance the harvest and the use of Retard Cherry® (RCH) in late varieties to delay flowering and harvesting were evaluated. In addition, the effect of gibberellins (Gb) on the delay of maturity and improvement in quality in different varieties was evaluated. The use of HC allowed to advance bloom by 10 days and the harvest by 7 days in fruits of New Star, while RCH delayed the bloom (10 days) and maturity (5 days) of Santina, Lapins and Regina cherries. The application of Gb at 20 ppm from straw yellow stage until the start of the pink improves the quality of the fruits, but the effect on delaying maturity decreases with later applications. The use of regulators in cherries allows to extend the harvest window in nearly 10 days, depending on each cultivar and the meteorological conditions of the season.

Keywords: hydrogen cyanamide, gibberellins, bio stimulants, New Star, Sweetheart, Regina

Resumen

La producción de cerezas se caracteriza por un ciclo productivo corto que abarca un promedio de 80 días desde floración a cosecha. Si bien existen variedades de diferentes ciclos, la cosecha en el Alto Valle de Río Negro y Neuquén, Argentina, es muy concentrada. El escalonamiento de la cosecha ayuda a mejorar la logística, descongestionar el trabajo en los empaques y regular en cierta medida la oferta de cerezas en el mercado. La cereza es un fruto de corta conservación y baja oferta en contraestación, lo que determina un mercado externo no saturado y la obtención de buenos precios. Los mayores precios en el mercado dependen del calibre y la calidad de las cerezas y del momento de la temporada de cosecha (primicia y tardicia). El objetivo de este trabajo fue evaluar la factibilidad de uso de regladores de crecimiento como estrategia para extender el período de cosecha de cerezas. Se evaluó el uso de cianamida hidrogenada (HC) en cultivares tempranos para adelantar la cosecha y el uso de Retard Cherry® (RCH) en cultivares tardíos para retrasar la floración y la cosecha. Además, se evaluó el efecto de las giberelinas (Gb) en el retraso de madurez y mejora en la calidad en diferentes cultivares. El uso de HC logró adelantar 10 días la floración y 7 días la cosecha en New Star, mientras que el RCH retrasó la floración (10 días) y la madurez (5 días) de cerezas Santina, Lapins y Regina. La aplicación de Gb a 20 ppm desde color pajizo hasta inicio pinta mejora la calidad de los frutos, pero el efecto en el retraso de la madurez disminuye con aplicaciones más tardías. El uso de reguladores en cerezas permite ampliar la ventana de cosecha en alrededor de 10 días dependiendo de cada cultivar y las condiciones de la temporada.

Palabras clave: cianamida hidrogenada, giberelinas, bioestimulantes, New Star, Sweetheart, Regina

Resumo

A produção de cerejas é caracterizada por um curto ciclo de produção, que abrange, em média, 80 dias desde a floração até a colheita. Embora existam variedades de ciclos diferentes, a colheita no Alto Valle de Río Negro e Neuquén, Argentina é altamente concentrada. O escalonamento da colheita ajuda a melhorar a logística, descongestionar o trabalho de embalagem e, até certo ponto, regular o fornecimento de cerejas no mercado. A cereja é um fruto de curta conservação e baixa oferta na contra-estação, o que determina um mercado externo insaturado e a obtenção de bons preços. Os preços mais altos do mercado dependem do calibre e qualidade das cerejas e da época da colheita (precoce ou tardia). O objetivo desse trabalho foi evaluar a possibilidade de uso de reguladores de crescimento como estratégia para estender o período de colheita de cerejas. Foram avaliados o uso de cianamida hidrogenada (HC) em cultivares precoces para adiantar a colheita e o uso de Retard Cherry® (RCH) em cultivares tardias para retardar o florescimento e a colheita. Além disso, foi avaliado o efeito das giberelinas (Gb) no retardamento da maturação e na melhoria da qualidade em diferentes cultivares. O uso de HC conseguiu adiantar a floração em 10 dias e a colheita em 7 dias, em 'New Star', enquanto o RCH atrasou a floração (10 dias) e a maturação (5 dias) das cerejas 'Santina', 'Lapins' e 'Regina'. A aplicação de Gb a 20 ppm quando as frutas estão na cor da palha ao início da rosa, melhora a qualidade dos frutos, mas o efeito no atraso da maturidade diminui com aplicações mais tardias. O uso de reguladores em cerejas permite estender a janela da colheita em cerca de 10 dias, dependendo da cultivar e das condições da estação.

Palavras-chave: cianamida hidrogenada, giberelinas, bioestimulantes, New Star, Sweetheart, Regina

1. Introduction

Sweet cherry (*Prunus avium* L.) ripens first among stone fruits, followed by apricot, peach and plum. Because sweet cherry is first on the fresh market, it is highly demanded in late spring and early summer. Cherry production is characterized by a very short fruit development period (FDP) that covers an average of 80 days from bloom to harvest. Although there are cultivars with different cycle lengths, the harvest time in our region is highly concentrated(1). The possibility of extending the harvest period helps to improve logistics, decongest packing activities and regulate —to a certain extent— the supply of cherries on the market. Cherries are highly perishable fruits and have a short cold storage period and low supply in counter season, conditions that determine an unsaturated external market and thus the possibility to obtain good prices. The highest prices on the market depend on the size and quality of the cherries and the harvest period (early and late)(2). The use of growth regulators may allow to advance or retard the time of harvest aiming to improve logistics and labour efficiency, decongest packaging and also reaching the market when the prices are the highest. In cherries, budburst and flowering were advanced and yield increased with the application of hydrogen cyanamide (Dormex®) prior to budburst in the field(3). Ripening advancement of 7 to 8 days was observed in Burlat, and of 7 to 9 days in Ferrovia(4). On the other hand, Retard Cherry® is a liquid bio stimulant that was used in Chile to delay bloom, avoid frost damage and also allows delaying the harvest by 3 to 5 days, enabling the farmer to stagger the harvest and optimizing the use of labour(5). Gibberellic acid (GA3) application is a standard commercial practice during sweet cherry production to increase the fruit size and soluble solids concentration. It is used to delay harvest and increase fruit firmness, being applications of 20 ppm at the straw-color stage the common recommendation(6)(7)(8).

The aim of this work was to evaluate the feasibility of using hydrogen cyanamide, bio stimulants and gibberellins to extend the sweet cherries harvest period.

2. Materials and methods

Trials were performed over three different seasons in an orchard located in Rio Negro, Argentina (39º 02' 24"S y 67º 38' 47" W; 245 m above sea level, 244 mm annual rainfall, 15 ºC annual average temperature). Hydrogen cyanamide trials were performed in 2008-09 season; the bio stimulant trials in 2017-18 and the gibberellins experiments in 2006-07 season.

2.1 Hydrogen cyanamide

The use of hydrogen cyanamide (HC) in early varieties to advance the harvest was evaluated. Three treatments were performed 30 days before bud break, each treatment covering 6 trees of New Star sweet cherries: Dormex® 2% (vol/vol), Dormex® 4%

and Control (water). Dormex® treatments were applied with commercial surfactant (2%).

2.2 Bio-stimulants

The use of Retard Cherry® (RCH) was evaluated in Kordia, Regina, Sweetheart and Santina. Five trees of each cultivar were treated with RCH (at commercial rate) and five were used as control.

2.3 Gibberellins

The effect of gibberellins (Gb) on the delay of maturity and improvement in quality in New Star was evaluated. Three treatments were tested: GA3 20 $mg \cdot L^{-1}$ at start of veraison (30% straw yellow coloration); at veraison (60% straw yellow skin color); and at control. Each treatment covering four trees.

2.4 Measurements

In trials 2.1 and 2.2, phenology was recorded twice a week following the method of Baggiolini[9].

In all trials, a sample of 100 fruit per treatment was randomly collected, in each harvest date, for evaluations of fruit quality. Fruit weight was determined using digital scales (Sartorius, Germany) and fruit firmness with a Durofel device (Durometer, Shore A). Total soluble solids content was determined on the fruit juice with a digital refractometer (Atago CO., Ltd.). Fruit juice was also analyzed for total titratable acidity using 0.1 N NaOH to pH 8.2. Skin color was classified using a Color Chart (EEA Alto Valle INTA, Post-harvest Area), into six color categories designated from 1 to 6. Skin color and soluble solids content are the main criteria used to judge fruit maturity. We used values between 2 and 3 as the optimal color for New Star harvest, and values between 6-20°Brix for New Star and 20-21°Brix for sweetheart.

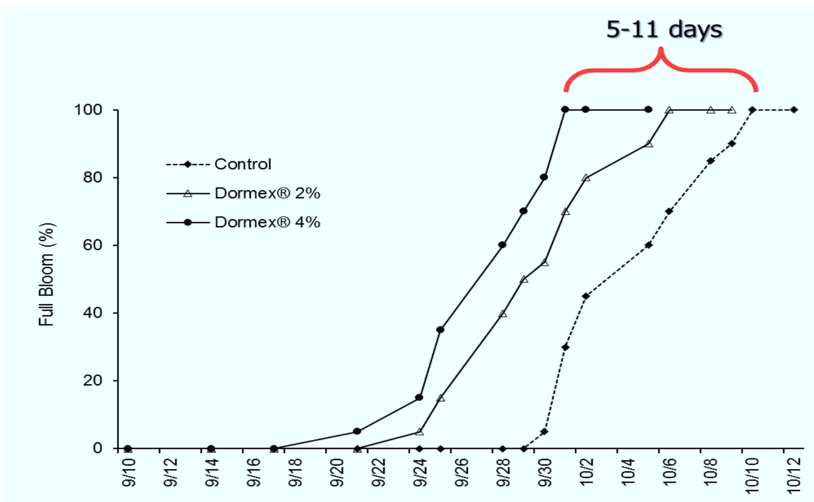
Data were analyzed by analysis of variance (ANOVA) with the statistical software Infostat (Universidad Nacional de Córdoba, Argentina). Means were compared using the LSD Fisher test.

3. Results and Discussion

3.1 Hydrogen Cyanamide

Dormex® treatments applied 30 days before the average flowering date promoted initial bloom eleven days earlier at concentration of 4% and five days earlier at 2%, compared to the control treatment. Thus, the effect increased with higher Dormex® dose (Figure 1), in accordance with previous reports[10], which observed a maximum advancement of bloom of 11 to 13 days in Burlat and 7 to 9 days in Ferrovia. In addition, in comparative studies carried out on cherries with three active ingredients, the HC consistently gave the most accelerated blooming[11]. Application of 2.5% HC also resulted in a marked increase in bud-break rate compared to control samples in *Vitis vinifera* L.[12].

Figure 1. Percentage of New Star sweet cherry full bloom after treatment with Dormex® at 2%, 4% and control treatments. Each value represents the average of six trees per treatment



Both Dormex® treatments advanced New Star maturity, achieving the earliest harvest with Dormex® at 4%.

Consumers are first attracted by color, while fruit sweetness is the second decisive criterion for quality. Dormex® at 4% achieved optimal sugar standards and color intensity for harvest, one week earlier than the other treatments (Table 1 and Figure 2). In contrast, previous reports found no effect on soluble solids of Bing cherries that had been treated with label rates of HC[13]. Probably due to climatic conditions between dates of application and fruit ripening[10].

Three days after the first harvest (Nov 28), 90% of fruit from the Dormex® 4% treatment showed appropriated color to be collected (color categories 2, 3 and 4), but only 45% of the control fruits were in these color categories (Figure 2). As previously reported, full skin color assure a large number of fruit with minimum soluble solids content[14].

The advancement in fruit maturity with Dormex® treatments was less than that observed in bloom, as reported before[4][10]. Consequently, Dormex® at 4% applied to early-ripening cultivars allowed an early harvest and may improve grower profits by reaching markets before prices drop.

Table 1. Fruit weight and soluble solids of New Star sweet cherries at three harvest dates

Factors	Fruit weight (g)	Soluble solids (°Brix)
Sample date		
Nov 19	5.9 a	14.6 a
Nov 25	-	15.4 b
Nov 28	7.4 b	17.8 c
Treatment		
Control	6.9 b	16.2 a
Dormex 2%	6.3 a	16.5 a
Dormex 4%	8.0 c	17.6 b
p-value Interaction	*0.25*	*0.10*
p-value Date	*<0.0001*	*<0.0001*
p-value Treatment	*<0.0001*	*0.0006*

*Means followed by the same letter in each column for each factor are not significantly different at $p<0.05$ according to LSD Fisher Test

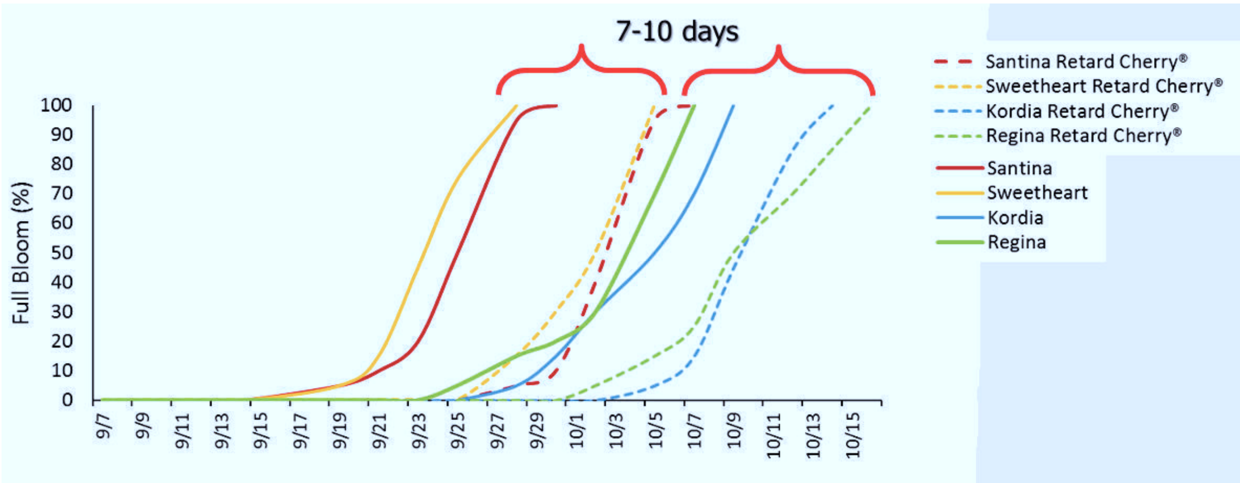
Figure 2. Percentage of New Star sweet cherry fruit treated with Dormex® 2%, 4% and control, classified into different skin color categories using a Color Chart (EEA Alto Valle INTA - Post-harvest area), during three harvest dates

3.2 Bio-stimulants

Retard Cherry® application in the fall of 2018 caused a delay in flowering of 7 to 10 days in all evaluated cultivars (Figure 3). Autumn treatments with Retard Cherry® were effective in delaying the leafing, flowering and ripening of Santina, Sweetheart, Regina and Kordia cherries. The same tendency was observed in tests carried out in the VII Region in Chile with Retard Chery® applications, where a delay of 7-12 days in full bloom was observed in the cultivars Lapins, Sweetheart, Kordia and Regina[5].

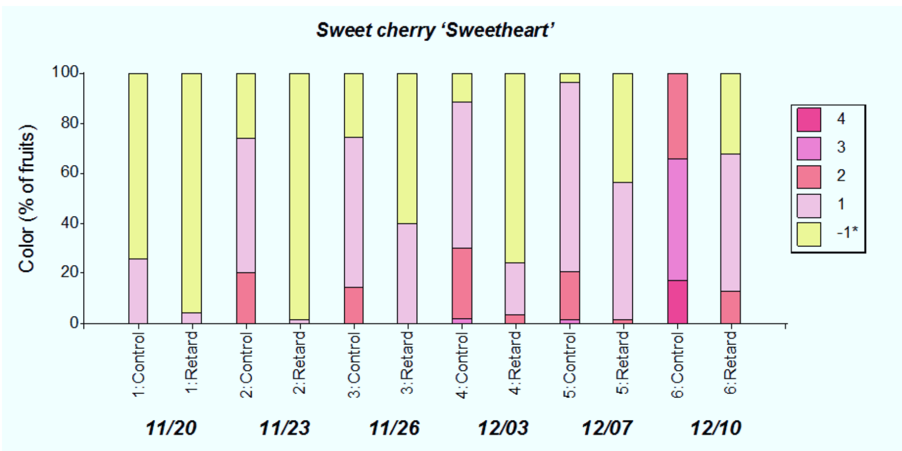
In Sweetheart, fruits treated with Retard Cherry® showed a marked delay in color development. On December 3rd sample, 35% of fruits of the control plants presented an average skin color classified as 3, while in those treated samples, 100% of the fruits had an average skin color below 2. Also fruits from control treatments were able to be harvested in December 10 (Figure 4). The same results were observed in the other cultivars (data not shown).

Figure 3. Percentage of Santina, Sweetheart, Kordia and Regina sweet cherry full bloom after treatment with Retard Cherry®



*Each value represents the average of five trees per treatment. Solid lines indicate control and dashed ones' RCH treatment in each variety

Figure 4. Percentage of Sweetheart sweet cherry fruit treated with Retard Cherry® and control, classified into different skin color categories using a Color Chart (EEA Alto Valle INTA- Post-harvest area), on six harvest dates



3.3 Gibberellins

Gibberellins application significantly increased the average fruit size, without showing differences between the two application moments (Table 2) in contrast to other previous study[11]. Likewise, it agrees with studies in Bing, where it was determined that GA3 applications were effective in increasing the fruits size when applied in stage II and III of the growth curve[15]. Regarding firmness, although a gradual increase was observed as application time was delayed (5.8% and 11.5%), no statistically significant differences were found between the two GA3 applications (Table 2). This concurs with findings from other studies where GA3 applications allowed harvest delay while maintaining acceptable firmness in different cultivars[6][7][11][16]. Also, other reports showed that GA3 treated sweet cherry fruit were significant firmer than those of the control at harvest time, and this firmness was better maintained than the control after storage[7]. The latest treatment with gibberellins caused an increase in the soluble solids content with an average value of 20.5 ºBrix, while the control had a value of 17.9 ºBrix (Table 2). An increase in firmness without a delay in the increase of soluble solids content is desirable. Same response was found in titratable acidity, with the later treatment of gibberellins showing the highest value respect to other treatments (Table 2). In contrast, soluble solids and titratable acidity did not vary with respect to GA3 treatment, but did with respect to year[11]. As previously reported[6][7][17] treatments of 20 mg L^{-1} of GA3 present better results in terms of fruit quality at harvest and post-harvest; and a positive relationship between GA3 applications and fruit quality parameters such as firmness, weight and soluble solids was observed. As previously reported, rate of accumulation of fruit soluble solids was similar for treated and non-treated fruit. So fruit soluble solids content could have been similar or higher, depending on the delay of harvest[16]. Although titratable acidity plays a role in consumers acceptance, the importance of its measurement is less relevant than soluble solids, because soluble solids changes are greater during the cherry ripening period.

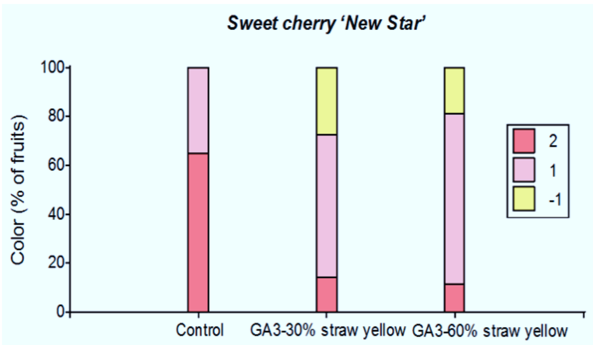
Fruit skin color is often the basis for timing of commercial sweet cherries harvest, and GA3 preharvest applications delays color development of New Star sweet cherries, regardless the time of the treatment application (Figure 5).

Table 2. Maturity index of New Star sweet cherries treated with GA3 20 mg L^{-1} at 30% straw yellow and 60% straw yellow and at control

Treatments	Weight (g)	Firmness (Durofel)	Soluble solids (º Brix)	Titratable acidity (%malic acid)
Control	6.51 a	66 a	17.9 a	0.96 a
GA3 at 30% straw yellow	8.02 b	69 ab	18.3 a	1.08 a
GA3 at 60% straw yellow	8.32 b	73 b	20.5 b	1.21 b
p-value	*0.0042*	*0.0112*	*0.0041*	*0.0041*

*Means followed by the same letter in each column are not significantly different at $p<0.05$ according to LSD Fisher Test

Figure 5. Percentage of New Star sweet cherry fruit treated with GA3 20 mg L^{-1} at 30% straw yellow and 60% straw yellow and a control, classified into different skin color categories using a Color Chart (EEA Alto Valle INTA - Post-harvest area), during an early harvest



4. Conclusions

Hydrogen cyanamide proved to be an effective dormancy-breaking agent in sweet cherries. Thus, in regions with average chilling hours of 1.200 hydrogen cyanamide applications are recommended for early cultivars to advance maturity.

Retard Cherry® applications were effective in delaying the leafing, flowering and ripening of sweet cherries.

Moreover, GA3 treatment allowed harvest delay while maintaining acceptable firmness. Also, delaying maturity may lengthen the growing season, allowing fruit to remain on the tree longer so that its size may increase.

The use of different growth regulators allows the advancement and delay of bloom date in ± 10 days, and the advancement or delay of fruit ripening to a lesser extent (5-7 days). Thus, their use allows to extend the harvest window in around 10-17 days, depending on each cultivar and meteorological conditions of the season.

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Author contribution statement

All authors contributed equally to the content.

References

1. Raffo D, Candan AP, Calvo P. Variedades de cereza en el Alto Valle. Río Negro: INTA; 2009.15p.

2. Quiroz I. Mercado de la Cereza 2017/2018: un desafío superado con mérito. Redagrícola. 2018;(set):20-3.

3. Raffo Benegas MD, Mañueco L, Candan AP, Santagni B, Menni F. Dormancy breaking and advancement of maturity induced by Hydrogen Cyanamide: a strategy to improve profits in sweet cherries production. Acta Hortic. 2014;(1020):497-503.

4. Palasciano M, Losciale P, Godini A. Dormancy breaking and advancement of maturity induced by hydrogen cyanamid (Dormex®) in cherry following normal and mild winters. Rivista di Frutticoltura e di Ortofloricoltura Vegetali. 2005;67(3):56-60.

5. Tapia C. Utilización de Retard Cherry® para retardar floración y cosecha en cinco variedades, en la zona de Molina VII Región: resultados temporada 2016-2017. Talca: Nehuen Agrofrutícola; 2017. 4p.

6. Kappel F, MacDonald RA. Gibberellic acid increases fruit firmness, fruit size, and delays maturity of 'Sweetheart' sweet cherry. J Amer Pomol Soc. 2002;56(4):219-22.

7. Özkaya O, Dündar O, Küden A. Effect of preharvest gibberellic acid treatments on postharvest quality of sweet cherry. J Food Agric Environ. 2006;4(1):189-91.

8. Choi C, Toivonen P, Wiersma PA, Kappel F. Effect of gibberellic acid during development of sweet cherry fruit: physiological and molecular changes. Acta Hortic. 2004;(636):489-95.

9. Baggiolini M. Les stades repères du pecher. Revue Romande d'Agriculture et d'Arboriculture. 1952;8(4):29.

10. Godini A, Palasciano M, Ferrara G, Camposeo S, Pacifico A. On the advancement of bud break and fruit ripening induced by hydrogen cyanamide (Dormex®) in sweet cherry: a three-year study. Acta Hortic. 2008;(795):469-78.

11. Tapia C. Factores más influyentes del potencial productivo y calidad de la fruta de cerezo. Redagrícola. 2018;(ago):46-50.

12. Pérez FJ, Vergara R, Rubio S. H2O2 is involved in the dormancy-breaking effect of hydrogen cyanamide in grapevine buds. Plant Growth Regul. 2008;55:149-55.

13. Clayton M, Biasi W, Tayfur Agar I, Suthwick SM, Mitcham E. Postharvest quality of 'Bing' cherries following preharvest treatment with Hydrogen Cyanamide, Calcium Ammonium Nitrate or Gibberellic Acid. HortScience. 2003;38(3):407-11.

14. Crisosto CH, Crisosto GM, Metheney P. Consumer acceptance ob 'Brooks' and 'Bing' cherries is mainly dependent on fruit SSC and visual skin color. Postharvest Biol Tec. 2003;28:159-67.

15. Zhang C, Whiting MD. Improving 'Bing' sweet cherry fruit quality with plant grouth regulators. Sci Hort. 2011;127:341-6.

16. Facteau TJ, Chestnut NE, Rowe KE, Payne C.

Brine quality of gibberellic acid treated 'Napoleon' sweet cherries. HortScience. 1992;27(2):118-22.

17. Lenahan OM, Whiting MD, Elfving DC. Gibberellic acid inhibits floral bud induction and improves 'Bing' sweet cherry fruit quality. HortScience. 2006;41(3):654-59.

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VIII Encuentro Latinoamericano Prunus sin Fronteras

Treatment with 1-MCP

an alternative to extend storage in plums harvested with advanced maturity

Tratamiento con 1-MCP

una alternativa para extender el almacenamiento en ciruelas cosechadas con madurez avanzada

Tratamento com 1-MCP

uma alternativa para estender o armazenamento em ameixas colhidas com maturação avançada

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Abstract

Maturity at harvest is a determining factor in fruit storage potential, especially in such perishable species as plums (*Prunus salicina L.).* However, harvest´s logistics is very complex, and a large percentage of fruits are harvested at a more advanced stage of maturity than the optimum recommended for long storage. Treatment with 1-MCP has shown to be effective in reducing the post-harvest deterioration rate of Japanese plums, but the effectiveness of this treatment may be reduced in late harvested fruit. The aim of this trial was to determine the efficiency of treatment with 0.4 µL L^{-1} of 1-MCP in Larry Ann plums harvested at 4 different maturity stages. The results showed that the treatment was effective in reducing the ripening rate of the fruit at all harvest timings. The duration of this effect and the number of parameters affected decreased as harvest was delayed. In maturity stage 1 (M1, ~62 N) and maturity stage 2 (M2, ~58 N), 1-MCP delayed ethylene production rate during shelf life after 30, 40, and 50 days of storage at 0 ºC and reduced loss of flesh firmness, and acidity. At the maturity stage 3 (M3, ~50N) 1-MCP delayed ethylene production rate during shelf life after 30 and 40 days of storage at 0 ºC and maintained higher flesh firmness values. In fruit harvested at the maturity 4 (M4, ~35 N), 1-MCP did not affect ethylene production rate, but reduced loss of flesh firmness during shelf life, supporting the hypothesis that the treatment has a direct inhibitory effect on softening enzymes, independent of ethylene.

Keywords: ethylene, flesh color, harvest maturity, *Prunus salicina*, softening

Resumen

La madurez en el momento de cosecha es un factor determinante del potencial de almacenamiento de los frutos, principalmente en especies tan perecederas como las ciruelas (*Prunus salicina L.).* Sin embargo, la logística de cosecha es muy compleja y un gran porcentaje de frutos se cosecha con un estado de madurez más avanzado al óptimo recomendado para larga conservación. El tratamiento con 1-MCP ha mostrado ser efectivo en reducir la tasa de deterioro poscosecha de ciruelas japonesas, pero la efectividad de este tratamiento puede verse reducida en frutos de cosechas tardías. El objetivo de este ensayo fue determinar la eficiencia del tratamiento con 0,4 µL L^{-1} de 1-MCP en ciruelas Larry Ann cosechadas en 4 estados de madurez diferentes. El tratamiento redujo la tasa de maduración de los frutos en todas las cosechas. La duración de este efecto y el número de parámetros afectados disminuyó a medida que se retrasó la cosecha. En el estado de madurez 1 (M1, ~62 N) y el estado de madurez 2 (M2, ~58 N), el 1-MCP retrasó la tasa de producción de etileno durante la vida en estante después de 30, 40 y 50 días de almacenamiento a 0 ºC y redujo la pérdida de firmeza y de acidez. En el estado de madurez 3 (M3, ~50 N) el 1-MCP retrasó la tasa de producción de etileno durante la vida en estante después de 30 y 40 días de almacenamiento a 0 ºC y mantuvo mayores valores de firmeza. En frutos cosechados con madurez 4 (M4, ~35 N) el 1-MCP no afectó la producción de etileno, pero redujo la pérdida de firmeza durante la vida en estante, apoyando la hipótesis de que el tratamiento tiene un efecto inhibitorio directo sobre las enzimas del ablandamiento, independiente del etileno.

Palabras clave: etileno, color de la pulpa, madurez a cosecha, *Prunus salicina*, ablandamiento

Resumo

O estádio de maturação na colheita é um fator determinante no potencial de armazenamento dos frutos, principalmente em espécies tão perecíveis como as ameixas (*Prunus persica* L.). No entanto, a logística da colheita é muito complexa e uma grande porcentagem de frutas é colhida com um estado de maturação mais avançado do que o ideal recomendado para conservação prolongada. O tratamento com 1-MCP vem demonstrando ser eficaz na redução da taxa de deterioração pós-colheita das ameixas japonesas, mas a eficácia desse tratamento pode ser reduzida em frutos de colheitas tardias. O objetivo deste estudo foi determinar a eficiência do tratamento com 0,4 µL L^{-1} de 1-MCP em ameixas 'Larry Ann' colhidas em 4 estádios de maturação. Os resultados mostraram que o tratamento com 1-MCP foi eficaz na redução da taxa de amadurecimento dos frutos em todos os momentos. A duração desse efeito e o número de parâmetros afetados diminuíram com o atraso da colheita. Nos estádios de maturação 1 (M1,~62 N) e estádios de maturação 2 (M2,~58 N), a aplicação de 1-MCP atrasou a produção de etileno durante a vida de prateleira após prazo de 30, 40 e 50 dias de armazenamento a 0ºC e reduziu a perda de firmeza de polpa e acidez. No estado de maturação 3 (M3, ~50N), o 1-MCP atrasou a produção de etileno durante a vida de prateleira após 30 e 40 dias de armazenamento a 0ºC e manteve valores mais altos de firmeza. Nos frutos colhidos no maturação 4 (M4,~35 N), o tratamento com 1-MCP não afetou a produção de etileno, mas reduziu a perda de firmeza de polpa durante a vida de prateleira, apoiando a hipótese de que o tratamento tem um efeito inibitório direto sobre as enzimas relacionadas ao amolecimento da polpa dos frutos independente do etileno.

Palavras clave: etileno, cor da polpa, maturação na colheita, *Prunus salicina*, amolecimento

1. Introduction

Most of the plums produced in the valleys of Río Negro and Neuquén (Argentina) are stored at low temperatures in order to extend the window of sale in the domestic market or to withstand the transport period to distant counter-market. Harvesting the fruits in their optimal stage of maturity is one of the determining factors of the final quality of the product(1). However, the logistics of the harvest are complex, and part of the fruit is harvested with an advanced maturity stage (more than the recommended for storage).

1-Methylcyclopropene (1-MCP) has shown to be effective in reducing the ethylene production rate and consequently softening, acidity loss, and epidermis color changes in different plum cultivars(2)(3). The effectiveness of this treatment depends on the stage of maturity of the fruits at which it is applied, and it has been observed in various species that the more mature the fruit is, the lower the response to treatment with 1- MCP(4). The aim of this trial was to determine the efficiency of treatment with 0.4 µL L^{-1} of 1- MCP in Larry Ann plums harvested in four different stages of maturity.

2. Materials and methods

Larry Ann plums (*Prunus salicina* L) were harvested from a commercial orchard in Río Negro (Argentina), at 4 maturity stages: maturity 1 (M1, ~62 N), maturity 2 (M2, ~58 N), maturity 3 (M3, ~50 N) and maturity 4 (M4, ~35 N).

After each harvest, the fruits were taken to the laboratory and maturity indexes were determined on 3 repetitions of 20 fruit each. Fruits were divided into two homogeneous lots: treated with 0 (Untreated control) or 0.40 µL L^{-1} of 1-MCP (Treated) for 24 hours during fruit-cooling. Subsequently, fruits were stored at 0 ºC and 90% of relative humidity for 30, 40 and 50 days and evaluated immediately after removal from the chamber, and after 3 and 7 days of shelf life at 20 ºC on 3 replicates of 20 fruit each.

Ethylene production rate (µL kg^{-1} h^{-1}) was determined on 3 repetitions of 6 fruits right after harvest and after removal from cold storage, for up to 20 days at 20 ºC or until reaching the climacteric peak. The fruits were weighed and enclosed in 3-L jars for 30 min at 20 ºC, and then 1 mL sample was extracted from the headspace. The sample was analyzed with a gas chromatograph (GC-14A, Shimadzu, Japan) equipped with an alumina column (40 ºC) and a FID detector (210 ºC). Helium was used as gas carrier.

Flesh firmness (FF) was determined with an electronic fruit texture analyzer (FTA-GS14, Güss, South Africa) with an 8 mm-diameter probe and expressed in Newtons. Sections of skin were removed at the widest point of the fruit on opposite sides to determine FF. Two slices of flesh were taken from each fruit and juiced to determine soluble solids content

(SSC) with a digital refractometer (PAL-1, Atago, Japan) expressed as %, and titratable acidity (TA) (%) by titration of 10 mL of juice with 0.1 N NaOH to a pH of 8.2, which is expressed as a percentage of malic acid.

Epidermis color was determined visually as color coverage (%) and with a tristimulus colorimeter (CR-300, Minolta, Japan) on two well-colored areas on each fruit after removing the epicuticular wax. Data are expressed in coordinates L*, Chroma, $(a^2 + b^2)^{1/2}$, and Hue $[\tan^{-1}(b/a)]$.

Flesh color and chilling injury (CI) development were assessed visually by cutting each fruit on half along the equatorial axis. A four-grade visual scale according to the percentage of flesh colored or injured was used: Uninjured (0%), G1 (up to 25%), G2 (25-50%), G3 (50-75%) and G4 (75-100%). Intensity of coloration and severity of CI were calculated as the total number of fruit in each grade multiplied by the grade and divided by the total of injured fruit. Chilling injury was also expressed as percentage of affected fruits.

Data were subjected to analysis of variance (Anova) using Infostat[5]. The separation of means was performed using Tukey test with a significance level of 0.05 (*p*-values).

3. Results and discussion

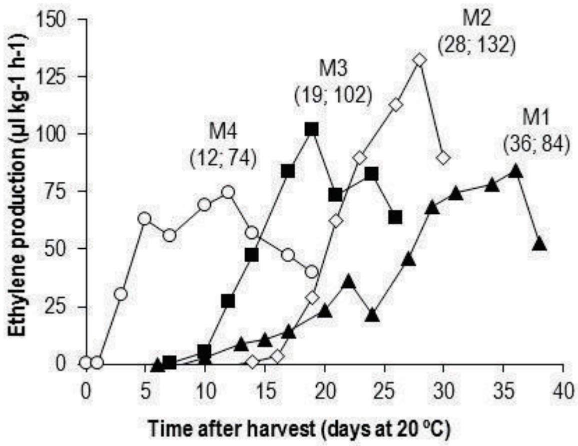
3.1 Harvest evaluations

Ethylene production rate at 20 ºC during ripening after harvest differed significantly between harvest dates (Figure 1). As the harvest was delayed, the time required to start the ethylene production and to reach the climacteric peak was reduced.

Other authors also observed that fruits harvested with more advanced maturity initiated ethylene production before those harvested earlier[6]. In other words, as harvest is delayed, the fruits are closer to reaching their climacteric maximum and consequently their deterioration, which reduces their storage potential.

Flesh firmness values decreased as harvest was delayed, showing significant differences between harvest dates (Table 1). The softening rate also increased with delayed harvest, being lower from the M1 to M2 stage (~ 0.6 N / day) than from the M2 to M3 stage (~ 1 N / day) or from M3 to M4 (2,2 N/day). Titratable acidity decreased significantly from 2.3% to 1.6%, thus increasing the SSC/TA ratio. As the harvest was delayed, an increase in the percentage of color coverage and a darkening of epidermis color (decrease in *L* and Hue*) was observed (Table 1).

Figure 1. Ethylene production rate of Larry Ann plums during shelf life at 20 ºC after harvest on 4 different maturity stages: M1 (▲), M2 (◇), M3 (■) and M4 (○)



*Values between brackets mean days to reach the peak, and maximum ethylene production rate, respectively

3.2 Storage evaluations

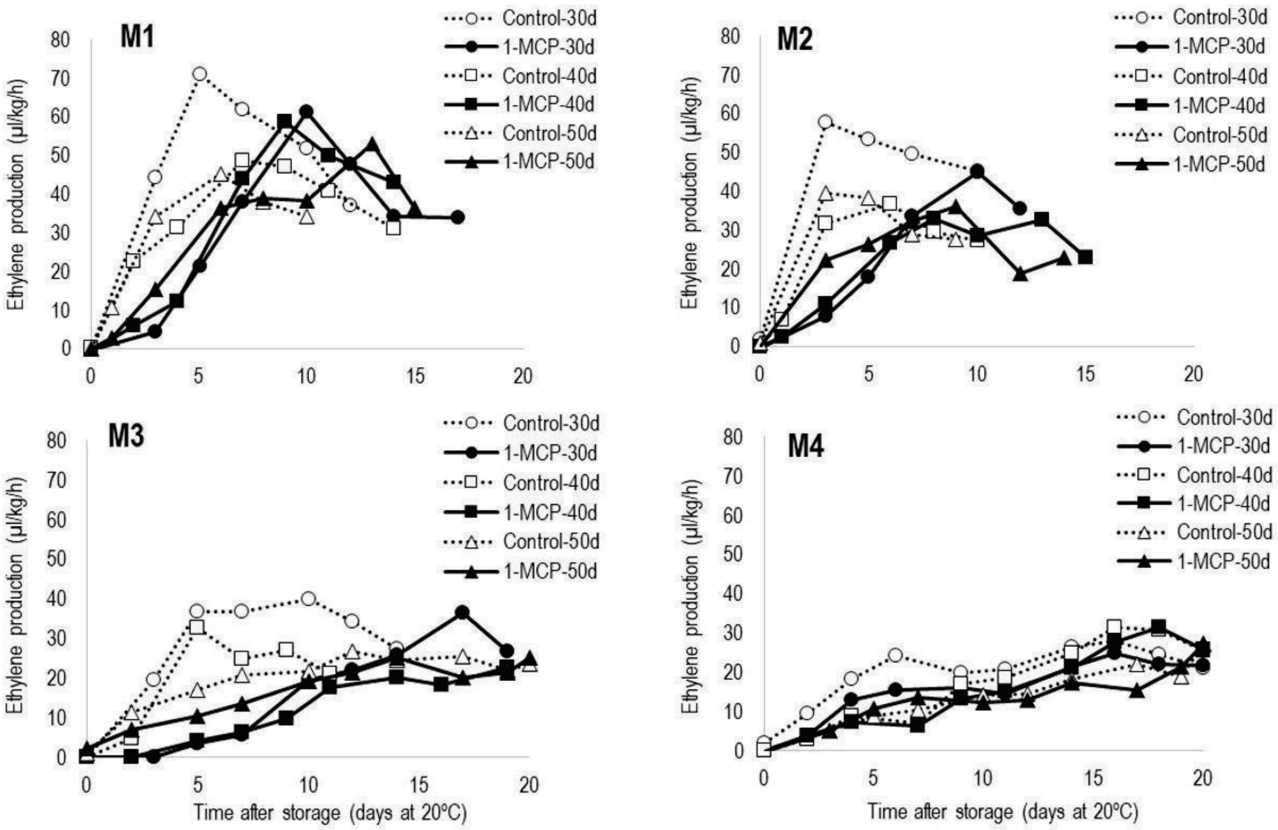
In the evaluations immediately after cold storage, ethylene production rate was undetectable in both control and 1-MCP treated fruits for all harvest dates and at all storage times. However, ethylene production increased during the shelf life period showing clear differences between treatments, harvest dates and storage times. 1-MCP delayed ethylene production after 30, 40 and 50 days of storage in fruit harvested with M1 and M2 (Figure 2, M1 and M2). In fruit harvested with M3 it was only effective after 30 and 40 days (Figure 2, M3), while for M4 fruits there were no differences at any storage period (Figure 2, M4). As storage was extended and harvest was delayed, the ethylene production curves flattened, the climacteric peak was weaker and the differences between control and treated fruit were lost (Figure 2). The reduction in ethylene production due to treatment with 1- MCP has been attributed to a decrease in the activity of the enzymes involved in ethylene biosynthesis (ACS and ACO) and to a lower accumulation of ACC[7].

Table 1. Maturity indexes of Larry Ann plums harvested on 4 successive dates

	M1 (31-jan)	M2 (8-feb)	M3 (16-feb)	M4 (3-mar)	*p*-value
Weight (g)	99.84	106.24	99.26	92.34	0.2160
Firmness (N)	62.06 a	57.75 b	50.66 c	35.20 d	<0.0001
Soluble solids (%)	15.73	15.53	15.80	15.33	0.7960
Titratable acidity (%)	2.32 a	2.26 a	2.04 b	1.64 c	<0.0001
Peel coverage (%)	46.67 d	66.67 c	81.67 b	89.42 a	<0.0001
L (peel)*	38.62 a	35.81 b	36.19 b	33.59 c	<0.0001
Hue (peel)	25.67 a	21.28 b	22.37 b	14.41 c	0.0001
Chroma (peel)	23.21 a	21.35 a	21.57 a	15.40 b	<0.0001

*Within each variable, values followed by different letters indicate significant differences according to the Tukey test (0.05)

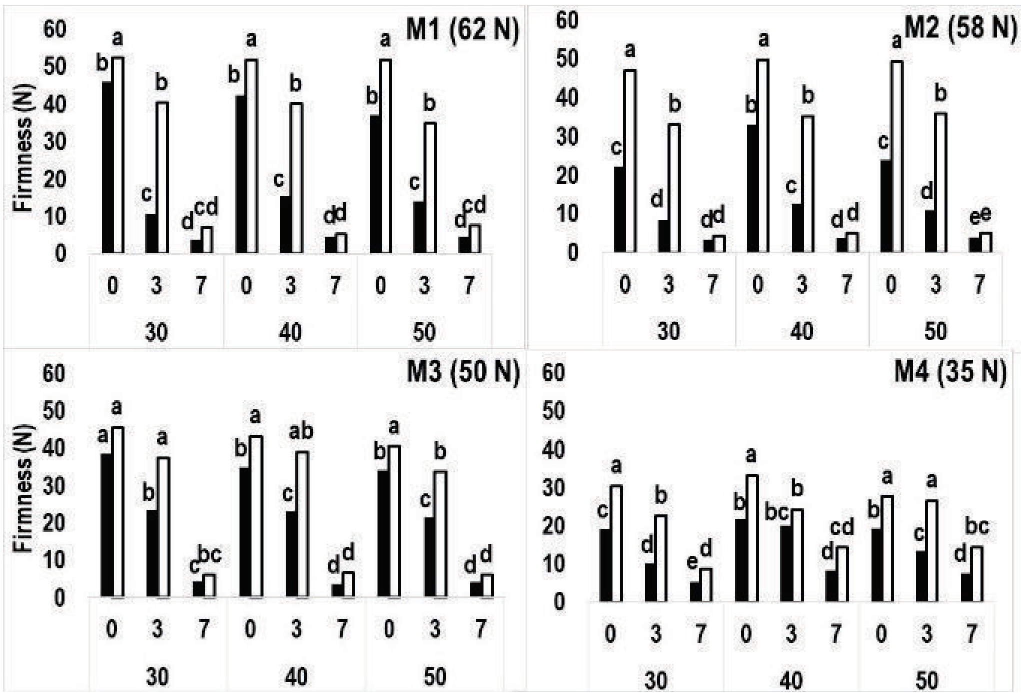
Figure 2. Ethylene production rate of control and 1- MCP treated Larry Ann plums harvested on 31-jan (M1), 8-feb (M2), 16-feb (M3) and 3-mar (M4) during shelf life at 20 ºC after 30, 40 or 50 days of cold storage



The effect on ethylene production rate was manifested in a delay in ripening associated with the maintenance of flesh firmness, acidity and epidermis color, mainly in early harvested fruits and after short storage periods.

Flesh softening was significantly lower in treated fruits than in control fruits of all the harvest dates, both when removed from the cold storage chamber and after 3 days of shelf life (Figure 2). Firmness is related to the sensitivity of the fruit to mechanical damage, which is an important cause of discard in plums and favors the incidence of rot[8]. Some authors recommend that the firmness for handling and marketing plums should not be less than 13 N[9]. Considering this reference value, only fruits treated with 1-MCP maintained recommended values for handling during more than 3 days at 20 ºC (Figure 2). Firmness is also related to the organoleptic quality of plums. The optimum quality of consumption is considered to be reached when the flesh firmness values are between 8 and 15 N for soft pulp plums[10], such as Larry Ann. In this work, control fruits reached firmness values for consumption at 3 days of shelf life at 20 ºC, while fruits treated with 1-MCP maintained values between 23 and 40 N, allowing to extend shelf life of the fruits irrespective of the harvest date (Figure 3).

Figure 3. Flesh firmness (N) in untreated control fruits (■) and treated with 1-MCP (□) of Larry Ann plums harvested in different maturation stages (M1, M2, M3 and M4), kept during 30, 40 or 50 days of cold storage period at 0 ºC, and exposed to different lengths of shelf life (0, 3 and 7 days)



*Different letters indicate significant differences between values, according to Tukey (0.05)

The acids and sugars content are directly related to the flavor of the fruits[11]. The treatment with 1-MCP maintained higher TA values, mainly in the fruits of M1 and M2, although the differences were not as significant as those observed for flesh firmness values (data not shown). SSC varied inconsistently throughout storage and, in general, higher values were observed in the M4 stage (15.3 - 17.2%) than in M3 (14.1 - 16.1%) or M2 (14.4 - 16%), and higher in these than in M1 (13.4 - 15.5%), without showing significant differences between untreated control and treated fruit.

The development of chilling injury symptoms did not limit the storage of the fruits in any of the evaluations done. Flesh translucency was the most frequently observed symptom and affected between 5% and 30% of the fruits harvested in M1 and M3 (data not shown). The severity of the symptom remained below grade 2, without limiting the commercial quality of the control or 1-MCP treated fruits. Internal browning was only observed after long periods of storage and shelf life, mainly in the untreated control fruits of the first harvest.

4. Conclusions

The treatment with 1-MCP was effective in reducing the ripening rate, where the duration of this effect and the number of parameters affected decreased as harvest was delayed.

In early harvested fruit (~62 N and ~58 N) 1-MCP reduced ethylene production, softening, loss of acidity and darkening of the epidermis, mainly in the shorter storage periods.

In fruits from intermediate maturity (~50 N) 1-MCP delayed ethylene production during shelf life after 30 and 40 days of storage at 0 ºC, and maintained higher flesh firmness values.

In fruit from late harvest (~35 N) treatment with 1-MCP only reduced the loss of flesh firmness, but that was enough to extend both the storage period and fruit shelf life.

Both control and treated fruits reached the flesh firmness for consumption.

Author contribution statement

All authors contributed equally to the content.

References

1. Kader AA, Mitchel FG. Maturity and quality. In: La Rue JH, Johnson RS, editors. Peaches, plums and nectarines: growing and handling for fresh market. Davis (CA): UC Davis; 1989. p. 191-6. (Publication; 3331).

2. Candan AP, Graell J, Crisosto C, Larrigaudière C. Improvement of storability and shelf life of ‘Blackamber’ plums treated with 1-methylcyclopropene. Food Sci Technol. 2006;15:437-44.

3. Martínez-Romero D, Dupille E, Guillén F, Valverde JM, Serrano M, Valero D. 1-Methylcyclopropene increases storability and shelf life in climacteric and nonclimacteric plums. J Agric Food Chem. 2003;51:4680-6.

4. Watkins CB.The use of 1-methylcyclopropene (1-MCP) on fruits and vegetables. Biotechnol Adv. 2006;24:389-409.

5. Di Rienzo JA, Casanoves F, Balzarini MG, Gonzalez L, Tablada M, Robledo CW. InfoStat [Internet]. Version 2011. Córdoba: Universidad Nacional de Córdoba, Facultad de Ciencias Agropecuarias; 2011 [cited 2021 Feb 05]. Available from: https://bit.ly/3dDvIyu.

6. Abdi N, Holford P, Mc Glasson WB, Mizrahi Y. Ripening behaviour and responses to propylene in four cultivars of Japanese type plums. Postharvest Biol Tec. 1997;12:21-34.

7. Khan AS, Singh Z. 1-MCP regulates ethylene biosynthesis and fruit softening during ripening of ‘Tegan Blue’ plum. Postharvest Biol Tec. 2007;43:298-306.

8. Amorim L, Martins MC, Lourencio SA, Gutierrez ASD, Abreu FA, Goncalves FP. Stone fruit injuries and damage at the wholesale market of Sao Paulo, Brazil. Postharvest Biol Tec. 2008;47:353-7.

9. Crisosto CH, Slaughter D, Garner D, Boyd J. Stone fruit critical bruising thresholds. Journal American Pomogical Society. 2001;55(2):76-81.

10. Neri F. Influence of maturity stage and ripening on sensory quality of peaches, necatrines and plums. In: Eufrin Workshop on fruit quality. Bologna: EUFRIN; 2003. p. 141-2.

11. Hoehn E, Gasser F, Naepflin B, Ladner J. Consumer expectations and soluble solids, acidity and firmness of plums (Prunus domestica ‘Cacaks Beauty’). Acta Hortic. 2005;(682):665-72.