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Studies on response of 1-methylcyclopropene treatment on ripening mechanism, quality preservation and shelf life extension in plum fruits (*Prunus sp.)* under multiple temperature regimes

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ABSTRACT: *The prime objectives of study was to assess the impact of 1-MCP on ripening changes (physical, physiological and biochemical) in plum fruits during storage at different storage temperatures (2°C and 20°C). European plum (cv. Hauszwetschge) fruits were treated with 0.5 µll^{-1} (500 ppb) 1-MCP and 100 ppm ethylene, alone or in combination (i.e. 1-MCP+ethylene) at 2°C for 24 h. After every 15 days interval (i.e. 15, 30, 45, 60 days at 2°C) fruits were transferred to 20°C for 6 days. At both the storage temperatures, 1-MCP treated European plum fruits exhibited lower physiological loss in weight, retained better firmness and higher L values (brightness), b* values (blue-yellow axis), showed minimum change in total soluble solids, and sugars as compared to other treatments and untreated fruits. Fruits lost nearly 16% of their physiological weight during 56 days of storage at 2°C and more than 30% of their weight by end of storage period of 60 days at 2°C plus 6 days at 20°C. PPO enzyme activity was lowest (3.01 units g^{-1} min^{-1}) in 1-MCP treated fruits. Fruits treated with 1-MCP have lowest carbon dioxide (3.14±0.98 ml kg^{-1} h^{-1}) and ethylene (17.59 µl kg^{-1} h^{-1}) production rates as compared to other treatments. The study has shown that 1-MCP has the potential to control the ripening of plum fruit and extending the storage period by more than 15 days at 2°C.*

INTRODUCTION

Plum is an important stone fruit of temperate zone and belongs to family Rosaceae. It ranks next in importance to the peaches so far as its economic importance is concerned. Plum is a rich source of sugars, carotene and dietary fiber. The fruit is used mainly for table purpose and to small extent for drying purpose. The plums are also used commercially for preparing jam, chutney and drinks. In European countries, plum cake is very popular. 1-methylcyclopropene (1-MCP) is a volatile unsaturated cyclic hydrocarbon which irreversibly binds to ethylene receptor sites and prevents the adverse effects of ethylene. 1-MCP has been effectively utilized to arrest the ethylene production, reduce respiration rate and delaying the softening in fruits like apple, banana, avocado, apricots and peach. In case of plums, 1-MCP has been reported to cause significant delay in respiration rate, ethylene production and losses of firmness but information on complete quality assessment is lacking. The present investigation was undertaken to provide a comprehensive coverage on enhancing shelf life and quality of plums by using 1-MCP can be grouped as under multiple temperature regime at 2°C followed by storage at 20°C

MATERIAL AND METHODS

Fresh European plum fruits were procured from Klien Alterndorf research station and were subjected to treatments of 1-MCP (500ppb), Ethylene (100 ppm), 1MCP+Ethylene and control for 24 hours at 2°C at 85% RH. Later, after treatments, fruits were transferred to cold storage (2°C at 85% RH). Ten fruits in a glass jar (1.75 liters) were enclosed for analysis of gas samples. Each set was replicated four times per treatment. Oxygen consumption was assessed using

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Paramagnetic oxygen analyzer (Type: OA-55, Servomex Ltd., U.K.). For analysis of carbon dioxide production gas chromatograph (GC-Type : Intersmat) equipped with 80 mesh Porapak 'Q' column and thermal conductivity detector was used. Ethylene evolution was estimated by gas chromatograph (GC Type-Carlo-erba 6000 Vega series) with 80 mesh Porapak 'Q' column and FID detector. Weight loss was expressed as the per cent loss in weight. Total soluble solids (%) in fruit juice were determined by using Zeiss-Optron-Abbe's refractometer. Total sugars were estimated using freez dried samples analyzed by HPLC (Kontron Autosampler HPLC-360, 515 HPLC pump) with a carbohydrate Ca^{2+} 40 x 8mm refill pre-coloumn (Art. No. 52998130, CS-Chromatographic Service, GmbH). Fruit firmness asured using intact unpeeled plums and 2 mm diameter plunger with a Bareiss penetrometer (Durofel S.A., France) giving Shore fruit firmness. Colour was measured at two positions on mesocarp of each half by Minolta Spectrophotometer CM-503i (Minolta GmbH, Ahrensburg, Germany) and was expressed as L* (black-white axis), a* (green-red axis) and b* (yellow – blue axis). The enzyme was assayed using slight modifications of method described by Siddiq *et al*. (1992).

RESULTS AND DISCUSSION

Physiological loss in weight (at dual temperature regime)

Effect of dual temperature regime on plum fruits treated with 1-MCP and ethylene, alone or in combination has been presented in Table 1. During storage at 2ºC (X+0, where 'X' = 15, 30, 45, 60 days), plum fruits under different postharvest treatments along with control showed a progressive physiological loss in weight but no significant differences within treatments or as compared to control observed. When fruits were transferred to 20ºC, rapid increase in PLW was observed. After 6 days at 20ºC, significantly lower PLW as compared to other treatments was observed in 1-MCP treated fruits (12.83±0.53%). After 60 days of storage, fruits at 2ºC lost weight between 16-17.5%, highest in 1-MCP + ethylene treated fruits (17.39±1.56%). Overall picture of data shows that effect of storage temperature was quite evident on PLW of fruits. Plum fruits stored at 2ºC lost approximately 16% weight after 60 days of storage whereas same level was achieved within 30 days of cold storage plums 6 days at 20ºC. High weight loss in fruits treated with ethylene, 1-MCP + ethylene and control fruits could be attributed to high rate of respiration resulting in rapid utilization of respiratory substrates coupled with evapo-transpiration losses. In 1-MCP + ethylene treated fruits despite 1-MCP application, high weight loss were observed. It was probably due to reason that effect of 1-MCP was partially counteracted by exogenous ethylene application and fruits over came the inhibition of 1-MCP by regenerating new receptor site for action of ethylene. Results are supported by findings of Golding *et al*. 1998 and Jiang *et al*. 1999.

Fruit firmness

Fresh fruits showed initial shore firmness value 65.98±1.17. Decrease in firmness of fruits was observed with increase in storage period irrespective of treatments (Table 2). After 15 days of cold storage at 2ºC, decrease in fruit firmness was observed in all treatments including control. Despite decrease, highest firmness value was recorded from 1-MCP treated fruits (47.63±1.44) which was statistically at par with control fruits (45.35±1.61). Lowest firmness (39.28±1.47) was in ethylene treated fruits which was significantly lower than all other treatments. After 60 days of storage at 2ºC, 1-MCP + ethylene treated fruits had highest firmness value (25.38±1.08), statistically being at par with 1-MCP treated and control fruits (24.35±1.38, 23.68±0.56 respectively). Fruits treated with ethylene had lowest firmness value (18.98±1.24). After 60 days of storage at 2ºC plus 6 days shelf life at 20ºC, 1-MCP treated fruits retained higher firmness (14.88±0.81) followed by 1-MCP + ethylene treatment, both being statistically at par but significantly higher than ethylene treated and control fruits. Results are in conformity with finding of Pesis *et al*. (2002) and Argenta *et al*. (2003).

Total soluble solids

Total soluble solid content (Table 3) of fruits was 14.68±0.28% in beginning, irrespective of treatments. 1-MCP treatment was found effective in retention of TSS in plum fruits at 2ºC and 20ºC. Although increase in TSS was observed but slow and gradual rise in TSS might be due to delay in ripening and senescence suggesting a direct correlation between reduced respiration rate, sugar metabolism and blocked action of ethylene receptors (Martierez-Romero *et al.* 2003).

Total Sugars

European plum fruits contained 8.079±0.230% total sugars in beginning (Table 4). On 60th day of cold storage, control fruits showed significantly higher

Table 1
Effect of postharvest treatments on the physiological loss in weight (%) of European plum stored at dual temperature regime

Treatments	*Days in storage*											
	Day 15			*Day 30*			*Day 45*			*Day 60*		
	X+0	*X+3*	*X+6*	*X+0*	*X+3*	*X+6*	*X+0*	*X+3*	*X+6*	*X+0*	*X+3*	*X+6*
1-MCP (500 ppb)	2.39 ±0.13	7.38 ±0.42	12.83 ±0.53	4.81 ±0.28	11.33 ±0.27	17.49 ±0.55	12.30 ±1.28	21.03 ±0.21	29.62 ±0.14	16.10 ±0.8	25.63 ±0.52	35.02 ±0.55
Ethylene (100 ppm)	2.41 ±0.18	8.06 ±0.31	14.12 ±0.46	4.96 ±0.32	11.92 ±0.20	18.53 ±0.48	12.76 ±0.44	21.80 ±0.67	31.66 ±0.82	16.96 ±0.49	28.30 ±0.63	39.77 ±0.61
1-MCP (500 ppb)+ Ethylene (100 ppm)	3.30 ±0.22	8.40 ±0.35	14.20 ±0.57	4.98 ±0.22	11.81 ±0.19	18.83 ±0.32	13.02 ±1.72	22.25 ±0.55	30.96 ±0.54	17.39 ±1.56	28.24 ±0.57	38.41 ±0.95
Control	2.88 ±1.16	8.50 ±0.17	14.16 ±0.55	4.61 ±0.25	12.05 ±0.67	18.95 ±0.61	12.14 ±1.49	22.19 ±0.27	31.70 ±0.83	17.09 ±1.36	27.90 ±0.42	39.63 ±0.83
CD at 5%	**NS**	**0.51**	**0.82**	**NS**	**0.60**	**0.78**	**NS**	**0.73**	**1.01**	**NS**	**0.84**	**1.17**

Data are mean ± standard deviation.

Where, 'X' = 15, 30, 45, 60 days of cold storage at 2ºC

X+0 = Initial (2ºC)

X+3 = X days at cold storage + 3 days at 20ºC

X+6 = X days at cold storage + 6 days at 20ºC

Table 2
Effect of postharvest treatments on the Firmness (Shore vale) of European plum stored under dual temperature regime

Treatments	*Initial firmness (Day 0)*	*Days in storage*											
		Day 15			*Day 30*			*Day 45*			*Day 60*		
		2ºC	*X+3*	*X+6*	*2ºC*	*X+3*	*X+6*	*2ºC*	*X+3*	*X+6*	*2ºC*	*X+3*	*X+6*
1-MCP (500 ppb)	65.98± 1.17	47.63± 1.44	31.48± 0.54	23.78± 0.74	40.53± 1.44	22.68± 0.90	16.73± 0.50	27.20± 1.61	19.40± 0.81	14.83± 1.04	24.35± 1.38	18.53± 0.58	14.88± 0.81
Ethylene (100 ppm)	65.98± 1.17	39.28± 1.47	29.80± 1.06	24.03± 1.49	35.68± 1.07	20.55± 0.47	15.10± 0.83	22.25± 1.18	13.43± 0.15	10.74± 0.65	18.98± 1.24	15.15 1.51	11.73± 0.93
1-MCP (500 ppb) + Ethylene (100 ppm)	65.98± 1.17	43.95± 1.54	31.78± 1.42	25.40± 1.24	36.73± 1.94	23.33± 1.16	15.73± 0.64	24.50± 1.39	16.28± 0.25	12.40± 1.19	25.38± 1.08	19.83± 1.69	14.25± 1.43
Control	65.98± 1.17	45.35± 1.61	28.80± 1.97	22.93± 1.95	36.50± 0.78	19.45± 1.21	13.08± 0.57	22.63± 0.59	17.00± 0.62	12.15± 1.70	23.68± 0.56	15.70± 1.54	11.38± 0.53
CD at 5%	**NS**	**2.63**	**2.10**	**NS**	**2.14**	**1.52**	**1.00**	**1.95**	**0.83**	**1.38**	**1.72**	**2.18**	**1.78**

NS- non significant

Data are mean ± standard deviation.

(Where, 'X' = 15, 30, 45, 60 days of cold storage at 2ºC, respectively

X+3 = X days at cold storage + 3 days at 20ºC

X+6 = X days at cold storage + 6 days at 20ºC

Table 3
Effect of postharvest treatments on the total soluble solids (%) of European plum stored under dual temperature regime

Treatments	*Initial TSS (%) (Days 0)*	*Days in storage*							
		Day 15		*Day 30*		*Day 45*		*Day 60*	
		2ºC	*X+6*	*2ºC*	*X+6*	*2ºC*	*X+6*	*2ºC*	*X+6*
1-MCP (500 ppb)	14.68 ±0.28	14.78 ±0.33	17.20 ±0.56	15.28 ±0.28	17.48 ±0.29	15.43 ±0.13	16.88 ±0.15	15.55 ±0.13	19.25 ±0.31
Ethylene (100 ppm)	14.68 ±0.28	15.38 ±0.34	17.03 ±0.10	15.60 ±0.48	17.13 ±0.30	15.83 ±0.15	18.65 ±0.24	15.75 ±0.47	20.28 ±0.21
1-MCP (500 ppb) + Ethylene (100 ppm)	14.68 ±0.28	14.75 ±0.24	16.90 ±0.45	15.25 ±0.29	17.68 ±0.53	15.88 ±0.74	17.73 ±0.68	15.33 ±0.47	18.98 ±0.39
Control	14.68 ±0.28	15.13 ±0.36	18.03 ±0.05	16.03 ±0.42	17.60 ±0.62	16.50 ±0.23	18.48 ±0.33	16.23 ±0.35	19.70 ±0.14
CD at 5%	NS	0.50	0.56	0.58	NS	0.62	0.63	NS	0.43

NS : Non significant
Data are mean ± standard deviation.
Where, 'X' = 15, 30, 45, 60 days of cold storage at 2ºC
X+6 = X days at cold storage + 6 days at 20ºC

total sugars (9.097±0.186%) as compared to all other treatments, minimum in 1-MCP treated fruits (8.377±0.180%). Total sugars concentration in fruits treated with 1-MCP, ethylene and 1-MCP + ethylene was statistically at par. Similar trend was observed when some fruits were transferred to 20ºC for 6 days after 60 days of cold storage, highest total sugars in control fruits (9.987±0.090%) and lowest in 1-MCP treated fruits (9.613±0.126%). Minimum change in total sugar contents in 1-MCP treated fruits could be attributed to inhibitory effect of 1-MCP in delaying ripening and senescence suggesting a direct correlation between reduced respiration rate, carbohydrate metabolism and blocked action of ethylene receptors (Martinez-Romero *et al.*, 2003). Results are in conformity with findings of Salvador *et al.* (2003) in plums and Selvarajah *et al.* (2001) in pineapples.

Colour

L* values of fruit flesh revealed that there was a gradual decrease in brightness of fruit flesh during the course of storage period (Table 5). Fruit treated with 1-MCP retained significantly higher mean L* values (26.55±4.27) as compared to untreated control fruits (24.21±3.27). However after 9 weeks of cold storage, fruits treated with 1-MCP retained higher a* value (2.51±0.65) as compared to control (2.25±0.28), differences were statistically non significant. 1-MCP treated fruits retained significantly higher b* value (6.47± 3.01) as compared to control fruits (5.09±2.89) indicating better retention of golden yellow flesh

Table 4
Effect of postharvest treatments on the total sugars (%) of European plum stored under dual temperature regime

Treatments	*Initial total sugars (%) (Days 0)*	*Days in storage*							
		Day 15		*Day 30*		*Day 45*		*Day 60*	
		2ºC	*X+6*	*2ºC*	*X+6*	*2ºC*	*X+6*	*2ºC*	*X+6*
1-MCP (500 ppb)	8.079±0.230	7.955±0.197	7.461±0.282	7.604±0.201	9.159±0.253	8.412±0.182	9.031±0.283	8.377±0.180	9.613±0.126
Ethylene (100 ppm)	8.079± 0.230	7.912± 0.194	8.394± 0.313	8.478± 0.233	9.101± 0.279	8.694± 0.178	9.397± 0.263	8.542± 0.354	9.918± 0.062
1-MCP (500 ppb)+ Ethylene (100 ppm)	8.079± 0.230	6.886± 0.172	8.236± 0.215	8.606± 0.186	8.850± 0.229	8.198± 0.192	9.055± 0.195	8.540± 0.097	9.775± 0.062
Control	8.079± 0.230	6.549± 0.259	7.912± 0.110	8.919± 0.173	8.843± 0.196	8.104± 0.289	9.346± 0.267	9.097± 0.186	9.987± 0.090
CD at 5%	**NS**	**0.324**	**0.379**	**0.311**	NS	**0.335**	**0.308**	**0.331**	**0.202**

NS : Non significant
Data are mean ± standard deviation.
Where, 'X' = 15, 30, 45, 60 days of cold storage at 2ºC, respectively
X+6 = X days at cold storage + 6 days at 20ºC

Table 5
The effect of 1-MCP treatment on the flesh colour change in European plum during storage at 2°C

Treatments		*Weeks in storage at 2°C*										
		0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Mean*
L	1-MCP (500 ppb)	32.92 ±2.01	31.06 ±2.27	29.72 ±2.48	29.77 ±2.77	28.90 ±2.66	25.98 ±2.31	22.75 ±2.26	23.18 ±1.81	22.61 ±0.85	18.63 ±0.67	**26.55 ±4.27**
	Control	32.92 ±2.01	28.41 ±2.36	26.30 ±2.55	25.94 ±2.31	22.54 ±2.16	21.95 ±2.67	22.41 ±1.00	22.75 ±1.51	21.92 ±1.31	16.97 ±1.32	**24.21 ±3.27**
	Mean	32.92 ±1.86	29.74 ±3.57	28.01 ±2.96	27.85 ±3.13	25.72 ±4.07	23.96 ±3.16	22.58 ±1.63	22.96 ±1.56	22.26 ±1.08	17.80 ±1.32	
a*	1-MCP (500 ppb)	2.67 ±0.72	2.65 ±0.58	2.93 ±0.70	2.64 ±0.32	2.10 ±0.34	2.39 ±1.03	2.53 ±0.95	2.70 ±0.31	2.66 ±0.24	2.51 ±0.65	**2.58 ±0.60**
	Control	2.67 ±0.72	2.20 ±0.57	2.51 ±0.29	2.49 ±0.29	2.05 ±0.58	2.86 ±1.11	2.59 ±0.75	2.58 ±0.58	2.56 ±0.20	2.25 ±0.28	**2.48 ±0.57**
	Mean	2.67 ±0.67	2.43 ±0.59	2.72 ±0.55	2.56 ±0.30	2.08 ±0.44	2.62 ±1.02	2.56 ±0.79	2.64 ±0.43	2.61 ±0.21	2.38 ±0.48	
b*	1-MCP (500 ppb)	9.08 ±0.40	10.02 ±0.94	9.30 ±0.73	9.18 ±0.70	7.94 ±0.72	6.64 ±0.75	4.36 ±0.75	3.40 ±0.62	2.46 ±0.54	2.30 ±0.81	**6.47 ±3.01**
	Control	9.08 ±0.40	8.47 ±0.75	8.53 ±0.47	6.77 ±0.89	4.75 ±1.05	3.43 ±0.43	2.97 ±0.83	2.24 ±1.40	1.60 ±1.20	4.06 ±0.59	**5.09 ±2.89**
	Mean	**9.08 ±0.37**	**9.24 ±1.14**	**8.91 ±0.70**	**7.97 ±1.49**	**6.35 ±1.90**	**5.04 ±1.81**	**3.17 ±1.47**	**2.82 ±0.18**	**2.03 ±0.97**	**3.18 ±1.15**	

(L*= black-white axis, a*= green-red axis, b* = blue-yellow axis)

CD at 5% (L)		CD at 5% (a*)		CD at 5% (b*)	
Treatment	: 0.92	Treatment	:NS	Treatment	: 0.35
Weeks	: 2.06	Weeks	:NS	Weeks	: 0.79
Treatment x weeks	: 2.91	Treatment x weeks	: NS	Treatment x weeks	: 1.11

colour. 1-MCP treated fruits retained significantly higher L* values and b* values indicating better retention of fruit flesh. The results are in conformity with findings of Argenta *et al*. (2003), Valero *et al*. (2003), and Martinez-Ramero *et al*. (2003) in plum fruits.

Polyphenol oxidase (PPO)

The data obtained on polyphenol oxidase activity has been present in Table 6. An increase in PPO activity was seen with increase in storage period. A significantly low PPO activity was measured in 1-MCP treated fruits (3.465 units g^{-1} min^{-1}) as compared to control fruits (4.383 units g^{-1} min^{-1}) up to 60th day of storage. Over all perception of data indicates that 1-MCP treatment retarded PPO activity (3.015 units g^{-1} min^{-1}) as compared to activity shown by untreated control fruits (3.557 units g^{-1} min^{-1}). The results are in conformity with findings of Shamam *et al*. (2003) in apples.

Table 6
The effect of 1-MCP treatment on activity of polyphenol oxidase enzymes in European plum stored at 2°C.

Treatments		*Days in storage at 2°C*					
		0	*15*	*30*	*45*	*60*	*Mean*
Polyphenol oxidase (PPO)	1-MCP (500 ppb)	2.425	2.755	3.145	3.285	3.465	**3.015**
	Control	2.425	3.353	3.784	4.023	4.383	**3.557**
	Mean	**2.425**	**3.054**	**3.465**	**3.654**	**3.924**	

CD at 5% (Polyphenol oxidase)
Treatment : 0.180
Days : 0.286
Treatment x Days : 0.404
1 unit of PPO = Change in absorbance by 1.0 due to oxidation of catechol

Respiration rate

The data representing respiratory behaviour of European plum treated with 1-MCP and ethylene, alone as well as combination and stored at 2°C has been presented in Table 7, Observations were recorded under two phases of storage duration. In one phase, observations were measured at 4 days interval upto 28th day of storage and afterwards at 7 days interval (upto 56th day of storage i.e. second phase). On overall mean basis rate of oxygen production in fruits treated with ethylene (4.80±1.98 ml kg^{-1} h^{-1}) was significantly higher from those treated with 1-MCP and 1-MCP + ethylene (3.74±1.38, 4.09±1.51, ml kg^{-1} h^{-1} respectively) but statistically at par with control fruits (4.70±0.79 ml kg^{-1} h^{-1}). Oxygen consumption rate in fruits treated with 1-MCP alone and 1-MCP + ethylene differed significantly; lower in 1-MCP treatment (3.74±1.38). The significantly lower rates of mean carbon dioxide production was observed in fruits treated with 1-MCP and 1-MCP + ethylene (3.14±0.98 and 3.15±0.96 ml kg^{-1} h^{-1} respectively) as compared to ethylene treated (3.55±1.08 ml kg^{-1} h^{-1}) and control fruits (3.65±1.07 kg^{-1} h^{-1}). Similar reports have been made on action of 1-MCP on reducing respiration rate in apples [2], pineapple [13], Pathak *et al*. [10] in banana and Salvador *et al*. [12] in plums. This also supports to climacteric pattern of ripening in European plum. Results are in conformity with earlier reports of Lippert and Blanke (2004) and Fuhrmann *et al*. (2002) in plum fruits.

Ethylene evolution

Data related to ethylene production (Table 8) by plum fruits treated with 1-MCP and ethylene in combination or alone during storage at 2°C shows that ethylene production (irrespective of treatments) gradually increased with increase in storage period. There were significant differences in treatments in rate of ethylene production from the initial day. Maximum amount of ethylene (23.33±2.02 µl $kg^{-1}h^{-1}$) was produced by control fruits followed by fruits treated with ethylene (20.86±2.18 µl $kg^{-1}h^{-1}$). A significantly high peak in ethylene production (68.90±3.42 µl $kg^{-1}h^{-1}$) was recorded on 20th day of storage in fruits treated with ethylene. Fruits treated with 1-MCP did not exhibit any peak in ethylene production through out of the storage period; however, a significant increase was observed upto 8th day of storage. Among various treatments applied lowest amount of ethylene (17.59 ?l kg^{-1} h^{-1}) was produced by 1-MCP treated fruits followed by 1-MCP + ethylene treated (23.22 µl kg^{-1} h^{-1}) and highest by ethylene treated fruits (32.42 ?l kg^{-1} h^{-1}) as compared to control fruits (28.69 µl $kg^{-1}h^{-1}$). The effect of 1-MCP on delaying the onset of

Table 7
Effect of postharvest treatments on the rate of oxygen consumption (ml kg^{-1} h^{-1}) and carbon dioxide production (ml kg^{-1} h^{-1}) of European plum stored at 2°C

Treatments		*Days in storage at 2°C*												
		0	*4*	*8*	*12*	*16*	*20*	*24*	*28*	*35*	*42*	*49*	*56*	*Mean*
Oxygen	1-MCP (500 ppb)	5.69± 0.74	6.35± 0.57	2.83± 0.48	2.64± 0.46	2.95± 0.43	5.17± 0.53	3.28± 0.93	2.64± 0.66	4.05± 0.52	3.57± 0.71	3.26± 0.30	2.42± 0.55	**3.74± 1.38**
	Ethylene (100 ppm)	6.62± 0.46	8.09± 0.59	3.80± 0.41	3.58± 0.58	4.32± 0.45	8.31± 0.51	4.80± 0.69	3.22± 0.87	5.18± 0.75	5.20± 0.58	3.01± 0.67	1.85± 0.49	**4.80± 1.98**
	1-MCP (500 ppb)+ Ethylene (100 ppm)	5.97± 0.48	7.05± 0.38	3.26± 0.49	3.06± 0.63	3.15± 0.64	5.67± 0.61	3.69± 0.74	3.27± 0.83	4.46± 0.53	4.16± 0.61	3.03± 0.69	2.32± 0.81	**4.09± 1.51**
	Control	6.36± 0.79	7.84± 0.50	3.75± 0.57	3.53± 0.45	4.79± 0.76	7.45± 0.63	3.90± 0.57	2.85± 0.79	5.31± 0.55	5.33± 0.82	3.12± 0.30	2.21± 0.50	**4.70± 0.79**
	Mean	6.06± 0.67	7.33± 0.85	3.41± 0.62	3.20± 0.64	3.80± 0.97	6.65± 1.41	3.92± 0.91	2.99± 0.81	4.75± 0.78	4.57± 1.00	3.10± 0.51	2.20± 0.62	
Carbon dioxide	1-MCP (500 ppb)	5.88± 0.52	2.49± 0.13	2.50± 0.21	2.33± 0.22	2.38± 0.23	2.71± 0.25	3.17± 0.42	2.65± 0.43	3.31± 0.30	3.34± 0.24	3.39± 0.40	3.02± 0.31	**3.14± 0.98**
	Ethylene (100 ppm)	5.50± 0.51	2.53± 0.21	2.59± 0.43	2.38± 0.14	2.35± 0.62	3.96± 0.34	4.22± 0.55	2.82± 0.56	4.16± 0.36	4.57± 0.64	3.82± 0.51	3.92± 0.45	**3.55± 1.08**
	1-MCP (500 ppb)+ Ethylene (100 ppm)	5.69± 0.40	2.43± 0.19	2.53± 0.44	2.49± 0.14	2.50± 0.44	2.77± 0.42	3.25± 0.29	2.53± 0.42	3.29± 0.46	3.44± 0.53	3.43± 0.15	2.99± 0.54	**3.15± 0.96**
	Control	5.93± 0.36	2.57± 0.12	2.65± 0.39	2.54± 0.14	2.62± 0.46	3.80± 0.41	4.01± 0.35	2.96± 0.62	4.45± 0.17	4.42± 0.56	3.92± 0.44	3.16± 0.41	**3.65± 1.07**
	Mean	**5.75± 0.47**	**2.50± 0.17**	**2.56± 0.37**	**2.43± 0.17**	**4.46± 0.46**	**3.31± 0.67**	**3.66± 0.61**	**2.27± 0.53**	**3.80± 0.61**	**3.94± 0.75**	**3.64± 0.45**	**3.02± 0.43**	

Data are mean ± standard deviation

CD at 5% (Oxygen)			CD at 5% (Carbon dioxide)		
Treatment	:	0.22	Treatment	:	0.12
Days	:	0.38	Days	:	0.21
Treatment x Days	:	0.77	Treatment x Days	:	0.41

Table 8
Effect of postharvest treatments on the rate of ethylene evolution (µl kg^{-1} h^{-1}) of European plum stored at 2°C

Treatments	*Days in storage at 2°C*												
	0	*4*	*8*	*12*	*16*	*20*	*24*	*28*	*35*	*42*	*49*	*56*	*Mean*
1-MCP (500 ppb)	9.55± 1.52	16.56± 3.34	21.83± 2.78	20.74± 2.39	22.90± 2.86	20.34± 3.50	21.13± 3.05	16.67± 1.20	20.64± 2.43	19.83± 2.68	14.97± 1.63	6.17± 2.52	**17.59**
Ethylene (100 ppm)	20.86± 2.18	26.25± 2.49	42.29± 3.24	42.01± 3.30	49.60± 2.60	68.90± 3.42	28.97± 3.30	22.62± 2.64	32.16± 2.05	28.74± 2.01	16.60± 3.62	10.08± 3.15	**32.42**
1-MCP (500 ppb)+ Ethylene (100 ppm)	11.96± 1.18	19.03± 2.48	24.13± 3.82	28.90± 2.60	39.82± 2.54	47.24± 2.62	23.88± 3.06	18.57± 2.31	20.78± 3.23	21.65± 2.83	14.03± 2.15	8.64± 2.69	**23.22**
Control	23.33± 2.02	28.84± 3.05	39.16± 2.51	32.24± 3.29	36.19± 2.36	44.87± 3.43	31.13± 3.01	22.06± 2.97	29.04± 2.44	31.60± 3.57	18.57± 2.06	7.18± 2.98	**28.69**
Mean	**16.43**	**22.67**	**31.85**	**30.97**	**31.13**	**45.34**	**26.28**	**19.98**	**25.66**	**25.46**	**16.04**	**8.02**	

Data are mean ± standard deviation

CD at 5%

Treatment	:	1.00
Days	:	1.90
Treatment x Days	:	3.81

ethylene production that occurs during climacteric repining was also observed in fruits like apricot (Fan *et al.* 2000) and avocado (Feng *et al.* 2000). This could be attributed to fact that 1-MCP binds irreversibly to existing ethylene receptors at time of treatment and blocks the ethylene production as mentioned by Sisler *et al.* (1996).

CONCLUSION

At both the storage temperatures, 1-MCP treated European plum fruits exhibited lower physiological loss in weight, retained better firmness and higher L values (brightness), b* values (blue-yellow axis), showed minimum change in total soluble solids, and sugars as compared to other treatments and untreated fruits. Fruits lost nearly 16% of their physiological weight during 56 days of storage at 2°C and more than 30% of their weight by end of storage period of 60 days at 2°C plus 6 days at 20°C. PPO enzyme activity was lowest (3.01 units g^{-1} min^{-1}) in 1-MCP treated fruits. Fruits treated with 1-MCP have lowest carbon dioxide (3.14±0.98 ml kg^{-1} h^{-1}) and ethylene (17.59 µl kg^{-1} h^{-1}) production rates as compared to other treatments. At both the storage temperatures, 1-MCP treated European plum fruits exhibited lower physiological loss in weight, retained better firmness and higher L values (brightness), b* values (blue-yellow axis), showed minimum change in total soluble solids, and sugars as compared to other treatments and untreated fruits. The results also confirm the climacteric ripening behaviour of European plum.

REFERENCES

Argenta, L.C., Krammes, J.G., Megguer, C.A., Amarante, C.V.T. and Mattheis, J. (2003), Ripening and quality of 'Laetitia' plums following harvest and cold storage as affected by inhibition of ethylene action. *Pesq. Agropec. Bras.* 38: 1139-1148.

Fan, X. and Mattheis, J.P. (2001), 1-Methylcyclopropene and storage temperature influence responses of 'Gala' apple fruit to gamma radiation. *Postharvest Biol. Technol.* 23: 143-151.

Fan, X., Argenta, L.C. and Mattheis, J.P. (2000), Inhibition of ethylene action by 1-methylcyclopropene prolongs storage life of apricots. *Postharvest Biol. Technol.* 20: 135.

Feng X.Q., Apelbaum, A., Sisler, E. C., and Goren, R. (2000), Control of ethylene responses in avocado fruit with 1-methylcyclopropene. *Postharvest Biol. Technol.* 20: 143-150.

Fuhrmann, N., Lippert, F. and Blanke, M. (2002), Einfluss der mechanischen Ernte und von '1-MCP' auf die lagerfahigkeit von Hauszwetschen. *Erwerbsobstbau.* 44: 161-166.

Golding, J.B., Shearer, D., Wyllie, S.G. and McGlasson, W.B. (1998), Application of 1-MCP and polypropylene to identify ethylene dependent ripening processes in mature banana fruit. *Postharvest Biol. Technol.* 14: 87-98.

Jiang, Y., Joyce, D.C. and Macnish, A.J. (1999), Extension of shelf life of banana fruit by 1-methylcyclopropene in combination with polyethylene bags. *Postharvest Biol. Technol.* 16: 187-193.

Lippert, F. and Blanke, M.M. (2004), Effect of mechanical harvest and timing of 1-MCP application on respiration and fruit quality of European plum (*Prunus domestica* L.). *Postharvest Biol. Technol.* 34: 305-311.

Martinez-Romero, D., Serrano, M., Guillen, F. and Valero, D. (2003), 1-Methylcyclopropene (1-MCP) increased storability in plum (*Prunus saliciana* Lindl. cv Golden Japan). *Acta Hort.* 599: 71-73.

Pathak, N., Asif, M.H., Dhawan, P., Srivastava, M.K. and Nath, P. (2003), Expression and activities of ethylene biosynthesis enzymes during ripening of banana fruits and effects of 1-MCP treatment. *Plant Growth Regul.* 40: 11-19.

Pesis, E., Ackerman, M., Ben-Arie, R., Feygenberg, O., Feng Xuqiao, Apelbaum, A., Goren, R., and Prusky, D. (2002), Ethylene involvement in chilling injury symptoms of avocado during cold storage. *Postharvest Biol. Technol.* 24: 171-178.

Salvador, A., Cuquerella, J. and Martinez-Javega, J.M. (2003), 1-MCP treatment prolongs postharvest life of 'Santa Rosa' plums. *J. Food Sci.* 68: 1504-1510.

Selvarajah, S., Bauchor, A.D. and John, P. (2001), Internal browning in cold stored pineapples is suppressed by post harvest application of 1-methylcyclopropene. *Postharvest Biol. Technol.* 23: 167-170.

Shamam, Z., Lers, A. and Lurie, S. (2003), Effect of heat or 1-methylcyclopropene on antioxidative enzyme activities and antioxidants in apples in relation to superficial scald development. *J. Amer. Soc. Hort. Sci.* 128: 761-766.

Sisler, E.C., Dupille, E. and Serek, M. (1996), Effect of 1-methylcyclopropene and methylcyclopropene on ethylene binding and ethylene action on cut Carnation. *Plant Growth Regul.* 18: 79-86.

Valero, D., Martinez-Romero, D., Valverde, J.M., Guillen, F. and Serrano, M. (2003), Quality improvement and extension of shelf life by 1-methylcyclopropene in plum as affected by ripening stage at harvest. *Innovative Food Science and Emerging Technologies.* 4: 339-348.