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Influence of 1-MCP on compression injury, fruit firmness and quality of Japanese plum cv. Santa Rosa during transportation

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ABSTRACT

Plum is a very delicate fruit and requires massive post-harvest managements for enhancing its shelf-life so as to make it available in the market for longer time. Thus, studies were conducted to observe the effect of 1-MCP treatment on Santa Rosa plums of two maturity groups (climacteric and pre-climacteric) during transportation. Plums of both maturity stages were subjected to 1-MCP treatments (control, 1- MCP @ 0.5 µl l^{-1}, 1-MCP @ 1.0 µl l^{-1}, 1-MCP @ 1.5 µl l^{-1} and Celfresh® tablet) for 24 h at 20°C, then packed in CFB boxes and transported to Delhi by road. After transportation, observations were recorded on several parameters. Our results revealed that untreated plums have very heavy loss during transportation due to compression injury in both stages of maturity (25.0 and 9.0%) being quite higher in climacteric stage than pre-climacteric stage. All 1-MCP treatments had significantly reduced compression injury, being the least (0.0) in 1-MCP (1.5 µl l^{-1}) and Celfresh® tablets. There was significant loss in quality parameters like fruit firmness, AOX capacity, TSS, acidity and ascorbic acid in untreated plums but was maintained quite appreciably by 1-MCP, especially by Celfresh® tablets. Similarly, respiration and ethylene evolution rates were higher in untreated plums than those, which were treated with different concentrations of 1-MCP, being the least in Celfresh® tablet treated fruits.

Key words: 1-methylcyclopropene, Japanese plum, compression injury, respiration rate, ethylene evolution rate.

INTRODUCTION

The plum is considered as an important stone fruit of temperate region. Several types of plums are cultivated in the world, but the climatic conditions of India favour the cultivation of Japanese plum (*Prunus salicina* Lindell) because it is hardy in nature and thrives well under adverse edaphic and climatic conditions. In India, Japanese plum variety Santa Rosa dominates because of its self-fruitfulness, prolific bearing habit and characteristic flavour (Chattopadhyay, 4). Plums harvested at climacteric stage usually attain attractive peel colour and have better flavour than those harvested at pre-climacteric stage. Thus, stage of maturity at which plums are harvested, may also have significant influence on colour, texture, fruit softening, enzyme activity and postharvest quality attributes. Further, the perishable nature of ripe plum fruit poses a serious problem for its storage, transport and marketing (Chattopadhyay, 4).

After ripening, plum has a limited shelf-life of about 3-4 days only. Although under cold storage conditions, it can be stored for about 18-20 days. In India, plums are usually produced in far-flung areas located in terrains and at high altitudes, and then transported to plains for marketing. Its shelf-life is further reduced drastically due to rough handling and poor storage conditions.

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Among different post-harvest management strategies of fresh fruits, 1-methylcyclopropene (1-MCP) has been reported to be very useful (Watkins, 19). 1-MCP, blocks the ethylene receptors, and thus prevents ethylene-dependent responses in several fruits (Watkins, 19). 1-MCP has been commercialized as SmartFresh® and registered for its commercial use in a wide range of crops in several countries of the world (Watkins, 19). 1-MCP has been reported to improve the shelf- and storage-life of different plum cultivars (Dong *et al*., 5; Menniti *et al*., 12). Hence, the studies have been conducted to observe the effect of 1-MCP on losses and quality of plums during wholesale marketing.

MATERIALS AND METHODS

The studies were conducted in the Division of Post Harvest Technology, IARI, New Delhi in 2010. The plums of Santa Rosa variety were harvested at two stages, *i.e*., climacteric (ready-to-eat) and pre-climacteric (ready-to-ripe) in the month of June from a private orchard at Katrain, Kullu (Himachal Pradesh), and were subjected to 1-MCP treatments (control, 1- MCP @ 0.5 µl l^{-1}, 1-MCP @ 1.0 µl l^{-1}, 1-MCP @ 1.5 µl l^{-1}, Celfresh® tablet) for 24 h at 20°C at IARI Regional Station, Katrain (HP), and after packaging in CFB boxes (5 kg capacity), they were transported to Delhi by road. Initial observations were taken at Katrain, HP, and to observe the effect of transportation

on these parameters, observations on compression injury, weight loss, fruit firmness, respiration rate, ethylene evolution rate, antioxidant capacity, TSS, acidity, and ascorbic acid contents were recorded after transporting them to Delhi.

Compression injury was recorded by counting the fruits damaged by pressure during transportation, and represented as percentage. PLW was determined by subtracting the final fruit weight from the initial weight and represented as percentage. Fruit firmness was determined by using a texture analyzer (Model: TA+Di, Stable microsystems, UK) using compression test and represented as N (Newton). Respiration was measured by using auto gas analyzer (Model: Checkmate 9900 O_2/CO_2, PBI DanSensor, Denmark) and expressed as ml CO_2 kg^{-1} h^{-1}. Ethylene evolution rate was determined by Hewlett Packard (H.P.) gas chromatograph (Model 5890 Series II) equipped with a flame ionization detector (FID), Porapack-N 80/100 mesh packed stainless steel column and a integrator was used for determination of ethylene. The rate of ethylene evolution was expressed as µl kg^{-1} h^{-1}. Antioxidant capacity was determined by following CUPRAC method (Apak *et al.*,1) and expressed as µmol Trolox g^{-1}. Total soluble solids of samples were estimated using Fisher's hand refractometer (0-50) and expressed as degree Brix (°B) at 20°C. Titratable acidity was determined by titrating a known amount of fruit sample against 0.1 N NaOH using a few drops of 1% phenolphthalein solution as indicator, and expressed as percentage (Ranganna,15). Ascorbic acid content was determined as per method of AOAC (2) and represented as mg of ascorbic acid per 100 g fruit pulp.

The experiments were laid out in factorial CRD design with each treatment consisting of 60 fruits with five replications. The data obtained from the experiments were analysed as per design and the results were compared from ANOVA (Panse and Sukhatme, 13).

RESULTS AND DISCUSSION

1-MCP treatments and stage of harvest have significantly influenced the compression injury in Santa Rosa plums during transportation, being lower in pre-climacteric stage of maturity (2.3%) than climacteric stage (8.7%) (Fig.1). In general, the compression injury was significantly higher (17.0%) in untreated (control) plums than those treated with various concentrations of 1-MCP. Interestingly, the compression injury in the plums of both the stages of maturity was nil when treated with1-MCP (1.5 µll^{-1}) and Celfresh® tablet (Fig. 1). The interaction, stage × treatment was also significant. Higher compression injury in plums of climacteric stage than that of pre-climacteric stage may be due to fact that plums of climacteric stage were fully mature and ripen, were soft enough to be crushed with a simple jerk and thus they had higher injury than those of pre-climacteric stage. Similarly, higher compression injury in untreated plums may be ascribed to lower firmness of such fruits in comparison to those treated with 1-MCP. 1-MCP (Celfresh®) treated plums must have lowest level of softening, respiration and ethylene evolution rates, thus have lowest (0.0%) compression injury during transportation.

The maturity stage has significant influence on physiological loss in weight in Santa Rosa plums during transportation, being significantly higher in climacteric stage (0.43%) than those harvested at pre-climacteric stage (0.25%). Treatments have also significantly influenced the physiological loss in weight, being significantly higher in untreated plums (0.55%) than those treated with 1-MCP (0.5, 1.0, 1.5 µl l^{-1} and Celfresh® tablet) (Fig. 2). Among different treatments, 1-MCP (1.5 µll^{-1}) and Celfresh® tablet were equally effective in reducing the physiological loss in weight during transportation. The interaction, stage × treatment was also significant. Higher PLW in plums of climacteric stage than that of pre-climacteric stage may primarily be due to higher respiration or transpiration rate. The significant effect of 1-MCP on PLW reduction may be attributed to its effect on reduction in respiration and transpiration rate. These findings are contradictory to the findings of Porat *et al*. (14) who reported that 1-MCP did not affect weight loss in oranges, but supportive to the findings of Jeong *et al*. (8), Bassetto *et al*. (3), and Jhalegar *et al*. (7), who reported delay in weight loss in 1-MCP treated avocado, guava, and kiwifruit,

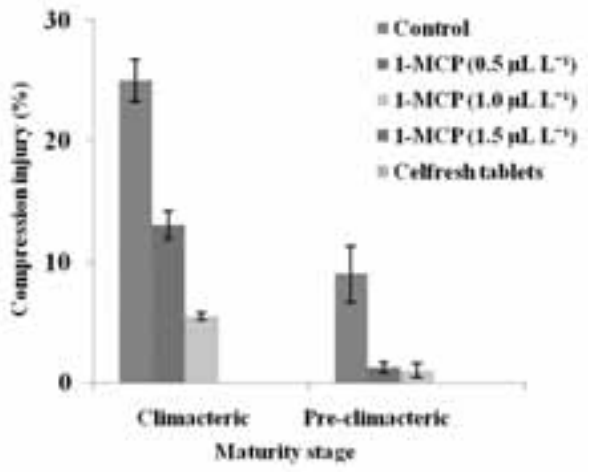

Fig. 1. Effect of 1-MCP on compression injury in Santa Rosa plum during transportation.

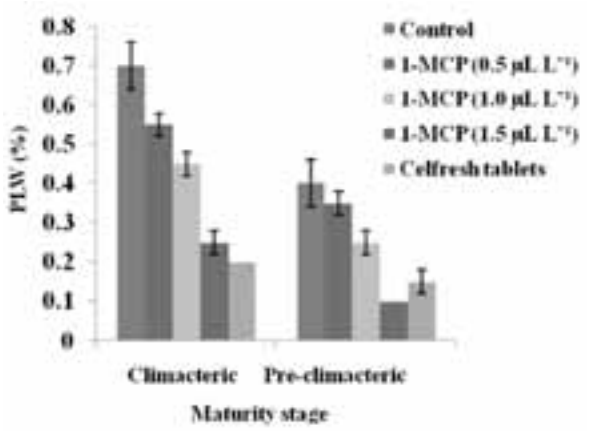

Fig. 2. Effect of 1-MCP on physiological in weight (%) in Santa Rosa plum during transportation.

respectively. Further, significant effect of Celfresh® tablet on reducing the PLW might be due to significant effect on reduction in respiration and transpiration rate of plums during transportation

Fruit firmness of Santa Rosa plums during transportation was significantly influenced by treatment and stage of maturity at which plums were harvested. Fruit firmness was significantly lower in plums harvested at climacteric stage of maturity (18.8 N) than those harvested at pre-climacteric stage of maturity (26.4 N) (Table 1). In general, the fruit firmness was significantly lower (21.8 N) in untreated (control) plums than those treated with 1-MCP (0.5, 1.0, 1.5 µl l^{-1} and Celfresh® tablet). Among different treatments, the fruit firmness was highest (23.4 N) in plums treated with Celfresh® tablets and lowest in untreated plums (Table 1). The interaction, stage x treatment was also significant. Lower firmness of climacteric stage of plums than pre-climacteric stage may probably be because of the fact that plums of this maturity group had ripened and were more prone to softening than plums of pre-climacteric stage. Further, better firmness of 1-MCP treated plums may be ascribed to lower moisture loss, less softening and melting of such fruits. 1-MCP is known to delay senescence by blocking the evolution of ethylene, thereby, it inhibits fruit softening (Schotsmans *et al*., 16). Thus, due to lesser softening, in 1-MCP or Celfresh® treated plums had better firmness than untreated ones.

Respiration rate of the plums was significantly influenced by the stage of maturity at which fruits were harvested and by the various treatments of 1-MCP (0.5, 1.0, 1.5 µl l^{-1} and Celfresh® tablet). The untreated plums have the higher respiration rate (3.0 ml CO_2 kg^{-1} h^{-1}) than those which were treated with different concentrations of 1-MCP (Table 1). Further, the maturity stage at which fruits were has significant effect on respiration rate, being higher in plums harvested at climacteric stage (2.4 ml CO_2 kg^{-1} h^{-1}) than those harvested at pre-climacteric stage (1.2 ml CO_2 kg^{-1} h^{-1}) (Table 1). Respiration rate was significantly higher in untreated plums (3.0 ml CO_2 kg^{-1} h^{-1}) (%) which was significantly lower in all the treatments of 1-MCP with no significant difference among the treatments (Table 1). Higher respiration rate in plums of climacteric maturity than that of pre-climacteric maturity may probably be because these plums might have acquired climacteric peak earlier than plums of pre-climacteric stage due to higher metabolic activities. Further, suppression of respiration rate by 1-MCP in Santa Rosa plums could be due to its effect through non-sensitization of fruit tissue to ethylene. Thus, our results are in accordance with the findings of Dong *et al*. (5), and Trinchero *et al*. (18) who reported a significant reduction or delay in respiration rate in 1-MCP treated plums and pears, respectively. Further, the significant effect of interaction, stage × treatment on respiration rate might be due the synergistic influence of 1-MCP in combination with maturity stage of plums

The maturity stage at which plums were harvested has significant effect on ethylene evolution rate, which being higher in plums harvested at climacteric stage (25.1 µl kg^{-1} h^{-1}) than those harvested at pre-climacteric stage (17.3 µl kg^{-1} h^{-1}). Ethylene evolution rate was significantly higher in untreated plums (28.5 µl kg^{-1} h^{-1}), which was significantly lower (14.0 µl kg^{-1} h^{-1}) in plums treated with Celfresh® tablets (Table 1). Higher ethylene evolution rate in plums of climacteric stage of maturity than that of pre-climacteric stage may be attributed to higher senescent nature of plums of this maturity group. The untreated plums have significantly higher ethylene evolution rate than treated ones, being least in Celfresh® treated plums, primarily because 1-MCP might have delayed the senescence in such plums (Watkins, 19). Khan and Singh (9, 10), and Luo *et al.* (11) have also reported that 1-MCP treated fruits of Tegan Blue and Qingnai plums, respectively have lesser rate of ethylene evolution than untreated fruits. Further, the synergistic effect of maturity stage and 1-MCP might have brought significant effect on the reduction in ethylene evolution during transportation.

Whatever was the treatment, antioxidants capacity (AOX) was significantly higher in plums harvested at climacteric stage of maturity (18.90 µmol Trolox g^{-1}) than those harvested at pre-climacteric stage of maturity capacity (16.98 µmol Trolox g^{-1}) (Table 2). The untreated plums have significantly lower antioxidants (16.85 µmol Trolox g^{-1}) than those treated with various concentrations of 1-MCP (0.5, 1.0, 1.5 µl l^{-1} and Celfresh® tablet). Among different treatments, the antioxidants capacity was the highest in plums,

Table 1. Effect of stage of maturity and 1-MCP on fruit firmness, respiration and ethylene evolution rate in Santa Rosa plum during transportation.

Treatment	Fruit firmness (N)			Respiration rate (ml CO_2 kg^{-1} h^{-1})			Ethylene evolution rate (µl kg^{-1} h^{-1})		
	Climacteric	Pre-climacteric	Mean	Climacteric	Pre-climacteric	Mean	Climacteric	Pre-climacteric	Mean
Control	18.5	25.2	21.8	4.0	2.0	3.0	32.0	24.9	28.5
1-MCP (0.5 µl l^{-1})	18.0	25.9	22.0	2.0	1.0	1.5	28.7	21.2	25.0
1-MCP (1.0 µl l^{-1})	18.6	26.4	22.5	2.0	1.0	1.5	24.2	17.5	20.9
1-MCP (1.5 µl l^{-1})	19.3	27.0	23.2	2.0	1.0	1.5	21.6	14.2	17.9
Celfresh® tablet	19.5	27.4	23.4	2.0	1.0	1.5	19.2	8.9	14.0
Mean	18.8	26.4	-	2.4	1.2	-	25.1	17.3	-
CD (P = 0.0.5)	Stage = 0.23, Treatment = 0.37, S × T = 0.52			Stage = 0.6, Treatment = 1.0 , S × T = 0.2			Stage = 0.68, Treatment =1.08, S × T = 1.53		

Table 2. Effect of stage of maturity and 1-MCP on antioxidant capacity and fruit quality parameters in Santa Rosa plum during transportation.

Treatment	Antioxidant capacity (µmol Trolox g^{-1})			Total soluble solids (ºBrix)			Titratable acidity (%)			Ascorbic acid (mg/100 g pulp)		
	Climacteric	Pre-climacteric	Mean	Climacteric	Pre-climacteric	Mean	Climacteric	Pre-climacteric	Mean	Climacteric	Pre-climacteric	Mean
Control	17.8	15.9	16.8	13.5	10.5	12.0	2.06	2.32	2.19	3.20	3.10	3.15
1-MCP (0.5 µl l^{-1})	18.1	16.5	17.3	13.5	10.5	12.0	2.08	2.32	2.20	3.27	3.17	3.22
1-MCP (1.0 µl l^{-1})	19.2	17.0	18.1	13.3	10.2	11.7	2.08	2.39	2.24	3.30	3.20	3.25
1-MCP (1.5 µl l^{-1})	19.6	17.5	18.5	13.3	10.0	11.6	2.09	2.39	2.24	3.30	3.23	3.27
Celfresh® tablet	19.8	18.0	18.9	13.5	10.0	11.3	2.11	2.40	2.25	3.30	3.25	3.28
Mean	18.9	16.9	-	13.2	10.2	-	2.08	2.36	-	3.37	3.19	-
CD (P = 0.05)	Stage = 0.27, Treatment = 0.43, S × T = NS			Stage = 0.40 , Treatment = NS, S × T = NS			Stage = 0.03 , Treatment = 0.04 , S × T = NS			Stage = 0.037, Treatment = 0.058 , S × T = NS		

which were treated with Celfresh® tablets (18.90 µmol Trolox g^{-1}), non-significantly followed by those treated with 1-MCP (1.5 µl l^{-1}). Higher AOX capacity in plums of climacteric stage than pre-climacteric stage might be due to accumulation of higher amount of phenolics, vitamin C and other compounds in climacteric stage of plums, which are usually responsible for higher AOX activity. The same reason could be ascribed to untreated plums as well. Thus, our results got the chord from the findings of Khan and Singh (9), and Hoang *et al*. (6) who reported that 1-MCP delayed decrease in antioxidants capacity in Tegan Blue plums and Cripps Pink apples, respectively. Further, the synergistic effect of stage of maturity and 1-MCP might have significantly influenced antioxidant capacity in Santa Rosa plums during transportation.

Only the maturity stage at which plums were harvested has significant effect on the TSS in Santa Rosa plums during transportation. While both the treatment and the interaction, stage x treatment was not significant (Table 2). TSS was significantly higher in plums harvested at climacteric stage (13.2°B) than those harvested at pre-climacteric stage of maturity (10.2°B) (Table 2). Higher TSS in plums of climacteric stage than pre-climacteric stage could be related to the hydrolysis of starch in to simple sugars in these plums than that of pre-climacteric stage. Wills *et al*. (20) have also reported that starch gets hydrolysed into mono and disaccharides, which are responsible for increased TSS in fruits.

The maturity stage, and 1-MCP treatment has individually significantly influenced titratable acidity in Santa Rosa plums during transportation (Table 2). The untreated plums have significantly lower titratable acidity (2.19%) than those which were treated with 1-MCP (0.5, 1.0, 1.5 µl l^{-1} and Celfresh® tablet) (Table 2). Further, the maturity stage at which fruits were harvested has significant effect on titratable acidity, being higher in plums harvested at pre-climacteric stage (2.36%) than those harvested at climacteric stage (2.08%). Among treatments, Celfresh® tablets maintained significantly higher levels of titratable acidity in plums (2.25%) than other concentrations of 1-MCP or control. Higher acidity in plums of pre-climacteric stage may be due to the fact that they were not ripened, might have higher concentrations of citric acid in them, which might have contributed to higher acidity. Similarly, 1-MCP treated fruits had higher acidity than untreated fruits. As per the available literature, the effects of 1-MCP on TA are mixed, with some commodities being affected and some not. Hence, our results are in accordance with the studies of Selvarajah *et al*. (17) who reported lower titratable acidity loss in 1-MCP treated fruits in pineapples. Similarly, TA loss was significantly delayed or maintained by 1-MCP in plums (Dong *et al*., 5), and kiwifruits (Jhalegar *et al*., 7). The interaction effect of stage x treatment was however, non-significant.

The stage of maturity and treatments have individually affected the ascorbic acid content in Santa Rosa plum significantly during transportation, but the interaction, stage × treatment could not (Table 2). Ascorbic acid content was significantly higher in plums harvested at climacteric stage of maturity (3.37 mg/100 g pulp) than those harvested at pre-climacteric stage of maturity (3.19 mg/100 g pulp) (Table 2). The untreated plums have significantly lower content of ascorbic acid (3.15 mg/100 g pulp) than those treated with various concentrations of 1-MCP (0.5, 1.0, 1.5 µl l^{-1} and Celfresh® tablet), the highest being in Celfresh® treated plums (3.28 mg/100 g pulp), however, treatments amongst themselves were non-significant (Table 2). The higher retention of ascorbic acid in climacteric stage of maturity may be ascribed to efficient accumulation of ascorbic acid due to higher and better metabolic activities of such fruits. Similarly, accumulation of higher ascorbic acid in 1-MCP treated fruits could be attributed to the ripening retarding effect of 1-MCP and slower rate of biological activities during transportation. The role of 1-MCP and unaturity stage in delaying the loss of ascorbic acid has been well documented by Selvarajah *et al.* (17) in pineapples and by Khan and Singh (9) in plum. Further, the interaction, stage × treatment was significant, thereby indicating the synergistic influence on ascorbic acid content during transportation.

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