

**INFLUENCE OF 1-METHYLCYCLOPROPENE (1-MCP) ON
POST HARVEST PHYSIOLOGY AND PHYSICO- CHEMICAL
CHANGES IN ALPHONSO MANGO (*Mangifera indica* L.)**

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INTRODUCTION

Mango (*Mangifera indica* L.) undoubtedly is one of the oldest and choicest fruits in the tropics and is acclaimed as “King” of fruits. It is the third widely produced fruit crops after banana and citrus, and occupy relatively the same position in the tropics as the apple in Europe and North America due to its wide adaptability, high nutritive value, richness in variety, delicious taste, pleasant flavour and attractive appearance. It enjoys the unique popularity among the masses and classes throughout the tropics.

Mango is believed to be indigenous to the Indian sub-continent. It is under cultivation in India for more than 4000 years and hence conspicuous bonds have been formed between the fruit and cultural history and heritage of the country. “Botanically, the species *Mangifera indica* L. originated several thousand years ago in Eastern Himalayas in the India-Burma (Myanmar) border. In Sanskrit, one the earliest known languages tree is called “aamra” and the fruit is called aamra-phalam. In the neighboring plains of North India where Hindi is the spoken language, it is called “aam-phal”. The tree then migrated to the south of the Vindhyas where Tamil was the spoken language. Until Vasco da Gama landed in Calicut, a port town in the Malabar Coast of Kerala, the mango fruit was not known to Europeans. The Portuguese adopted the Malayalam word maanga (manga) in Portuguese. Then one of the Portuguese who landed in Calicut happened to write to his British friend that they have found a new fruit in India called manga. The British friend read the name as mango, since most of Portuguese words end in “o” and those found in the new world ended in “o” as in avocado, potato, tomato, tobacco, and so on. Thus the word “mango” entered the English vocabulary (Anon., 2012a).

The mango is the national fruit of India and is very popular throughout the length and breadth of the country. It is a rich source of vitamin A and C and is consumed raw or ripe. Good mango varieties contain 20 per cent of total soluble sugars. The acid content of ripe desert fruit varies from 0.2 to 0.5 per cent and protein content is about 1 per cent. Raw fruits of local varieties of mango trees are used for preparing various traditional products like raw slices in brine, amchur, pickle, muramba, chutney, panhe (sharabat) etc. The mango kernel also contains about 8-10 % good quality fat which can be used for saponification. The ripe fruit has fattening, diuretic and laxative properties. The tartaric acid, malic acid, and a trace of citric acid found in the fruit believed to help in maintaining the alkali reserve of the body. Extracts of leaves, bark, stem and unripe mangoes are believed to possess antibacterial properties against some micro-organisms.

This marvellous fruit is currently being grown in atleast 111 countries spreading over five continents with an area of 5.16 million ha with a total production of 39.98 million metric tons, with an average productivity is 7.7 tons/ha (Anon., 2012b). India still dominates the world production and ranks first with a total production of 16.196 m metric tons from about 2.378 m ha, which is 21.19 per cent of the total production under fruit crop in the country (Anon., 2012c) and nearly 43 per cent of the total world mango production.

Mango is an important foreign exchange earner with an export of 1,50,499 metric tons worth Rs. 620 crores of processed products and 63,441 metric tons worth Rs. 209 crores of fresh fruits (APEDA, 2012).

Maharashtra is emerging as a leading mango growing state in India which currently occupy 4.82 lakh ha area with a total production of 5.03 lakh tons. The other major states in India which produce mango (lakh tons) are Uttar Pradesh (38.41), Andhra Pradesh (35.15), Karnataka (18.68), Bihar (12.42), Gujarat (9.66), Tamil Nadu (8.90), Orissa (7.15), West Bengal (6.62), Jharkhand (5.16) and Kerala (3.73) (Anon., 2012d).

Konkan region on the West coast of Maharashtra is emerging as one of the largest mango growing belts in the country, which comprises four mango growing districts viz., Thane (43492 ha), Raigad (47400 ha), Ratnagiri (63500 ha) and Sindhudurg (25494 ha), occupying 1.65 lakh ha of area under mango (Anon., 2012e). This region which occupies about 1 per cent of the total land area of the country, accounts for 7 per cent of the total area under mango in the country. Out of total area under mango in Konkan, more than 80 per cent is occupied by a single largest growing mango variety ‘Alphonso’, locally called as ‘Hapus’ with a major export share to the tune of over 30 per cent. It enjoys virtual dominance both in domestic as well as in international markets due to its typical sugar-acid blend, attractive colour and shape, pleasant aroma, highly appreciable flavour, taste and distinctly having long keeping quality. Under changing WTO regime, this variety has recently attracted the attention of APEDA, New Delhi and efforts are on to have international registration for ‘Alphonso’ mango for IPR norms under geographical indication.

Though India is the largest mango producer in the world, its performance on export front is very poor. Hardly less than 2 per cent of the total mango produced is exported which is far below some of the leading mango exporting countries like Mexico, Brazil and Philippines who have their major share in mango export in USA, Europe and Japan, respectively. Indian export is mainly confined to the neighbouring countries such as Bangladesh (70%) and Middle East (20%). This is mainly because of poor post harvest management chain and lack of technological backup required for long distance shipment.

In recent times, Alphonso is increasingly gaining popularity in European countries and holds the tremendous potential for future export. However, high shipment cost by air transportation is one of the bottlenecks in exporting to European destination. Some attempts made in the recent past to export Alphonso mango by sea transportation were of little success as 20 to 24 days are required to reach the destination. This warrants for urgent need for research interventions to prolong storage and improve the shelf life.

Mango being a climacteric fruit, it provides less scope for long distance shipment through cold storage due to short shelf life, unlike that of apple or grapes. Thus any treatment which can inhibit the rapid softening in fruits after harvest is of paramount importance to increase the storage life. Mango is a climacteric fruit and onset of ethylene production is initiated from fruit set and attains threshold value at physiological maturity stage. Fruit softening is partially controlled by ethylene and the application of exogenous ethylene to fruit causes faster softening (Abdi *et al.*, 1998). In recent times, number of chemicals which have their role in inhibition of ethylene have been explored both in India and abroad but, with erratic and inconsistent results particularly in a fruit like a mango.

More recently, 1- methylcyclopropene (1-MCP), an anti-ethylene agent has been widely used to delay ripening and senescence and to extend shelf-life of fruits, vegetables and flowers (Bassetto *et al.*, 2005a; Blankenship and Dole, 2003; Kluge and Jacomino, 2002 and Sisler and Serek, 1997). It has been identified as a potent inhibitor of ethylene action and has been shown to prevent ethylene induced effects in tomato, banana, plum, apple at very low concentration (Sisler and Serek, 1997). Jiang *et al.* (1999b) have shown that even 1 ppm of 1-MCP could substantially delay the ripening in banana. The recent registration of 1-Methylcyclopropene (1-MCP) to inhibit ethylene perception in horticultural products has resulted in an exciting era for post harvest research. The research available so far indicates that just like any traditional technology, such as low temperature and controlled atmosphere (CA) storage (Watkins and Ekman, 2005), effects of 1-MCP on product quality can be variable (Blankenship and Dole, 2003; Watkins, 2006).

Current scenario indicates that, 1-MCP is still a new product for edible horticultural crops and registration for its commercial use is still in process. The use of 1-MCP in agricultural products including apples, kiwifruit, tomatoes, bananas, plums, persimmons, avocados and melons has been approved and accepted in more than 34 countries including the European Union and the United States.

Commercial use of 1-MCP based technologies for apple was launched as recently as 2002 in Chile and Argentina and 2003 in New Zealand, South Africa and the United States.

The compound 1-methylcyclopropene (1-MCP) is an odourless gas that has a physical similarity to ethylene allowing it to bind to the ethylene receptors in fruits, thus inhibiting the normal action of ethylene and prolonging the storage life of fruit. It is structurally related to the natural plant hormone ethylene and it is used commercially to slow down the ripening of fruit and to help maintain the freshness of cut flowers. It is available in powder form, releasing 1-MCP when diluted in water. Thus, the inhibitor of ethylene perception is the basis of a new technology that is increasingly being used to improve storage potential and maintain quality of fruits and vegetables. Successful commercialization of 1-MCP in mango will thus require an appropriate balance between 1-MCP concentration and storage conditions that will delay but not inhibit the ripening.

Mango being a major fruit crop and backbone of Konkan economy, it is necessary to extend the shelf life and research on this aspect is of paramount importance to help mango growers and exporters. Not much work has been carried out on this aspect in India. Hence, the present investigation was undertaken with the following objectives;

- To evaluate the efficiency of different doses of 1-MCP in prolonging the ripening and storage behaviour of Alphonso mango fruits under different storage conditions.
- To study the effect of different doses of 1-MCP on physiological and physico-chemical properties of Alphonso mango fruits ripened under different storage conditions.
- To find out the most optimum dose of 1-MCP for prolonging the ripening and storage of Alphonso mango without affecting fruit quality.

REVIEW OF LITERATURE

India is a leading producer of mango with a major share of more than 3% in the global mango production. In spite of the lion's share in production, the export of mango fruit from India is very meagre accounting less than 20 per cent of the production. Among several factors ascribed, lack of post harvest management is one of the prime reasons for low export. Most critical factor affecting the post harvest life of mangoes is their climacteric ripening nature.

Mango being a typical climacteric fruit, follows a ripening pattern which is characterized by lag phase, log phase, stationary and senescence. This poses a great limitation for extending the post harvest life of mango beyond 2-3 weeks under ambient conditions. Hence, it is necessary not only to increase the post harvest storability of Alphonso mango but also to retain the fruit quality for long distance transport. Recently evolved storage technology involving 1- methylcyclopropene (1-MCP) treatment has led to supply of high qualitative temperate fruits all round the globe. However, its application and usefulness in climacteric fruits like mango are lacking. Keeping this in view, investigations were carried out to find out the influence of 1-MCP on physical changes, ripening behaviour, storability, physiological changes, physico- chemical properties and pulp quality of Alphonso mango fruits. The literature pertaining to these aspects is presented in this chapter.

2.1 INFLUENCE OF 1-MCP ON PHYSICAL CHANGES AND RIPENING BEHAVIOUR

Delay in ripening and maintaining the quality due to 1-MCP treatment vary with plant genetic, physiological and morphological characteristics (Sisler and Serek, 1997).

Feng *et al.* (2000) investigated the effect of various concentrations of 1-MCP (0.5, 1, 5, 15, 30, 50 or 70 nl l^{-1}) with exposure time of 24 hours at 22°C on Avocado fruits of four different cultivars and observed that the 1-MCP @ 30-70 nl l^{-1} delayed the ripening of avocado fruits by 10-12 days, after which the fruit resumed normal ripening. While, 1-MCP at 15 nl l^{-1} had a moderate effect in delaying the climacteric peak, softening and skin colour change by 6, 5 and 3 days.

Similarly, Vilas-Boas and Kader (2001) studied the effect of 1-MCP on different types of fresh cut fruits and reported that the exposure of partially ripe 'Keitt' mango to 1-MCP was not effective in slowing the softening rate of fresh cut mango cubes beyond first 3 days at 5°C (41°F) after cutting. However, the treatment of fresh-cut mango cubes with 1-MCP was effective in delaying their softening by 1 or 2 days during storage at 5°C (41°F).

The response of 1-MCP on ripening behaviour and quality parameters of mango and other fruits viz., avocado, custard apple and papaya were studied by Hofman *et al.* (2001) who found that 1-MCP treatment significantly increased the ripening by 5.1 days (37%) for avocado, 4.4 days (40%) for custard apple, 3.4 days (58%) for papaya and 15.6 days (32.5%) for Mango.

Jeong *et al.* (2001) evaluated the effect of different doses of 1-MCP (0, 100, 200, 300, 600 and 900 nl l^{-1}) on delay in ripening and storage life of "Simmonds" Avocado fruits. They observed that the fruit loss was 77% of initial firmness in untreated while; mangoes treated with 1-MCP at dose equal or higher than 300 nl l^{-1} lost only 11 per cent of the initial firmness. In another study, they observed that control fruits reached firmness of ready to eat (10-20 N) only three days after keeping at room condition; while 1-MCP treated @ 300 nl l^{-1} reached this stage after seven days under room temperature conditions.

Commercial application of 1-MCP (0, 10, 100, 200, 400 and 600 ppb) on storage life and quality of four cultivars of pears was investigated by Calvo (2002) under cold storage conditions for 9 months. Irrespective of doses, 1-MCP application delayed the ripening period and retained firmness and green colour much longer than control fruits. Further he observed that 1-MCP was less effective in prolonging the green life of late harvested fruits. Similarly, delayed application of 1-MCP also showed reduced effect on ripening behaviour in pears.

Moretti *et al.* (2002) investigated the ability of 1-MCP (0, 250, 500 and 1000 ml l^{-1}) on tomato fruits which were exposed for 12 hours and then stored at ambient conditions for 2 days again followed by cold storage for 15 days. They noticed that the firmness of fruits treated with 1000 ml l^{-1} was about 88 per cent higher than control fruits after 17 days of storage. The a^*/b^* ratio, an indicator of skin colour was also 38 per cent lower than that of control fruits. Ripening in tomatoes treated with 250, 500 and 1000 ml l^{-1} of 1-MCP delayed the ripening by 8 - 11, 11 - 13 and 15 - 17 days, respectively.

Jeong *et al.* (2002) observed that the peel of avocado fruit treated with 1-MCP at $0.45 \mu\text{l l}^{-1}$ for 24 hours retained moderate green colour with low colour intensity (light) during 12 days storage at 20°C . They also investigated the effect of two levels of 1-MCP (0.09 and $0.45 \mu\text{l l}^{-1}$) with three exposure times (6, 12 and 24 hours) at 20°C and ambient condition on ripening and cell-wall maturity and reported maximum delay in ripening by 4 days in 1-MCP treatment @ $0.45 \mu\text{l l}^{-1}$ for 24 hours at 20°C exposure. This delay was characterized by a significant reduction in the rate of fruit softening, timing and intensity of ethylene and respiratory climacterics. This treatment also exhibited significantly less physiological loss in weight, retained more green colour at full-ripe storage (10-20 N).

Kluge and Jacomino (2002) studied the shelf life of peaches treated with 1-MCP (0, 100, 300 and 900 nl l^{-1} for 12 hrs at 25°C) followed by storage at room temperature (25°C) for 6 days, and revealed that 1-MCP (100 nl l^{-1}) treated fruits retained 40-60% greater firmness, more green colour index and least rotting index.

Argenta *et al.* (2003) it was reported that 1-MCP inhibited ethylene release during ripening and quality of plums (cv. Laetitia) following harvest and cold storage. Among five levels of 1-MCP tried (0, 0.05, 0.10, 0.50 and $1 \mu\text{l l}^{-1}$) at 1°C for 24 hours followed by storage at ambient temperature (23°C) for 5 days or 1°C for 50 days, a saturation response occurred between 0.5 to $1.0 \mu\text{l l}^{-1}$. The fruit shelf life was extended by approximately 6 and 20 days due to 1-MCP treatment stored at 23°C and 1°C respectively.

Botondi *et al.* (2003) studied the effect of 1-MCP ($1 \mu\text{l l}^{-1}$ for 12 hrs at 20°C followed by storage at 20°C) on inhibition of ethylene and its effect on quality attributes of three varieties of apricots (cv. Castrese, Boccuccia and Spinosa) but did not observe any significant change with control and 1-MCP treated apricots with respect to colour change.

Benassi *et al.* (2003) studied the shelf life and ripening associated factors of custard apple when treated with different concentrations of 1-MCP (0, 30, 90, 270 and 810 nl l^{-1}) and stored at 25°C for four days. It was revealed that the fruits treated with 810 nl l^{-1} of 1-MCP presented higher firmness (50 to 60%) than control fruits. The non treated and fruits treated with 30 and 90 nl l^{-1} of 1-MCP ripened significantly faster than fruits treated with higher concentrations of 1-MCP.

Pelayo *et al.* (2003) evaluated the effect of 1-MCP (100, 300 and 1000 nl l^{-1} at 14 and 20°C for 6, 12 and 24 hours) on the response of banana at different stages of ripening. Their results revealed that the exposure to 1-MCP delayed changes in skin colour, flesh softening and the magnitude of its effect was dependent on its concentration, but during the exposure decrease in hue angle shown no significant differences in flesh firmness, irrespective of storage time and condition. However, there were no differences in the aroma compound between 1-MCP treated fruits and control.

The effect of 1-MCP (25 ppm for 24 /12 hrs), ethanol vapour and heat was investigated on shelf life of intact and fresh cut slices of 'Kent' and 'Tommy Atkins' mangoes by Plotto *et al.* (2003). They observed maximum retention of firmness & green colour in 1-MCP treated as compared to other treatments with reduced spoilage in fresh cut fruits.

Sisler and Serek (2003) manipulated ethylene effects in horticultural crops by 1-MCP and related receptor blocking compounds. While selecting and testing various strained olefins as ethylene antagonists, led to the discovery of 1- methylcyclopropene (1-MCP) and other cyclopropenes which effectively block ethylene responses at the receptor level. It is very effective in blocking ethylene responses in a range of ornamental crops. Ripening of banana and other fruits was delayed by 12 days after a single exposure to 0.5 nl l^{-1} of 1-MCP and then they ripened normally.

Alves *et al.* (2004) studied the post harvest ripening of Tommy Atkins mangoes at two maturation stages treated with 1-MCP and revealed that the days to ripen, as indicated by softening and loss of chlorophyll, can be increased, and increases in soluble solids concentrations and aroma volatiles can be delayed by 1-MCP treatment.

Santos *et al.* (2004) investigated the influence of 1-MCP on ripening and conservation of 'Tree- Dropped mango fruits of cv. Rosa and carefully picked up at two maturity stages. The fruits were exposed to 1-MCP (@100 ppb) for 24 hours followed by storage at room temperature $24 \pm 1^{\circ}\text{C}$ for 16 days, where they found that the treating of mango fruits with 1-MCP slowed down the senescence process caused by the dropping impact only when fruits were dropped in green yellowish stage but not yellowish green stage. They further observed that irrespective of treatment combinations, the weight loss decreased with increasing storage time.

Cocozza *et al.* (2004) exposed 'Tommy Atkins' mangoes of stage two maturity to 1-MCP (100 and 500 nl l⁻¹) at room temperature for 12 hours and studied the effect of different doses of 1-MCP alone and without modified atmosphere followed by storage for 25 days at 11.5^oC and after that 7 days at 25.4^oC. They noticed that 1-MCP @ 100 and 500 nl l⁻¹ in combination with modified atmosphere maintained 25 per cent firmness of fruits than control. Similarly, 1-MCP combined with modified atmosphere delayed the skin colour change from green to yellow and also indicated lower chroma (c) and Luminosity (*L) values. The weight loss significantly lower (4.7%) in this treatment compared to control (7%).

Silva *et al.* (2004) exposed fruits of three exotic mango cultivars 'Rosa', 'Jasmin' and 'Espada' harvested at two stages of maturity (mature green and pre climacteric maturity stages) to 1-MCP @ 100 ppb for 24 hours followed by ripening at room temperature (23±1^oC) for 16 days. They witnessed that varieties differ in their response to 1-MCP in relation to ripening behaviour. Among cultivars, 'Espada' lost far much less weight when compared with 'Jasmin' and 'Rosa' by the end of storage period. They also observed that all 1-MCP treated fruits exhibited delayed rate of colour change.

Azzolini *et al.* (2005) studied the effect of 1-MCP exposed for 12 hrs at 23^oC (300 nl l⁻¹ at 23^oC and 85% RH) and found that 1-MCP exposed fruits of guava, cv. Pedra Sato had market change in fruit firmness, skin and pulp colour matric structure. Loss of firmness was found to be significantly reduced in fruits treated with 1-MCP; while skin colour remained green up to 12 days as compared to 8 days in control.

Bassetto *et al.* (2005a) investigated the effect of different concentrations of 1-MCP (0, 100, 300 and 900 nl l⁻¹ for 3 hours followed by storage at 25 and 10 ^oC with 90 ± 5% RH) on guava fruit cv. 'Pedro Sato'. Their study revealed that irrespective of concentrations, fruits treated with 1-MCP and stored at 25^oC showed lower loss of green colour than non treated fruits. The retention of green colour was higher with higher concentration of 1-MCP. Further, firmness of fruit also increased with increasing concentration of 1-MCP. Their study also revealed that non treated fruits had high percentage of rot (above 30%) on 4th day of storage; while it was higher on 6th day to 8th day in 1-MCP treated fruits.

Hayama *et al.* (2005) investigated the effect of 1-MCP (1µl l⁻¹) gas with and without sub-atmospheric pressure (25-29 kPa) on softening of 'Akatsuki' peach and observed that 1-MCP treatment under sub-atmospheric pressure followed by only 1-MCP (without pressure) significantly delayed the softening of fruits.

Maya *et al.* (2005) studied the storage behaviour and quality of citrus when exposed to different concentrations of 1-MCP (0, 0.01, 0.1, 0.5 and 1.0 µl l⁻¹ for 6, 12 or 24 hours at 20^oC) and then stored in dark at 20^oC. The treatment with 0.1 µl l⁻¹ 1-MCP for 24 hrs. was the most effective in delaying the degreening of fruits, whereas the physiological loss in weight was faster only in higher concentrations (*i.e.*, 0.5 and 1.0 µl l⁻¹) of 1-MCP for 24 hrs. than rest of the lower concentrations including control.

Arias *et al.* (2005) investigated the effect of 1 ppm of 1-MCP in sealed container at 7^oC (45^oF) for 24 hours on fruit firmness, colour and post harvest storage of avocado cv. 'Donnie' and indicated that the fruits treated with 1-MCP were significantly firmer after 5 to 21 days of storage compared to control. Further, they observed 1-MCP treated fruits maintained green colour and were significantly greener during storage. Five days after storage, control fruits began to show signs of rotting whereas 1-MCP treated fruit turned light green.

The response of cherry tomato fruit to post harvest treatments with 1-MCP (0, 0.035, 0.07 and 0.11 µl l⁻¹) to ethylene production, fruit softening pigmentation was studied by Opiyo and Ying (2005) and observed that 1-MCP (0, 0.035, 0.07 and 0.11 µl l⁻¹) at higher concentrations maintained the better firmness towards the end of the study.

Ortiz *et al.* (2005) found that the rate of weight loss in control and 1-MCP treated 'Rendajii' persimmon fruit during storage at 20^o C showed no differences until 6 days after harvest, then the rate and magnitude of weight loss in the control fruits surpassed the treated fruits. On 15th day, average weight loss for the control and the 1-MCP treated fruits were 10.47 and 8.89 %, respectively.

Tromp (2005) studied fruit ripening and quality characters of apple and concluded that during ripening, apple fruit generally show a rapid loss of green colour, which results from the degradation of chlorophyll.

Aguayo *et al.* (2006) determined the effect of 1-MCP ($1 \mu\text{l l}^{-1}$ for 24 hours at 5°C) alone and in combination with CaCl_2 dip under ambient and atmospheric modified condition on quality attributes and shelf life of fresh cut strawberries. They observed that the combined effect of 1-MCP and CaCl_2 dip had extended shelf life by 9 days at 5°C as compared to 6 days in untreated control. However, they did not find any significant effect of 1-MCP on firmness retention when applied alone. While, 1-MCP treated fruits, had more green colour and exhibited less colour change. None of the treatments had any significant effect on microbial count.

Chaiprasart and Hansawasdi (2009) showed that the highest 1-MCP concentration (1000 ppb for either 6 or 12 hours) at cold storage delayed the changes in peel colour of mango cv. Nam-dawg-mai-sri-tong.

Vilas-Boas and Kader (2007) studied the effect of 1-MCP (0.5 and $1 \mu\text{l l}^{-1}$) on the fresh cut kiwifruit, mango (cv. Kent and Keitt) and persimmon slices and found that the fresh cut mangoes (Kent) retained the firmness during storage at 10°C when treated with 1-MCP ($1 \mu\text{l l}^{-1}$ for 6 hrs). While, colour darkening (L^* value) decreased during 9 days of storage at 50°C .

Mostofi and Toivonen (2006) investigated the multifactor effect of 4 maturity stages, 5 storage periods and 3 storage temperatures of 1-MCP treated and untreated tomato fruits in relation to ripening related parameters and they observed that the parameters such as fruit firmness, hue angle and chroma were significantly influenced by all the factors and the effectiveness was more with 1-MCP treatment.

Penchaiya *et al.* (2006) fumigated 'Nam Dokmai' mango fruits to different concentrations of 1-MCP (250, 500 and 1000 ppb) for 24 hours at 25°C followed by storage at 20°C and found that 250 ppb was most effective in delaying the fruit firmness until the end of storage and the colour changes were delayed with increase in L^* and b^* values towards the end of storage. Finally, they observed that 1-MCP treatment also prolonged the shelf life of mango by 15 days of storage at 20°C .

The effect of 1-MCP immersion (5 min) formulation (0, 10, 100, 1000, 10,000 ng kg^{-1}) followed by ripening at 23°C and at cold storage (5°C) for 10 days was investigated by Manganaris *et al.* (2008) and reported that all 1-MCP immersion reduced firmness loss, skin colour changes and fruit weight loss. Overall 1-MCP concentration of 1000 ng kg^{-1} was not effective in controlling the fruit ripening change and extended the shelf life of plum fruits. They claimed their study is of first of its kind where immersion was successful method of treating fruits with 1-MCP.

Pandey and Singh (2007) studied the comparative response of 1-MCP and KMnO_4 on post harvest behaviour of mango cv. Lucknow Safeda under ambient conditions and reported that among various treatments, 1-MCP at 100 ppm was found to be most effective for extending the shelf life by 3 days. Further, they found that same treatment imparted more firmness, attractive bright yellow colour with minimum spoilage.

Singh *et al.* (2007) compared 1-MCP treatments to silver nitrate, gibberellic acid, sodium metabisulphite, and ascorbic acid treatments on 'Dashehari' mangoes and found that the 1-MCP treatment was most effective in delaying ripening.

Ramin (2008) investigated the effect of three doses of 1-MCP (0.5 , 1 and $1.5 \mu\text{l l}^{-1}$) on persimmon fruit cv. Nathanzy exposed for 24 hrs. at 20°C and kept at ambient air temperature (20°C) and found that the 1-MCP treatment inhibited the fruit softening at least by two times over the non treated control fruits, although he did not observed any significant change in skin colour of fruits by visual observations. However, decrease in hue angle was slow down by 1-MCP treatments.

Nature of development of fruit greasiness and internal ethylene concentration as influenced by 1-MCP treatment ($1.0 \mu\text{l l}^{-1}$) was examined by Curry (2008) and found that 1-MCP strongly inhibited ethylene production and delayed development of certain wax constituents thought to be responsible for fruit greasiness during cold storage.

Huber (2008) extensively reviewed the suppression of ethylene responses through application of 1-MCP, while elucidating ripening and senescence mechanisms in climacteric and non-climacteric fruits and vegetables and found that climacteric fruits confirmed that the antagonist operates in opposition of ethylene while, non-climacteric fruits challenged 1-MCP and other ethylene inhibitors.

Mahajan and Gagandeep (2008) evaluated the effect of gaseous vapour treatment of various concentrations of 1-MCP (100, 200 and 300 ppb) on storage life and various quality attributes of guava cv. Allahabad Safeda and found that the 1-MCP treated fruits, when stored at $6 \pm 1^{\circ}\text{C}$ and 90-

95 per cent RH could prolong the shelf life by maintaining good quality attributes. Among the treatments, 1-MCP @ 300 ppb proved to be most effective as it could extend the storage life upto 4 weeks as against two weeks in non treated fruits and could maintain significantly higher firmness, decrease in physiological loss in weight, delay in green colour loss.

Byers *et al.* (2008) studied the Arlet apples combined effect of aminoethoxyvinylglycine (AVG) + 1-MCP on 35th day of harvest and observed that AVG + 1-MCP maintained significant firmness value (74.3 N) as compared to untreated fruit (61.4 N). While, Sankhla *et al.* (2010) studied the effect of 1-MCP (0, 100, 200 400 nl l⁻¹) on change in certain chemical constituents and quality of *Ziziphus mauritiana* fruit of cv. Seb and found that the 1-MCP treatments decreased fruit firmness.

The response of 1-MCP on respiration rate, ethylene evolution and associated post harvest physiological changes in three mango cultivars viz., Chausa, Dashehari and Langra during storage under ambient conditions were studied by Singh and Pathak (2008) and observed that irrespective of variety, the 1-MCP treated fruits remained significantly firmer even after 7th day of storage compared to control. Further they observed that treated fruits of all the three cultivars showed significantly reduced rate of weight loss on 4th, 7th and 9th day of storage as compared to control, in addition to significantly higher fruit firmness.

Tully *et al.* (2009) investigated the effect of 1-MCP at 650 ppb exposed for 24 hours on different cultivars of plums, widely marketed in UK and reported that the effect was cultivar dependent in which, 1-MCP maintained higher fruit firmness during cold storage and reduced the number of fruits showing the post ripening disorder.

Watkins (2008) noted that the application of 1 MCP is best suited for a crop like apple, where the goal is to maintain the crunchy texture from harvest through to consumption. In fruits like mangoes, where the goal is to have a change in texture between harvest and consumption (i.e. the normal softening associated with ripening in these fruits), the use of 1 MCP is more challenging because the requirement is to delay, not inhibit, ripening.

Burondkar *et al.* (2009) concluded that the loss in physiological weight of fruits during ripening was significantly lower in 1-MCP treatments as compared to control. In all the 1-MCP treatments, significantly lowest PLW of 10.18 per cent was observed as compared to control (18.64%).

Chaiprasart and Hansawasdi (2009) determined the efficiency of different doses of 1-MCP (0, 500 and 1000 ppb) with different exposure time (0, 6 and 12 hrs.) in mango fruits of cv. Nam-dawg-mai-sri-tong kept at 20°C for ripening and revealed that 1-MCP (1000 ppb) treatment for 6 or 12 hours delayed the change in peel and pulp colour and fruit softening by 3 days as compared to untreated control.

Osuna – Garcia and Perez – Barraza (2009) evaluated the effect of different doses of 1-MCP (0, 100, 200, 300, 600 and 900 nl l⁻¹) on shelf life and quality of 'Kent' mangoes under Mexico condition and found that all 1-MCP treatments delayed the ripening process and maintain pulp firmness longer and extended the shelf life. They observed that at the end of 20 days of storage, only 40 per cent of fruits ripened under 1-MCP treatment at dose equal or higher than 300 nl l⁻¹.

Ozkaya and Dundar (2009) determined the effect of 1-MCP (325 and 650 nl l⁻¹) at 20°C for 24 hours on apple quality in cv. 'Fuji' under 8 months of cold storage at 0°C and 85-95% RH. They observed that 1-MCP treated fruits reduced the weight loss, softening of fruits and hue angle.

Wang *et al.* (2009) carried the investigation on effect of 1-MCP (1 µl l⁻¹ and 5 µl l⁻¹) and exogenous ethylene (5 µl l⁻¹) on green mature mango fruits of cv. Tainong which were exposed for 24 hour and stored at 20°C up to 16 days and witnessed that 1-MCP maintained fruit firmness while ethylene decreased the fruit firmness.

The efficacy of 1- methylcyclopropene (1-MCP) in arresting the ripening and prolonging the storage and shelf life of Alphonso mango fruit to suit export by sea transportation from India, for three consecutive years (2006-07-08) was investigated by Burondkar *et al.* (2009). Effect of 1-MCP on ripening pattern of fruits examined as six difference stages (viz., unripe, turning pale green, ¼ ripe, ½ ripe, full ripe and decaying) indicated that 1-MCP treatment significantly arrested the ripening by 8 days and prolonged the subsequent stages by 9, 10, 11, 12 and 13 days, respectively, over untreated control. Fruits quality assessed at different intervals viz., after 14, 21 and 28 days of storage and shelf life behaviour at two stages (0 and 5 days) after storage in terms of TSS, acidity, total sugar, reducing sugar and an organoleptic ratings, were found to improve by 1-MCP treatment with 21 days storage

plus 5 days shelf life (17.93⁰B, 0.31%, 14.15%, 4.3%, 6.78%) and 28 days storage with zero days shelf life (17.24⁰B, 0.29%, 14.53%, 4.63%, 6.45%) over control (16.93⁰B, 0.38, 14.02, 4.04%, 6.33%) with significant reduction in occurrence of spongy tissue (physiological disorder) from 25.07 per cent in control to 9.45 to 12.34 per cent in both these 1-MCP treatments, respectively.

Liu *et al.* (2010) investigated the effect of 1-MCP released from dissolving 3-Chloro-2 methylpropene in water on quality of harvested mango fruit ripened under ambient temperature for 12 days at 25⁰C. They observed that 1-MCP treatment delayed fruit firmness by 3 days.

While studying the effect of different concentrations of 1-MCP (0.5, 1 and 2 $\mu\text{l l}^{-1}$) on physiological and biochemical changes in kiwifruit cv. Alliso. Jamel *et al.* (2011) observed that regardless of concentrations of 1-MCP treated fruits delayed the ripening of kiwifruit, but a dose of 2 $\mu\text{l l}^{-1}$ found to be most effective as treated fruits started ripening after 12 days of storage as against 6 days in control.

Wang *et al.* (2006) found that applying of 1-MCP using vacuum in filtration techniques, a 5-ppm concentration of 1-MCP provided an increase in shelf life of 8 to 12 days.

2.2 INFLUENCE OF 1-MCP ON PHYSICO-CHEMICAL CHANGES DURING RIPENING PROCESS

Fan *et al.* (1999) observed that 1-MCP treated 'Fuji' apples held 17 days at 20⁰C had higher total soluble solids than non treated fruits. Total soluble solids (TSS) content was higher in 1-MCP treated fruits only after 6 months storage and equalized between treatments after holding at room temperature. Total soluble solids were statistically higher in 1-MCP treated in 'Delicious' and 'Fuji' after 6 or 7 months. There were no differences between treatments in total soluble solids for 'Ginger Gold', 'Gala' and 'Jonagold'. Although 1-MCP did not always increase total soluble solids, it also did not cause reduction in total soluble solids when compared with non-treated fruits. 'Delicious' exhibited higher total soluble solids content in 1-MCP treated apples.

Fan *et al.* (1999) observed that 1-MCP treated 'Fuji' apples held 17 days at 20⁰C had higher titratable acidity than non treated fruit. Climacteric 'Delicious' apples treated with 1-MCP held for 7 days at 20⁰C after 0⁰C storage for 3 or 6 months had higher titratable acidity than non treated fruit. Titratable acidity was greater in 1-MCP treated fruit for all cultivars during storage. These changes in titratable acidity are related to ethylene action. Titratable acidity was generally higher in 1-MCP treated fruits (Jonagold, Delicious, Ginger Gold and Gold and Gala) when compared with non treated apples at room temperatures.

Lopez *et al.* (2000) evaluated the effect of concentrations (8.16 and 24 g l⁻¹) of edible sucrose – polyester coating film on ripening and quality changes in mango fruits stored at 13⁰C and 85 per cent RH and observed that irrespective concentrations of edible coating registered higher titratable acidity and TSS. were lower with non coated fruits. However, there was no significant effect on ascorbic acid content.

Selvarajah *et al.* (2001) reported that 1-MCP slows vitamin C loss in cold stored pineapples.

Calvo (2002) investigated 1-MCP (0, 10, 100, 200, 400 and 600 ppb) on storage life and quality of four cultivars of pears under cold storage conditions during the storage for 9 months. Irrespective of doses, 1-MCP application reduced the acidity and there was no effect of 1-MCP on TSS and weight loss.

Argenta *et al.* (2003) studied the effect of 1-MCP inhibited ethylene release effect on ripening and quality of plums cv. Laetitia following harvest and cold storage. Among the five levels of 1-MCP (0, 0.05, 0.10, 0.50 and 1 $\mu\text{l l}^{-1}$) at 1⁰C for 24 hours followed by storage at ambient temperature (23⁰C) for 5 days or 1⁰C for 50 days, 1-MCP delayed the change in titratable acidity and change the flesh and skin colour without any significant effect of TSS.

Botondi *et al.* (2003) studied the effect of 1-MCP (1 $\mu\text{l l}^{-1}$ for 12 hrs. at 20⁰C followed by storage at 20⁰C) on inhibition of ethylene and its effect on quality attributes in three varieties of apricots (cv. Castrese, Boccuccia, Spinosa) but they did not observe any significant changes with control and 1-MCP treated apricots with respect to acidity and TSS.

Benassi *et al.* (2003) studied the shelf life and ripening associated factors of custard apple when treated with different concentration of 1-MCP (0, 30, 90, 270 and 810 nl l^{-1}) and stored at 25⁰C for four days. Their study revealed that TSS remained unaffected due to any 1-MCP treatment.

Jomari *et al.* (2003) studied the effect of 1-MCP (0, 1.0 $\mu\text{l l}^{-1}$ for 12 hours and stored at 5 or 10°C during 30, 60 and 90 days of storage) on 'Tahitt' Lime in cold storage. They observed that there were no differences observed in physico- chemical characters such as TSS., titratable acidity, vitamin c in fruits due to the treatments.

Plotto *et al.* (2003) investigated the effect of 1-MCP (25 ppm for 24/12hrs.) and ethanol vapour and heat on shelf life in intact and fresh cut slices of 'Kent' and 'Tommy Atkins' mangoes. Study revealed that, among these fruits tried. increase in total soluble solids content and titratable acidity of 'Kent' cut mangoes was lower in heat treated fruits compared to the other treatments. 1-MCP treated fruits showed a decrease in titratable acidity over time, while a general decrease in acidity was observed in 'Tommy Atkins' cut fruits during storage. Overall a little significant difference were found between treatments. Lower total soluble solids and higher titratable acidity in indicate slower ripening.

Cocozza *et al.* (2004) found that 1-MCP treated 'Tommy Atkins' mango fruits had higher vitamin C content.

Santos *et al.* (2004) investigated the influence of 1-MCP @ 100 ppb on ripening and conservation of 'Tree- Dropped mango fruits' cv. Rosa dropped and carefully picked up fruits of two maturity stages were exposed to 1-MCP @100 ppb for 24 hours and followed by storage at room temperature $24\pm 1^{\circ}\text{C}$ for 16 days and they observed that, irrespective of treatment combination the total soluble solids increased and titratable acidity decreased with increasing storage time.

Silva *et al.* (2004) exposed fruits of three exotic mangoes cultivars Rosa, Jasmin and Espada harvested at two stages of maturity (mature green and pre climacteric maturity stages) to 1-MCP @ 100 ppb for 24 hours followed by ripening at room temperature ($23\pm 1^{\circ}\text{C}$) for 16 days, and observed that, total soluble solids was statistically higher in per- climacteric 1-MCP treated 'Espada' fruit while total titratable acidity tended to be higher for mature green treated with 1-MCP.

Bassetto *et al.* (2005b) studied the effect of 1-MCP on conservation of 'Pedro Sato' guava on quality parameters and they revealed that the amount of TSS was initially lower in fruits when treated with 1-MCP as compared to control. Similarly, the organic acids retention of acidity was higher with increase in the concentration of 1-MCP from 100 to 900 nl l^{-1} . However, the amount of ascorbic acid found to be remained unaffected due to 1-MCP treatment.

Maya *et al.* (2005) studied the storage behaviour and quality of citrus when exposed to different concentrations of 1-MCP (0, 0.01, 0.1, 0.5 and 1.0 $\mu\text{l l}^{-1}$) for 6, 12 or 24 hours at 20°C and then stored in dark at 20°C they did not find any significant differences in titratable acidity and TSS in both control and 1-MCP treated fruits.

Kondo *et al.* (2005) investigated the aroma volatile biosynthesis in two cultivars of (Delicious and Golden Delicious) apple treated by 1-MCP and methyl jasmonate (MeJA) during ripening, detected forty – four volatile compounds in delicious and 40 compounds in golden delicious fruits. They further observed that, aroma volatile production was high in untreated control and ethephon treatment while, it was lower in 1-MCP treated fruits as compared to untreated control.

Ortiz *et al.* (2005) reported that at harvest, TSS content in the 'Rendajji' Persimmon fruit had 15.33^o Brix values and it slowly increased after treatment with ethanol and 1-MCP during storage at 20°C. TSS content in 1-MCP treated fruit was slightly higher that of control.

Qiuping *et al.* (2006) evaluated the effect of 1-MCP treatment on physico- chemical properties of sapodilla fruits and reported that, fruits exposed to 1-MCP had significantly higher ascorbic acid content and higher TSS and delayed the acidity loss in sapodilla fruits during storage.

Pandey and Singh (2007) studied the comparative response of 1-MCP and KMnO_4 on post harvest behaviour of mango cv. Lucknow Safeda under ambient conditions. They noticed that, among various treatments 1-MCP @ 100 ppm was found more TSS and acid blend.

Rathore *et al.* (2007) studied the effect of storage periods (0, 3, 6, 9, 12, 15 days) on different physiological properties of Dashehari mango under ambient conditions and they observed that, the storage period significantly regulated the average per cent TSS (10 to 25.27%) and showed decreasing trend of per cent titratable acidity (0.5% to 0.094%) with an average mean of 15.67 per cent, 11.55 per cent and 0.28 per cent respectively during 15 days of storage period.

Ramin (2008) investigated the effect of three doses of 1-MCP (0.5, 1 and 1.5 $\mu\text{l l}^{-1}$) on persimmon fruit cv. Nathanzy exposed for 24 hrs. at 20°C and kept at ambient air temperature (20°C)

observed that, 1-MCP treatments had significantly influenced the course of change in total soluble solids content and fruit acidity.

Mahajan and Gagandeep (2008) evaluated the effect of gaseous vapour treatment of various concentrations of 1-MCP (100, 200 and 300 ppb) on storage life and various quality attributes of guava cv. "Allahabad Safeda" and revealed that 1-MCP treated fruits when stored at $6 \pm 10^{\circ}\text{C}$ and 90-95 per cent RH, the treatment 1-MCP @ 300 ppb could maintain significantly slow increase in the total soluble solids (10.3%), while, control fruits recorded lowest average TSS content (9.2%).

Manganaris *et al.* (2008) found that, titratable acidity values ranged from 0.052 to 0.078 H^+ mol l^{-1} , respectively for all of the treatments, without any difference between the control and 1-MCP treated fruits during ripening.

Ramin (2008) observed that, 1-MCP treated fruits effectively reduced loss of titratable acidity after 30 days stored at 20°C . Fruits treated with 1-MCP ($1 \mu\text{l l}^{-1}$) showed higher fruit titratable acidity after 30 days stored at 20°C as compared to control and the differences were highly significant.

Singh and Pathak (2008) studied the response of 1-MCP on post harvest physiological changes in different mango cultivars and TSS up to 7 days due to 1-MCP treatment highlighted inhibitory role of 1-MCP on fruit ripening. However, they did not notice any significant effect of 1-MCP on acidity.

Singh and Dwivedi (2008) investigated the level of antioxidant in mango var. Dashehari fruits during ripening as influenced by 1-MCP and ethrel treatment and reported that, 1-MCP treatment led to decrease in the level of H_2O_2 and lipid peroxidation and increased activity of isozymes, catalase (CAT) and superoxide dismutase (SOD) as compared to respective control. On the other hand, this trend was observed to be reverse with ethrel treatment.

Sankhla *et al.* (2010) they studied the effect of 1-MCP (0, 100, 200 400 nl l^{-1}) on certain chemical constituents and quality of *Ziziphus mauritiana* fruits of cv. "Seb", and recorded that, 1-MCP treatments increased total sugar and vitamin C content.

Ozkaya and Dundar (2009) determined the effect of 1-MCP (325 and 650 nl l^{-1}) at 20°C for 24 hours in apple cv. 'Fuji' under 8 months of cold storage at 0°C and 85-95 per cent RH. They observed that, 1-MCP treated fruits increased TSS but, titratable acidity of both in control and 1-MCP treated fruits were decreased gradually during storage.

Chaiprasart and Hansawasdi (2009) determined the efficiency of different doses of 1-MCP (0, 500 and 1000 ppb) with different exposure times (0, 6 and 12 hrs.) in mango fruits cv. Nam-dawg-mai-sri-tong kept at 20°C for ripening. They observed that, 1-MCP treated mango fruits slowly increase ratio of TSS and titratable acidity as compared to untreated control.

Wang *et al.* (2009) carried the investigation on effect of 1-MCP ($1 \mu\text{l l}^{-1}$ and $5 \mu\text{l l}^{-1}$) and exogenous ethylene ($5 \mu\text{l l}^{-1}$) on green mature mango fruits of cv. Tainong which were exposed for 24 hours and stored at 20°C up to 16 days. They noticed that, exogenous ethylene accelerated increase in ethylene and 1- amino cyclopropene -1- carboxylate (ACC) oxidase whereas 1-MCP reduced both. Exogenous ethylene stimulated H_2O_2 production, while 1-MCP inhibited the production of H_2O_2 of mango fruits during storage. High concentration of ascorbic acid content was maintained in 1-MCP treated fruits but, was low in ethylene, treated fruits. 1-MCP inhibited activity of anti oxidant enzymes including catalase, superoxide, dismutase and ascorbate peroxidase.

Burondkar *et al.* (2009) concluded that under different period of cold storage with 0 and 5 days shelf life, a pooled mean for per cent acidity in control fruits ranged from 0.28 to 0.38 per cent with mean acidity of 0.32 per cent while it was ranged from 0.29 to 0.39 percent and mean value of 0.32 per cent in 1-MCP treated fruits.

Further, they observed that reducing sugar percentage in the pulp was significantly influenced due to various levels of 1-MCP treatments and ranged from 3.38 to 4.04 per cent in control and 3.63 to 4.63 per cent in 1-MCP treatments. Total sugar percentage in the pulp was significantly influenced due to 1-MCP treatment and ranged from 11.15 to 14.02 per cent in control and 11.91 to 15.17 per cent in 1-MCP treatments. Whereas, TSS in fruit pulp ranged from 15.72 to 17.61⁰ Brix in control, whereas, 15.40 to 17.93 in 1-MCP treatments, but they did not differ significantly.

Burondkar *et al.* (2013) studied the efficacy of 1- methylcyclopropene (1-MCP) in arresting the ripening and prolonging the storage and shelf life of Alphonso mango fruits to suit for export by sea transportation from India, for three consecutively years (2006,2007 and 2008) The fruits were

qualitatively assessed at different intervals viz., after 14 , 21 and 28 days of storage and shelf life behaviour at two stages (0 and 5 days) after storage in terms of TSS, acidity, total sugar and reducing sugar were found to improve by 1-MCP treatment with 21 days storage plus 5 days shelf life (17.93⁰Brix, 0.31%, 14.15%, 4.3%) and 28 days storage with zero days shelf life (17.24⁰Brix, 0.29%, 14.53% 4.63%) over control (16.93⁰Brix, 0.38, 14.02, 4.04%).

Liu *et al.* (2010) investigated effect of 1-MCP on quality in harvested mango fruits ripened under ambient temperature for 12 days at 25⁰C. They observed that, in treated fruits with 1-MCP, titratable acidity content in the pulp decreased faster throughout the whole storage period while, TSS was initially lower within the first stage of 9 days but higher in the later stage and TSS /T.A. ratio increased suddenly at the end of the storage. 1-MCP treated fruits also promoted ethanol and acetaldehyde production during most of the storage periods except towards the end of storage in 1-MCP treated fruits as compared to control.

2.3 INFLUENCE OF 1-MCP ON PHYSIOLOGICAL CHANGES DURING RIPENING PROCESS

Vilas-Boas and Kader (2001) reported the effect of 1-MCP on different types of fresh cut fruits and reported that, exposure of 4 bananas to 1-MCP before cutting stimulated more ethylene production but did not influence softening or browning rate of banana slices. In contrast, exposure of banana slices to 1-MCP had no effect on their ethylene production and browning rates, but reduced their softening rate and extended their post cutting life by 1 or 2 days at 10⁰C (15⁰F) especially when they were exposed to 2 ppm ethylene in air.

Moretti *et al.* (2002) investigated the ability of 1-MCP (0, 250, 500 and 1000 ml l⁻¹) on tomato fruits which were exposed for 12 hours and then held at ambient conditions for 2 days followed by cold storage of 15 days and they noticed that, the higher concentrations of 1-MCP delayed the total carotenoids synthesis and had 190 per cent less carotenoids than untreated control fruits.

Jeong *et al.* (2002) investigated the effect of two levels of 1-MCP (0.09 and 0.45 µl l⁻¹) with three exposure times (6, 12 and 24 hrs.) at 20⁰C on ripening and cell-wall maturity polysaccharides in avocado fruits, followed by ripening at 20⁰C in ambient condition. They observed that, 1-MCP treatment significantly affected the activity of major cell- wall matrix polysaccharides and observed completely suppressed of PG activity up to 12 days. 1-MCP treatments also delayed and slightly reduced the depolymerization of 4 M alkali-soluble hemicelluloses, including xyloglucan. They further observed that the ethylene production in untreated fruits and fruits treated with 1-MCP at 0.45 nl l⁻¹ for 6 hrs. showed characteristic climacteric pattern during storage at 20⁰C. The application of 1-MCP at 0.45 µl l⁻¹ for 6 hrs. slightly suppressed the magnitude of the respiratory peak, although the differences were non significant.

Argenta *et al.* (2003) studied the effect of 1-MCP inhibited ethylene release effect on ripening and quality in plums cv. Laetitia following harvest and cold storage. Among the five levels of 1-MCP tried (0, 0.05, 0.10, 0.50 and 1 µl l⁻¹) at 1⁰C for 24 hours followed by storage at ambient temperature (23⁰C) for 5 days or 1⁰C for 50 days, irrespective of doses 1-MCP treatment, delayed the climacteric respiration and ethylene production and slow down the rate of fruit softening.

Botondi *et al.* (2003) studied the effect of 1-MCP (1 µl l⁻¹ for 12 hrs at 20⁰C followed by storage at 20⁰C) on inhibition of ethylene production and its effect on quality attributes in three varieties of apricots (cv. Castrese, Boccuccia, Spinosa), they observed that 1-MCP, significantly inhibited ethylene production in the fruit as compared to control.

Bower *et al.* (2003) examined the effect of different levels of ethylene (0.01, 0.05, 0.1 and 1 µl l⁻¹) and its inhibitor 1-MCP (0.01, 0.1 and 1.0 µl l⁻¹) on the quality attributes and respiration rate of strawberries stored at 0 or 5⁰C and they observed that, neither the removal of low levels of ethylene from the storage environment nor the treatment with 1-MCP found effective in extending strawberries storage life.

Jomari *et al.* (2003) studied the effect of 1-MCP (0, 1.0 µl l⁻¹ for 12 hours and stored at 5 or 10⁰C during 30, 60 and 90 days of storage) in 'Tahitt' Lime. They observed that the 1-MCP treated fruits maintained green colouration with delay in ethylene production and low activity of chlorophyllase that degrades the chlorophyll.

Pelayo *et al.* (2003) evaluated the effect of 1-MCP (100, 300 and 1000 nl l⁻¹ at 14 and 20⁰C for 6, 12 and 24 hours) on responses of bananas at different ripeness stages. The results revealed

that exposure of bananas to 1-MCP (1000 nl l⁻¹) for 6 or 24 hours had higher rate of ethylene production but respiration rate was reduced.

Jiang and Joyce (2000) studied the effect of 1-MCP alone and in combination with polythene bags on the post harvest life of mango fruits and they observed inhibited rate of ethylene production due to 1-MCP throughout the ripening period.

Azzolini *et al.* (2005) studied the effect of 1-MCP exposed for 12 hrs. at 23°C (300 nl l⁻¹ at 23°C and 85% RH). They observed that 1-MCP treated fruits guava cv. 'Pedro Sato' exhibited low respiratory rate and ethylene production.

Bassetto *et al.* (2005a) investigated the effect of different concentrations of 1-MCP (0, 100, 300 and 900 nl l⁻¹ for 3 hours followed by storage at 25°C and 10°C with 90 ± 5% RH) on guava fruit cv. 'Pedro Sato'. They observed that the respiration rate was lower in fruits treated with 300 and 900 nl l⁻¹ of 1-MCP during storage at 25°C. In general, 1-MCP (900 nl l⁻¹) was found more efficient in delaying the ripening both under 10°C and 25°C storage temperatures.

Opiyo and Ying (2005) studied the response of cherry tomato fruits to post harvest treatments with 1-MCP (0, 0.035, 0.07 and 0.11 µl l⁻¹) in respect to ethylene production, fruit softening pigmentation and observed that 1-MCP at 0.07 and 0.11 µl l⁻¹ reduced ethylene production although 1-MCP at 0.03 µl l⁻¹ was effective in retarding fruit ripening. 1-MCP treatment significantly influenced the course of change in chlorophyll, lycopene and carotenoids contents and found that accumulation of lycopene and carotenoids was almost permanently hampered as the colour could not reach the control level even 2 weeks after 1-MCP treatments.

Aguayo *et al.* (2006) studied the effect of 1-MCP (1 µl l⁻¹ for 24 hours at 5°C) alone and in combination with CaCl₂ under ambient and atmospheric modified conditions on quality attributes and shelf life in fresh cut strawberries. They observed that 1-MCP applied before and after cutting of strawberries increased respiration rate but reduced rate of ethylene production.

Vilas-Boas and Kader (2007) studied the effect of 1-MCP (0.5 and 1 µl l⁻¹) on the fresh cut kiwifruit, mango (cv. Kent and Keitt) and persimmon slices. They found that in fresh cut mangoes (Kent) the ethylene production was decreased when stored at 5°C on 4th day without any change in respiration rate.

Masalkar *et al.* (2006) investigated effect of various post harvest treatments such as waxol (6%), calcium chloride (2%), alone and in combination with fungicides (0.1% carbendazim, 0.2% captan) on shelf life and quality of Alphonso mango fruits in cool chamber (21.36-23.15°C) and ambient condition (27.18-32.57°C), they found that Alphonso mango fruits treated with CaCl₂ (2%) + waxol (6%) + carbendazim (0.1%) could exhibit slow increase in TSS, total sugars and total carotenoids content as compared to control and slow decrease in acidity.

Qiuping *et al.* (2006) examined the effect of different concentration of 1-MCP (0, 40 and 80 nl l⁻¹) on different physiological parameters like release of ethylene, chlorophyll degradation during ripening of sapodilla fruit under control atmospheric condition (20±1°C) and 80-90% relative humidity. They observed that the fruits exposed to 1-MCP had a lower respiration rate than control fruits during storage. The inhibition of the respiration enhanced with the increase of the concentration of 1-MCP from 1 to 80 nl l⁻¹. They further observed that 1-MCP treatments delayed respiration rate by 6 days and also significantly delayed the chlorophyll degradation, thus delayed the skin colour change.

Manganaris *et al.* (2008) investigated effect of 1-MCP immersion (5 min) formulations (0, 10, 100, 1000, 10,000 ng kg⁻¹) followed by ripening at 23°C and at cold storage (5°C) for 10 days. They found that all 1-MCP immersion formulation reduced the respiration rate and suppressed ethylene production in fruits treated with 1-MCP (1000 and 10,000 ng kg⁻¹).

Mao *et al.* (2007) studied the effect of 1-MCP (1 µl l⁻¹) application prior to cutting on quality of 'kiwifruit' and reported that 1-MCP treatment resulted reduction in respiration rate and ethylene production and lowered electrolyte leakage.

Pandey and Singh (2007) studied the comparative performance of 1-MCP and KMnO₄ on release of ethylene during the ripening period of cv. Lucknow safeda under ambient condition and reported that the rate of release of ethylene was minimum in 100 ppm 1-MCP treated fruits than control throughout the storage period.

Singh and Pathak (2008) studied the response of 1-MCP on respiration rate and ethylene evolution and associated post harvest physiological changes in three mango cultivars viz., Chausa,

Dashehari and Langra during storage under ambient conditions. They observed that irrespective of varieties 1-MCP treated fruits remained significantly firmness even after 7th day of storage compared to control.

Ozkaya and Dundar (2009) investigated the effect of 1-MCP (325 and 650 n l l^{-1}) at 20 $^{\circ}\text{C}$ for 24 hours on apple quality cv. 'Fuji' under 8 months of cold storage at 0 $^{\circ}\text{C}$ and 85-95% RH. They observed that 1-MCP suppressed internal ethylene concentration over control.

Chaiprasart and Hansawasdi (2009) determined the efficiency of different doses of 1-MCP (0, 500 and 1000 ppb) with different exposure time (0, 6 and 12 hrs.) in mango fruits cv. Nam-dawg-mai-sri-tong kept at 20 $^{\circ}\text{C}$ for ripening. The results indicated that the higher dose of 1-MCP (1000 ppb) exposed at 6 or 12 hours extended the shelf life for 15 days in association with suppression of respiration and ethylene evolution.

Wang *et al.* (2009) carried the investigation on effect of 1-MCP (1 $\mu\text{l l}^{-1}$ and 5 $\mu\text{l l}^{-1}$) and exogenous ethylene (5 $\mu\text{l l}^{-1}$) on green mature mango fruits of cv. Tainong which were exposed for 24 hours and stored at 20 $^{\circ}\text{C}$ up to 16 days. They witnessed that 1-MCP maintained fruit firmness while ethylene decreased fruit firmness. They noticed that exogenous ethylene accelerated the increase in ethylene and 1- amino cyclopropane -1- carboxylate (ACC) oxidase whereas 1-MCP reduced both. Exogenous ethylene stimulated and 1-MCP inhibited the production of H $_2$ O $_2$ of mango fruit during storage.

Sankhla *et al.* (2010) studied the effect of 1-MCP (0, 100, 200 400 n l l^{-1}) on change in certain chemical constituents and quality in *Ziziphus mauritiana* fruit of cv. Seb, in which they reported that 1-MCP treatments irrespective of doses considerably prevented chlorophyll degradation.

While studying the effect of different concentrations of 1-MCP (0.5, 1 and 2 $\mu\text{l l}^{-1}$) on physiological and biochemical changes in kiwifruit cv. Allison, Jamel *et al.* (2011) observed that regardless of concentrations of 1-MCP treated fruits maintained low rate of respiration and evolved less ethylene during the course of ripening.

Penchaiya *et al.* (2006) fumigated Nam Dokmai mango fruits with different concentrations of 1-MCP (250, 500 and 1000 ppb) for 24 hours at 25 $^{\circ}\text{C}$ followed by storage at 20 $^{\circ}\text{C}$. They observed that treatment with higher concentrations of 1-MCP (500 and 1000 ppb) resulted lower respiration rate and ethylene production.

2.4 INFLUENCE OF 1-MCP ON ORGANOLEPTIC EVALUATION OF RIPE ALPHONSO MANGO FRUITS

Kondo *et al.* (2005) investigated the aroma volatile biosynthesis in two apple cultivars (Delicious and Golden Delicious) affected by 1-MCP and Methyl Jasmonate (MeJA) during ripening. Forty – four volatile compounds in Delicious and 40 compounds in Golden Delicious were detected. They further observed that, aroma volatile production was high in untreated control and ethephon treatments. While, it was lower in 1-MCP treated fruits as compared to untreated control.

Rathore *et al.* (2007) studied the effect of storage periods (0, 3, 6, 9, 12, 15 days) on different physiological properties of Dashehari mango under ambient condition and they observed that, the storage period significantly regulated the average per cent taste (5.00 to 8.46) and flavour score was increased from 5.0 to 7.61.

Mahajan and Gagandeep (2008) evaluated the effect of gaseous vapour treatment at various concentrations of 1-MCP (100, 200 and 300 ppb) on storage life and various quality attributes of guava cv. "Allahabad Safeda" and observed 1-MCP @ 300 ppb treated fruits when stored at 6 \pm 1 $^{\circ}\text{C}$ and 90-95 per cent RH could maintain significantly higher sensory qualities.

Occurrence of spongy tissue (internal flesh breakdown) in ripened fruits of Alphonso has received great attention of the scientists for the last 30 years due to worldwide expansion of mango production and assured fruit quality for International trade. The incidence of flesh breakdown is not confined only to Alphonso in India but it has also been reported from as many as 23 mango producing countries in the world (Victor and Craknell, 1996) including Australia (Winston, 1986), Florida (Young, 1957), Venezuela (Diaz *et al.*, 1971) and South Africa (Lelyveld *et al.*, 1979).

The occurrence of spongy tissue in Alphonso mango was first reported by Cheema and Dani (1934). It is due to the development of yellowish white corky patches, soft and spongy in nature, with

or without air packets accompanied by off flavour, which ultimately deteriorates the quality of fruits (Gunjate *et al.* 1982 and Patkar *et al.* 1984).

This disorder is known in different countries with different names *viz.*, flesh breakdown in India (Krishnamurthy, 1981), Australia (Winston, 1986) and Florida (Malo and Campell, 1982); jelly seed in Australia and South Africa (Brodrick and Thord, 1982); lumpy tissue in Thailand and Philippines (Lizada *et al.* 1984); ricey tissue in Philippines (Lizada *et al.* 1984) and spongy tissue in India (Subramanyam *et al.* 1971). Besides Alphonso, other important mango cultivars in international market like Tommy Atkins, Kent, Keitt, Irwin and Sensation (Malo and Campell, 1982); Carbo and Pico of Philippines (Lizada *et al.*, 1984) and Kensington of Australia (Chaplin, 1986) suffer from International Food Business.

Worldwide research work on this malady has been reviewed extensively by Katrodia (1988), Wain Wright and Burbage (1989), Lad (1990), Joshi and Roy (1985a), Katrodia and Bhuva (1993) and Victor and Craknell (1996). However, in recent times, a significant progress has been made in order to find out the main cause and remedy for this malady.

Joshi and Roy (1985a) reported that most of the research workers found that 1-MCP treated fruits scored more organoleptic score in respect of colour as compared to non-treated fruits during ripe stage.

Woolf *et al.* (2005) reviewed that 1-MCP treatment acted as a tool to reduce physiological disorders such as internal but not external chilling injury in avocado. However, more delay in ripening may increase decay development.

Watkins (2007) suggested that, in addition to the effects of 1-MCP on ripening and senescence of fruit and vegetables, it can greatly influence susceptibility of these products to physiological and pathological disorders. These effects must be taken into account in commercial application of 1-MCP based technology.

Watkins (2008) reviewed that, 1-MCP inhibits or delays the development of some disorders in apple such as senescence breakdown and superficial scald while increasing sensitivity to external carbon dioxide injury.

Burondkar *et al.* (2009) concluded that 1-MCP treatment had significant effect on incidence of spongy tissue which significantly reduced the overall incidence by 66.10 per cent i.e. 26.55 per cent in control to 9.90 per cent in 1-MCP treatments. Further, they reported that 1-MCP treated fruits showed significantly more score on flavour over control.

Burondkar *et al.* (2013) assessed at different intervals *viz.*, after 14, 21 and 28 days of storage and shelf life behaviour at two stages (0 and 5 days) after storage and reported that an organoleptic ratings were found to improve by 1-MCP treatment with 21 days storage plus 5 days shelf life (6.78%) and 28 days storage with zero days shelf life (6.45%) over control (6.33%) with significant reduction in occurrence of spongy tissue (physiological disorder) from 25.07 per cent in control to 9.45 to 12.34 per cent in both of these 1-MCP treatments, respectively.

2.5 INFLUENCE OF STORAGE CONDITIONS ON PHYSICAL CHANGES AND RIPENING BEHAVIOUR

Mukherjee (1960 and 1958) studied the right stage of maturity for cold storage in Dashehari, Langra, Chausa and Fazli Zafrani cultivars and found that, the fruits which sank in water were kept better in cold storage at 48-51⁰F and exhibited all physical changes of normal ripe fruits, rather than those floated on water.

According to Agnihotri *et al.* (1963) Dashehari mango fruits stored at 90-100⁰F (32.3-37.7⁰C) had post harvest life up to 20-22 days at room temperature with three distinct stages *viz.*, ripening, senescence and decay. During storage, the fruits started shrinking in dimensions and developing wrinkles on the surface gradually lost its weight. The average weight loss in control, pal and waxed fruits was 12.34, 6.46 and 9.91 per cent respectively.

Akamine (1963) stored haden mangoes at 35, 45 and 55⁰F for various periods up to 4 weeks and reported that ripe fruits remained in good condition only for one week at 55⁰F and 4 weeks at 35-45⁰F while mature green, ¼ ripe, ½ ripe, ¾ ripe remained in good condition for two weeks at 55⁰F during storage. He opined that the ripening was dependent on maturity of fruits.

Lakshminarayana and Subramanyam (1971) reported that when Alphonso mangoes were stored at 13°C no chilling injury was observed.

Sadasivam *et al.* (1971) reported that the fully mature fruits of Neelum showed chilling injury at refrigerated storage conditions (with 6 ±1°C and 9 ±1°C with 85 to 90% RH) within 15 days while, in 'Banglora' the external symptoms of chilling were not so clearly marked but the ripening was irregular.

Verma and Bajpai (1971) studied the effect of low temperature (20°F) on storage in Fazli Kalan, Taimuriya, Lucknow Safeda and Summer Bahist Chausa varieties of mango and analysed at fortnightly interval of 3 months and found no significant weight loss during storage.

According to Musa (1974) the fully mature fruits of Totapuri at half ripening showed more chilling injury than the half ripened fruits when stored at 6 or 13°C and 85 per cent RH. The size of Alphonso fruits influenced the chilling injury while stage of maturity had no significant effect when stored at 7, 10 and 13°C (Musa and Mirghani, 1974).

Singh (1974a, b) reported that the optimum cold storage temperature range for mangoes to be 45 to 48°F with a relative humidity of 85- 90 per cent. The storage life varied from four to eight weeks, depending upon the variety and stage of maturity. The fruits of Alphonso variety proved well in cold storage. Fruits picked when mature but still green and hard condition can be stored satisfactorily at 45 to 48°F for seven weeks and subsequently ripened at ordinary temperature. He also recorded the storage life of Pairi variety up to 6 weeks at 45-48°F and 85-90 per cent RH.

Aziz *et al.* (1976) reported that the mature fruits of Pairi cultivars kept at 5°C showed better quality than fruits at any other storage temperatures and it was almost double than those stored at room temperature.

Subramanyam and Krishnamurthy (1976) reported that the Alphonso mango fruits having specific gravity in the range 1.00-1.02 at harvest found to be optimum stage for storage.

Kapse *et al.* (1979) reported that Malda, Mulgoa and Neelum cultivars of mango stored at room temperature started decaying after 10 days. The PLW of these fruits during storage was found to be 15.20 per cent, 16.33 per cent and 13.19 per cent respectively at the end of shelf life.

Yuniarti (1980) reported that local mangoes (cv. Arumanias) stored at room temperature (+26°C) for 14 days, fruit texture was deteriorated with time and eating condition was reached in 8-10 days. After that, part of pulp became brown and fruit over riped.

Joshi and Roy (1985b) reported that, in Alphonso mango fruits during transport and storage had higher with higher specific gravity followed by increase in PLW and pH of the fruits. The Alphonso fruits with specific gravity 1.00 to 1.04 could be considered as best for both shelf life and nutritive values.

Naik (1985) reported that the chemical changes in Alphonso fruits at cool chamber were slower than those stored at ambient temperature and the fruits at ambient temperature were more palatable than those ripening at cool chamber.

Upadhyay and Tripathi (1985) reported that the fruits (Gaurijeet mango) stored at ambient temperature (32-35 °C) had shelf life of 6 days.

Vazquez-Salinas and Lakshminarayana (1985) stored Haden, Erwin Kent and Keitt mangoes at 16°C to 28°C and 85-90 % RH to determine optimum storage conditions and reported that at higher temperature (25-28°C), weight loss was higher than those at lower temperature (16-22°C). They recommended 20-22°C as most suitable temperature for storage.

Gole (1986) studied the effect of lower temperature with high humidity (12.7-15°C, 85-89% RH) on storage Alphonso, Pairi and Seedling mango varieties, and reported that, the PLW was least in all varieties at cold storage but their palatability was lower than those stored at room temperature. At cold storage mango fruits recorded more shelf life (24, 18 and 24 days in Alphonso, Pairi and Seedling mango, respectively) compared to cool chamber (15, 10 and 16 days in Alphonso, Pairi and Seedling mango respectively) and at ambient temperature (12, 9 and 14 days in Alphonso, Pairi and Seedling mangoes respectively). The fruits at ambient temperature recorded maximum physiological loss in weight, shrivelling and spoilage as compared to cool chamber and cold storage. Pairi fruits recorded maximum PLW at all storage conditions than Alphonso and seedling mango.

Kalra *et al.* (1986) studied the ripening behaviour of Dashehari mangoes at room temperatures (30°C and 25°C) and observed that, after 8 days, the fruit ripening was well under

ambient conditions although there was slight shrinkage in few fruits. While at 30°C the fruits were shrivelled with subdued ripening and at 25°C fruit appearance was good and had slightly sour taste. The PLW after 10 days of storage, was highest (26.2 per cent) at 30°C and the lowest (13.0 per cent) at 25°C. There was extensive shrinkage of fruits at 30°C, slight at room temperature and no shrinkage at 25°C. Even after 16 days, PLW at 25, 50 per cent, fruits were marketable.

Hardenburg *et al.* (1986) found that, the storage under low temperatures has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and rotting.

Sethi (1987) studied the quality characteristics of ripening in Chausa mango fruits treated with calcium carbide under ambient conditions. He observed that PLW increased in Chausa mango irrespective of ripening treatments. In another study, he observed that mango ripened at 11.5 days storage at ambient temperature and PLW was 14.0 per cent.

Badar (1990) carried out storage studies on Ratna and Kesar varieties of mango and reported that, the fruits ripened at ambient temperature were more palatable than those at cool chamber but, the PLW was higher at ambient temperature than cool chamber. Ratna fruits ripened earlier than Kesar fruits. Kesar fruit was found better than Ratna as far as shelf life and palatability were concerned.

Patil (1990) found that the Pairi mango fruits recorded faster rate of ripening followed by Ratna, Alphonso and Kesar. The maximum ripe fruits were observed on 12th day of storage in all varieties under this study. Maximum shelf life was observed in Alphonso (15 days) followed by Ratna and Kesar (13 days) and minimum (10 days) in Pairi. At ambient temperature storage, Alphonso, Ratna, Kesar and Pairi mango fruits showed variation in PLW (16.21%, 15.13%, 14.66% and 17.19% respectively) after 20 days of storage period.

McCullum *et al.* (1993) kept Keitt mango fruits at 38°C for 0, 24 or 48 hrs. before storage and they were subjected to at 5°C for 11 days of storage. The non heated fruits show chilling injury symptoms like severe pitting of rind and discolouration after 11 days of storage. These chilling injury symptoms decreased with increase in duration at 38°C. Respiratory rates were slightly higher in non heated fruits than heated ones after storage. They also reported that mango tolerance to chilling injury may be increased after pre storage heat treatments.

Rangavalli *et al.* (1993) noticed that per cent of PLW gradually increased during ambient temperature storage and reached maximum of 11.50 per cent at 8th day in Baneshan mango fruits and attained ripening stage after a mean of 5.5 days. Spoilage was initiated at 6th day (25.16%) and it was 100 per cent at 12th day.

Sahani *et al.* (1994) reported that in Amrapali mango fruits, PLW was 12 per cent at 15th day of storage at ambient temperature. The fruits had an appealing colour on 6th day of storage.

Patil (1996) reported that Pairi fruits recorded faster rate of ripening followed by Amrapali, Ratna, Kesar and Alphonso. Spoilage was also highest in Pairi fruits followed by Ratna, Kesar and Amrapali fruits and minimum was in Alphonso mango fruits (41.67%) at the end of storage period. The PLW increased continuously throughout the storage periods irrespective of varieties, and it was maximum in Pairi (26.57%) and minimum in Ratna (17.19%).

Lopez *et al.* (2000) evaluated the effect of concentrations (8.16 and 24 g l⁻¹) of edible sucrose – polyester coating film on ripening and quality changes in mango fruits stored at 13°C and 85 per cent RH. They observed that irrespective of concentrations of edible coating registered higher titratable acidity, full firmness and intensity of green colour in coated fruits while, physiological loss in weight and pH were lower with non coated fruits.

Minz *et al.* (2004) investigated the effect of different treatment combinations involving captan (2000 ppm), GA₃ (50 ppm) and newspaper wrapping on physiological loss in weight and spoilage percent of mango cv. Chausa Sabor (Bihar). They found maximum physiological loss in weight in untreated fruits (35.43%) while minimum PLW (24.13%) was recorded in a treatment involving captan (2000 ppm) for 5 minutes + News paper wrapping and lowest spoilage (11.66%) on the 15th day of storage gaining maximum score of 85.6 as compared to fruits treated with 2000 ppm captan + news paper wrapping.

Masalkar *et al.* (2006) investigated the effect of various post harvest treatments with waxol (6%), calcium chloride (2%), alone and in combination with fungicides carbendazim (0.1%), captan

(0.2%) on shelf life and quality in Alphonso mango fruits in cool chamber (21.36 - 23.15⁰C) and ambient condition (27.18 -32.57⁰C). They found that Alphonso mango fruits treated with CaCl₂ (2%) + waxol (6%) + carbendazim (0.1%) could be kept up to 22 days in cool chamber as against 16 days at room temperature.

Rathore *et al.* (2007) studied the effect of storage period (0, 3, 6, 9, 12, 15) on different physiological properties of Dashehari mango fruits under ambient condition and they observed that, the storage length significantly regulated the average per cent weight loss (0.00 to 36.1%), skin colour score (5.0 to 8.7) and texture (6.00 to 8.68).

2.6 INFLUENCE OF STORAGE CONDITIONS ON PHYSICO-CHEMICAL CONDITIONS DURING RIPENING PROCESS

Cheema and Dani (1934) stored the fruits of Alphonso at 45-48⁰F at four different stages of maturity and considered 'B' stage (the shoulders outgrown, the stem end colour olive green) as the best for cold storage. However, chilling occurred in 'B' stage, at temperature lower than 45⁰F caused severe pitting and rotting. The total sugar content was normal and there was positive correlation between acid content of green fruit and length of cold storage life.

Chaudhary (1950) reported that at room temperature, the total carotenoids and individual carotene pigments of mango raised rapidly to a maximum and then lowered at a temperature above 36⁰C.

Singh and Mathur (1952) observed that ripened mangoes (Alphonso and Totapuri) stored at 67-70⁰F (19.40-21.1⁰C) and 75-80⁰F (23.9-26.7⁰C) reported better colour development, increased percentage of total soluble solids, increased retention of acids, better sugar acid blend and more ascorbic acid at lower ripening temperature than at higher ripening temperature.

Krishnamurthy *et al.* (1960) reported that in mangoes (Badami, Raspuri, Totapuri and Neelum) total solids, pH, carotens and total sugars increased while acid content decreased during ripening.

Agnihotri *et al.* (1963) found that during storage (at 32 to 38⁰C for 17 days) of Dashehari mango fruits, there was a little change in reducing sugars, while, non reducing sugars increased rapidly during first 4-5 days and then remained constant.

Leon and Lima (1968) reported that the mature green Pico mangoes stored at 72⁰F (22.2⁰C) and 76⁰F (24.4⁰C) with 45-60 per cent RH, recorded decrease in starch, acidity and ascorbic acid and increase in soluble solids and total carotenoids content.

Chaudhary and Farooqi (1969) reported that Sundri, Banganpalli and Seedling mangoes showed increase in TSS and total sugar till ripening, while both acidity and vitamin 'C' content were decreased during ripening.

Krishnamurthy and Subramanyam (1970) reported an increase in total soluble solids, sugars and pH and decrease in acidity and alcohol insoluble residues during ripening of Pairi mangoes under ambient conditions.

Garg *et al.* (1971) reported that Dashehari mango fruits exhibited increase in physiological loss in weight, followed by decrease in sugars, TSS and decrease in acidity and ascorbic acid content during storage.

According to Ram and Date (1971) total sugars increased during storage till ripening and then remained more or less constant in Ketaki mangoes. Total soluble solids were increased throughout the period and acidity decreased.

Thompson (1971a, b) studied the storage behaviour of Jullie, Graham and Ceylon cultivars of mango at 'A', 'B' and 'C' stages (classified by Wardlaw and Leconard, 1936) of maturity. Generally fruits of 'B' stages stored well for 3-4 weeks at 41-44⁰F, found more rotting than fruits of 'A' and 'C' stages and higher TSS in fruits.

Verma and Bajpai (1971) studied low temperature storage of Fazli Kalan, Taimuriya, Lucknow Safeda and Summer Bahist Chausa varieties of mango which were stored at 20⁰F and analysed at fortnightly interval of 3 months. They observed that, after long storage, acidity decreased continuously regardless of cultivars and was reversed in case of pH of fruit pulp. While, Fazli Kalan, the reducing sugars decreased gradually in storage and reverse was true for non reducing sugars. In S.B. Chausa,

Taimuriya and Lucknow Safeda, both reducing and non reducing sugars were higher for some time and then decreased.

Lakshminarayana (1973) reported that regardless of the stage of maturity, the chemical constituents such as titratable acidity and apparent ascorbic acids showed decrease trend whereas, carbohydrates and carotenoids increased and then decreased during ripening of mango.

Kapur (1974) reported that during the period of ripening the TSS values were 12.0, 11.5 and 8.5 per cent in Dashehari, Safeda and Samar Bahisht cultivars of mango respectively. Further a fully ripened stage TSS increased to 19.0, 18.0 and 20.0 per cent in these varieties, respectively. However, in later stage of ripening, overall increase in the values of TSS in all varieties was observed. Similar trend was observed in case of reducing sugars, total and non reducing sugars. While acid was decreased throughout the storage period.

Lakshminarayana (1975) reported that mango cultivars Haden, Irwin and Kent were harvested at two periods viz., on attaining physiological maturity and second fruits were physiologically over matured. Physiologically mature fruits stored at 25°C showed an increase in TSS total sugars and β-carotene and storage life was about 12-14 days. Whereas physiologically over matured fruits showed a reduction in TSS slight increase in sugars and carotenoids.

Mann and Singh (1975a and b) stored Langra and Dashehari fruits of mango at 45-48°F and at 85-90 per cent relative humidity, and reported that Dashehari fruits were stored in cold immediately after harvest or after 2-4 days holding at ambient temperature. The fruits stored immediately after harvest and after two days of harvest were in good condition for upto 35 days while those stored after four days of harvest were in good condition only up to 25 days. There was steady increase in TSS and total sugars with corresponding decrease in acid content as the storage period increased in all treatments.

Passera and Ali (1978) observed an increase in pH, sugars and carotenoids during storage ripening.

According to John *et al.* (1979) the total carotenoids increased during ripening upto a certain stage and then decreased when, stored at room temperature.

Kapse *et al.* (1979) reported that Malda, Mulgoa and Neelum varieties of mango stored at low temperature were in good condition upto 30 days in case of Mulgoa and Neelum and upto 37 days in case of Malda, and afterwards they started decaying. The quality of low temperature stored fruits was impaired considerably as there was no proper development of sugars and carotenoids and there was less reduction in acid content during entire period of storage.

Mukherjee and Srivastava (1979) reported that critical chilling temperature is governed by TSS content of fruit. Chilling temperature in mango could be lowered by increasing the TSS through ripening process at optimum storage conditions (9-15°C) and then fruits were allowed to store at lower temperature (4-6°C) without any chilling effect. They further reported that, the storage life of Langra and Dashehari could be increased upto 12 weeks when they were kept at 9°C for one week so that TSS should increase to 8 - 8.5 per cent followed by fruits stored at 4.5 – 6°C against 4 weeks at 9°C .

According to Thomas and Beyera (1979), acidity decreased during ripening process of the fruits in post harvest storage under ambient conditions.

Fuchs *et al.* (1980) reported that during first 8 days storage of mango there was a gradual increase in the total reducing and non reducing sugars, while on 10th day there was a decrease in both reducing and total sugars content whereas, non reducing sugar content continued to accumulate. The acidity was decreased from harvest to ripening and practically it was nil on the 10th day.

Thomas and Oke (1980) reported that the Alphonso, Dashehari, Langra and Pairi fruits stored for several days at ambient temperature (29-32°C) lost vitamin 'C' content more rapidly than the fruits stored at 20°C.

Yuniarti (1980) reported that local mangoes (cv. Arumanias) stored at room temperature (+26°C) for 14 days showed no significant differences in total soluble solids, acidity, reducing and non reducing sugars. Fruit texture was deteriorated with time whereas, pH increased. Best eating condition was attained at 8-10 days. After this, parts of pulp become brown and fruits were over riped.

Asraf *et al.* (1981) reported that, during the storage and ripening of Chausa, Langra, Dashehari and Anwar Ratul, vitamin 'C' content, total soluble solids and carotenoids showed an increase trend and thereafter it was decreased. While, moisture content and pH increased.

Deol (1985) reported that the titratable acidity and ascorbic acid contents decreased during storage. During fruit ripening total acidity decreased rapidly and during senescence reduction in ascorbic acid was more pronounced. The reducing sugars exhibited the similar trend as observed in total soluble solids. The percentage of reducing sugars decreased with the length of storage life (20 days) in Samar Bahisht, Chausa varieties of mango.

Joshi and Roy (1985b) reported that in Alphonso mango fruits during transport and storage a rise (higher with higher specific gravity) followed by a decline in TSS reducing and total sugars and total carotenoid pigments was observed. The non reducing sugars after attaining a peak remained more or less constant whereas the moisture, acidity ascorbic acid and tannins declined continuously and the reverse was with PLW and pH of the fruits. The Alphonso fruits with specific gravity 1.00 to 1.04 could be considered best as far as both shelf life and nutritive values concerned.

Naik (1985) observed an increase in TSS sugars and total carotenoids of mangoes (cv. Alphonso) during storage till ripening followed by decrease upto end of storage period irrespective of specific gravity and storage conditions. The moisture, starch, titratable acidity and ascorbic acid content of the fruit went on declining. While pH increased throughout the storage period.

Vazquez-Salinas and Lakshminarayana (1985) stored Haden, Erwin Kent and Keit mangoes at 16 to 28^oC and at 85-90 per cent RH to determine optimum storage conditions. At higher temperature (25-28^oC) β - carotene was higher than that of fruits stored at lower temperature (16-22^oC). There was no significant difference in carbohydrates and soluble solids. In all varieties pattern of chemical changes was similar. They recommended that 20-22^oC is most suitable temperature for storage of mangoes, for good acceptability.

Medlicott *et al.* (1986) studied the effect of temperature on ripening of mango cv. Tommy Atkins and reported that fruits stored at 22, 27 and 32^oC had higher β - carotene, good texture and sugar: acid ratio. Time taken to reach optimum quality was 8 days at 22^oC and 5 days at 27-32^oC. While, fruits stored at 12^oC did not ripen to attain full eating quality within 16 days of experiment. Acid levels in these fruits were quite high and they retained some green colouration and they had lower carotenoids and showed incomplete softening, with low sugar: acid ratio.

Gole (1986) stored Alphonso, Pairi and Seedling mango varieties at low temperature (12.7-15^oC and 85-89% RH) and reported that the biochemical changes with respect to moisture, sugars, ascorbic acid, TSS, acidity, β -carotene were slowest in cold storage irrespective of varieties. There was slight increase in TSS, pH and sugars while, acidity and ascorbic acid were also lower than fruits stored at cool chamber and ambient temperatures. At cold storage, mango fruits recorded more shelf life (24, 18 and 24 days in Alphonso, Pairi and Seedling mango, respectively) compared to cool chamber (15, 10 and 16 days in Alphonso, Pairi and Seedling mango respectively) and at ambient temperatures (12, 9 and 14 days in Alphonso, Pairi and Seedling mangoes, respectively).

Sethi (1987) studied the quality characters during ripening of Chausa mangoes treated with calcium carbide under ambient conditions. He observed that during ripening TSS reducing sugar, total sugars and total carotenoids increased, while ascorbic acid and acidity decreased in irrespective of ripening treatments.

Shanta Krishnamurthy and Joshi (1989) made a comparative study on effect of low temperature storage of freshly harvested Alphonso mangoes at 7^oC and at 30^oC, with respect to histological and chemical changes. The changes were similar in fruits stored at both temperatures but there was delay in these changes at 7^oC. Beyond 14 weeks of storage at 7^oC, disruption of mesocarp cells was observed. Carotenoids development was inhibited at 7^oC, disruption at 7^oC, and fruits did not show normal ripening, even after prolonged storage of 5 weeks.

Badar (1990) carried out storage study on Ratna and Kesar varieties of mango and reported that TSS, sugars, pH and total carotenoids increased during storage at ambient temperature, irrespective of varieties, while moisture, titratable acidity, ascorbic acid and tannins decreased throughout in both varieties.

Patil (1990) reported that in Alphonso, Ratna, Pairi and Kesar fruits of mango during storage, TSS, reducing sugars, total sugar, β -carotene increased and attained a peak stage at ripe and subsequently declined towards the end of shelf life. The moisture, titratable acidity, ascorbic acid and

tannins showed a decline till the end of shelf life of mango fruits, while pH increased till the end of shelf life.

According to Salvi (1991) during the storage, ripening of Alphonso mango fruits, TSS, reducing sugar, total sugars, pH and β -carotene increased continuously and attained a peak at ripe stage. While, moisture, titratable acidity and ascorbic acid showed a declined trend.

Rangavalli *et al.* (1993) while studying the post harvest changes in mango cv. Baneshan reported that ripening is normally accompanied with increase in TSS at ripe stage and declines towards the end of shelf life. Titratable acidity decreased during post harvest period. There was a gradual increase in non-reducing and reducing sugar contents at ripe stage.

Sahani *et al.* (1994) studied the effect of ripening aids on quality of Amrapali mango and reported that during ripening an increase in TSS, pH and total carotenoids and decrease in moisture, acidity and ascorbic acid were observed in mango fruits irrespective of ripening aids.

Patil (1996) observed that during storage ripening of Alphonso, Ratna, Pairi, Kesar and Amrapali mango fruits, total soluble solids, reducing and total sugars and β -carotene increased and attained a peak at ripe stage and subsequently declined towards the end of shelf life. The moisture, titratable acidity and ascorbic acid showed a decline trend till end of shelf life of mango fruits of all varieties while, pH was found to increase till the end of shelf life.

According to Singh *et al.* (2007) acidity decreased throughout the storage period of Dashehari mangoes.

2.7 INFLUENCE OF STORAGE CONDITIONS ON PHYSIOLOGICAL CHANGES DURING RIPENING PROCESS

Karmarkar and Joshi (1941) reported that in Alphonso mangoes, there was maximum respiratory peak at 5 days after harvest and fruits ripen within 7 days to 8 days under ambient/normal conditions. While, Akamine and Goo (1973) observed that the respiration decreases as the fruits mature and the respiratory rise then commences with ripening. Whereas, ethylene production decreases as the fruit matures under normal conditions.

Cua and Lizada (1990a) observed the peak of ethylene production in mangoes at 110 days after flower initiation, which declines as the fruits approach full maturity. While, Reddy and Raju (1984) reported that the fruits stored in polybags could be attributed to reduced rate of respiration. Burg and Burg (1967) were first to show the notable peak of ethylene in mango during ripening under normal conditions. Tucker and Seymour (1991) reported that different mango varieties have been shown to exhibit different degrees of softening during storage, which can be grouped as either good or bad which may be due their different ethylene synthesis rate.

The activity of Enzymes, NADP-malic enzyme (NADP-ME) and phosphoenol pyruvate carboxylase generally increases to a peak level during ripening which are mainly responsible for higher respiration rate (Lazan *et al.*, 1993).

Roy and Joshi (1988) reported that the fruits stored at cool storage (10°C) showed maximum storage life, with lower total carotenoid pigments as compared to those fruits ripened at room temperature, irrespective of different packaging. Further, changes in composition of Alphonso fruits in different packaging indicated that CFB box with partition displayed lower carotenoids during storage than any other packaging materials.

Esquerra *et al.* (1978) showed that perlite KMnO_4 inserts reduced ethylene production and retarded the ripening Carabro mangoes enclosed in polyethylene bags (PEB) at 10°C . Chaplin (1988) reported the most obvious visual response of the fruits stored in sealed PEB apparently lost much of their (normal) capacity to degrade chlorophyll in the peel and to synthesize carotenoids in the pulp during ripening.

Peak respiration rates for mango have been reported to be more than $175 \text{ mg CO}_2 \text{ Kg}^{-2}\text{h}^{-1}$ at 25°C in some cultivars, by Brown *et al.* (1984), while, Lam *et al.* (1982), reported that the climacteric pattern of respiration is associated with the onset of ethylene production, with the former preceding the latter in 'Golek'. Cua and Lizada (1989) reported that, in 'Carabro' mango, the internal level of ethylene production rises to only about 0.6 ppm during the climacteric.

Lizada *et al.* (1984) reported that the ethylene production ceases as the fruit becomes over-ripe and ACC, the precursor of ethylene accumulates. While, Dubery *et al.* (1984) observed a

suppression of malate enzyme activity and an altered pattern of respiration in 'Haden' mangoes irradiated at a dose of 0.75 KGy.

A distinct upsurge in respiration rates and ethylene production rates during ripening has been observed in climacteric fruits by Ables *et al.* (1992).

The increase in respiration during ripening of climacteric fruit seems to be a consequence of the increase in ethylene production (Brady, 1987).

Wertheim (2005) reported that early season varieties have high respiration and ethylene production rates and show storability whereas, late season varieties with low ethylene rates and low respiration ripen slowly and can be stored for longer periods.

2.8 INFLUENCE OF STORAGE CONDITIONS ON ORGANOLEPTIC EVALUATION DURING RIPENING

In Trinidad Thompson (1971a and b) studied the storage behaviour of Jullie, Graham and Ceylon cultivars of mango at 'A', 'B' and 'C' stages (according to Wardlaw and Leconard, 1936) of maturity. Generally fruits of 'B' stage of maturity stored well for 3-4 weeks at 41-44^oF, but upon ripening the flavour of the fruit was excellent.

Kapse *et al.* (1979) reported that Malda, Mulgoa and Neelum varieties of mango stored at low temperature were in good condition upto 30 days in case of Mulgoa and Neelum and upto 37 days in case of Malda, and afterwards they started decaying. The quality of low temperature stored fruits was impaired considerably as there was no proper development of colour and taste.

Ramana *et al.* (1984) studied the low temperature storage and ripening behaviour of early and late harvested (15 days after early harvest) Alphonso mangoes and the total storage life of 28 days (22 days at 12.8^oC, RH 90-95%) and 6 days at RT. 22-30^oC 45-63 % RH) for early and 20 days (15 days at 12.8^oC and 5 days at RT) for late harvest compared to 16 and 14 days at RT. stored fruits respectively. The overall quality of low temperature fruits ranged between fair and good, at the end of storage.

Chaplin *et al.* (1991) stored Kensington mangoes upto 4 weeks at 15, 10, 5 or 1^oC and then subjected for ripening at 20^oC. They found that external appearance, flesh colour, aroma, sweetness and general acceptability, declined to unacceptable levels when fruits were stored for longer periods than 2 or 3 weeks at 5^oC and for as little as one week at 1^oC. Storage at low temperature caused an increase in acid content of fruits which explains a corresponding decrease in perception of sweetness. Storage temperature of 10^oC or higher for 4 weeks maintained fruit quality above minimum acceptability rating value but shortened the shelf life.

Rathore *et al.* (2007) studied the effect of storage period (0, 3, 6, 9, 12, 15 days) on different physiological properties of Dashehari mango under ambient condition and they observed that, the storage length significantly regulated flesh colour (5.0 to 8.44), texture (6.00 to 8.68), flavour score (5.0 to 7.61) and average per cent taste (5.0 to 8.46).

MATERIAL AND METHODS

The investigation on "Influence of 1-methylcyclopropene (1-MCP) on post harvest physiology and physico- chemical changes in Alphonso mango (*Mangifera indica* L.)" was undertaken at the Department of Agril. Botany, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during the mango season of 2010-11 and 2011-12. During the investigation ripening behaviour, physical changes, physico-chemical changes, physiological changes and organoleptic evaluation under the influence of 1-MCP at ambient, cold storage, modified atmospheric packaging with and without cold storage conditions were investigated during the course of study. Alphonso mango fruits having 85 per cent maturity were harvested in the month of May 2011 and 2012 and utilized for the experiment.

3.1 DETAILS OF THE EXPERIMENT

- i) Experimental Design : Factorial Completely Randomized Block Design (FCRD)
- ii) Years Experimentation : 2010-2011 and 2011-2012
- iii) Location : Dept. of Agril Botany, Dept. of Horticulture, Dept. of Processing Engineering at Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli.
- iv) Crop/Cultivar : Mango (Alphonso)
- v) Fruit maturity at harvest : 85 per cent maturity (Specific gravity 1.01-1.02)
- vi) Treatment details
 - Main treatments (Factor 1) : Storage conditions
 - i) S₁- Ambient condition (control)
 - ii) S₂ - Cold storage at 13± 1⁰C
 - iii) S₃ – Cold storage 13± 1⁰C with shrink wrapper
 - iv) S₄ - Ambient condition with shrink wrapper
 - Factor 2 : Concentrations of 1-MCP
 - i) C₁- 0 ppb (control)
 - ii) C₂- 1000 ppb
 - iii) C₃- 2000 ppb
 - iv) C₄- 3000 ppb
- vii) Treatment combinations : 16 as given below
 - 1. C₁S₁ : Control *i.e.*, Ambient storage of fruits without 1-MCP
 - 2. C₂S₁ : Ambient storage of fruits treated with 1-MCP @ 1000 ppb
 - 3. C₃S₁ : Ambient storage of fruits treated with 1-MCP @ 2000 ppb
 - 4. C₄S₁ : Ambient storage of fruits treated with 1-MCP @ 3000 ppb
 - 5. C₁S₂ : Cold storage (13± 1⁰C) of fruits without 1-MCP
 - 6. C₂S₂ : Cold storage (13± 1⁰C) of fruits treated with 1-MCP @ 1000 ppb
 - 7. C₃S₂ : Cold storage (13± 1⁰C) of fruits treated with 1-MCP @ 2000 ppb

8.	C ₄ S ₂	:	Cold storage (13± 1 ⁰ C) of fruits treated with 1-MCP @ 3000 ppb
9.	C ₁ S ₃	:	Cold storage (13± 1 ⁰ C) of shrink wrapped fruits without 1-MCP
10.	C ₂ S ₃	:	Cold storage (13± 1 ⁰ C) of shrink wrapped fruits with 1-MCP @ 1000 ppb
11.	C ₃ S ₃	:	Cold storage (13± 1 ⁰ C) of shrink wrapped fruits with 1-MCP @ 2000 ppb
12.	C ₄ S ₃	:	Cold storage (13± 1 ⁰ C) of shrink wrapped fruits with 1-MCP @ 3000 ppb
13.	C ₁ S ₄	:	Ambient storage of shrink wrapped fruits without 1-MCP
14.	C ₂ S ₄	:	Ambient storage of shrink wrapped fruits with 1-MCP @ 1000 ppb
15.	C ₃ S ₄	:	Ambient storage of shrink wrapped fruits with 1-MCP @ 2000 ppb
16.	C ₄ S ₄	:	Ambient storage of shrink wrapped fruits with 1-MCP @ 3000 ppb
viii)	No. of fruits / treatment	:	150
ix)	No. of Replications	:	Three
x)	Total No. of fruits per treatment	:	450
xi)	Total No. of fruits	:	7200
xii)	Source of 1-MCP	:	Rohm & Hass India Pvt. Ltd. through Global Agri. System Pvt. Ltd.
xiii)	Source and type of Shrink wrapper film	:	Pin holes 15 μ polyolefin film bags packed and passed from the shrink wrapper machine at 160 ⁰ C at speed 1.

3.2 SELECTION OF FRUITS AND IMPOSITION OF TREATMENTS

Physiologically mature, hard green fruits having 85 per cent maturity (stage 'B') of mango cv. Alphonso were harvested from 30 years old Alphonso mango orchards belonging to Department of Horticulture, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli on a single day and taken to packing centre of the Department. Except the fruits required for absolute control (1800 fruits), rest of the 5400 fruits were stored in air cooled chamber for removing the field heat till the fruit temperature reaches 13⁰C. This was followed by de-stalking, washing of fruits and dipping into bio-safe solution (disinfectant) for 5 minutes followed by air drying. In all, 7200 fruits of uniform size, weight of a desirable maturity (specific gravity 1.01-1.02) were selected and placed in 96 plastic crates, of each with the capacity of accommodating 75 fruits. Further, these fruits in the crates, exposed to various treatments as per the above treatment details (Plate 1).

Fruits under ambient storage conditions were stored in ordinary rooms with room temperature ranging from 26⁰C (night) to 34⁰C (day) with sufficient aeration. For 1-MCP treatments at three different concentrations, independent three independent air tight foldable chambers of 4 m x 2 m x 1 m dimension were erected using PVC pipe framework and thick but transparent polyethylene sheet of 200 gauge. The Smart Fresh containing 3.3 per cent of 1-MCP crystalline powder was used as a source for generation of 1-MCP fumes of desired concentrations by gently adding it into 100 ml distilled water in a glass vial, placed in the chambers. To facilitate the uniform spread of the fumes small pen size cell operated fans were placed in the chambers. The 1-MCP treatment was continued



Fruits immediately after the harvest



Grading of fruits before treatment imposition



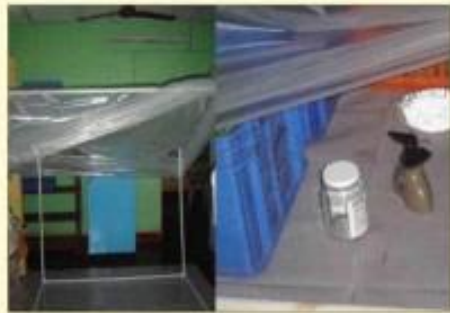
Washing of fruits



Fungicide treatment before treatment imposition



Air drying of fruits

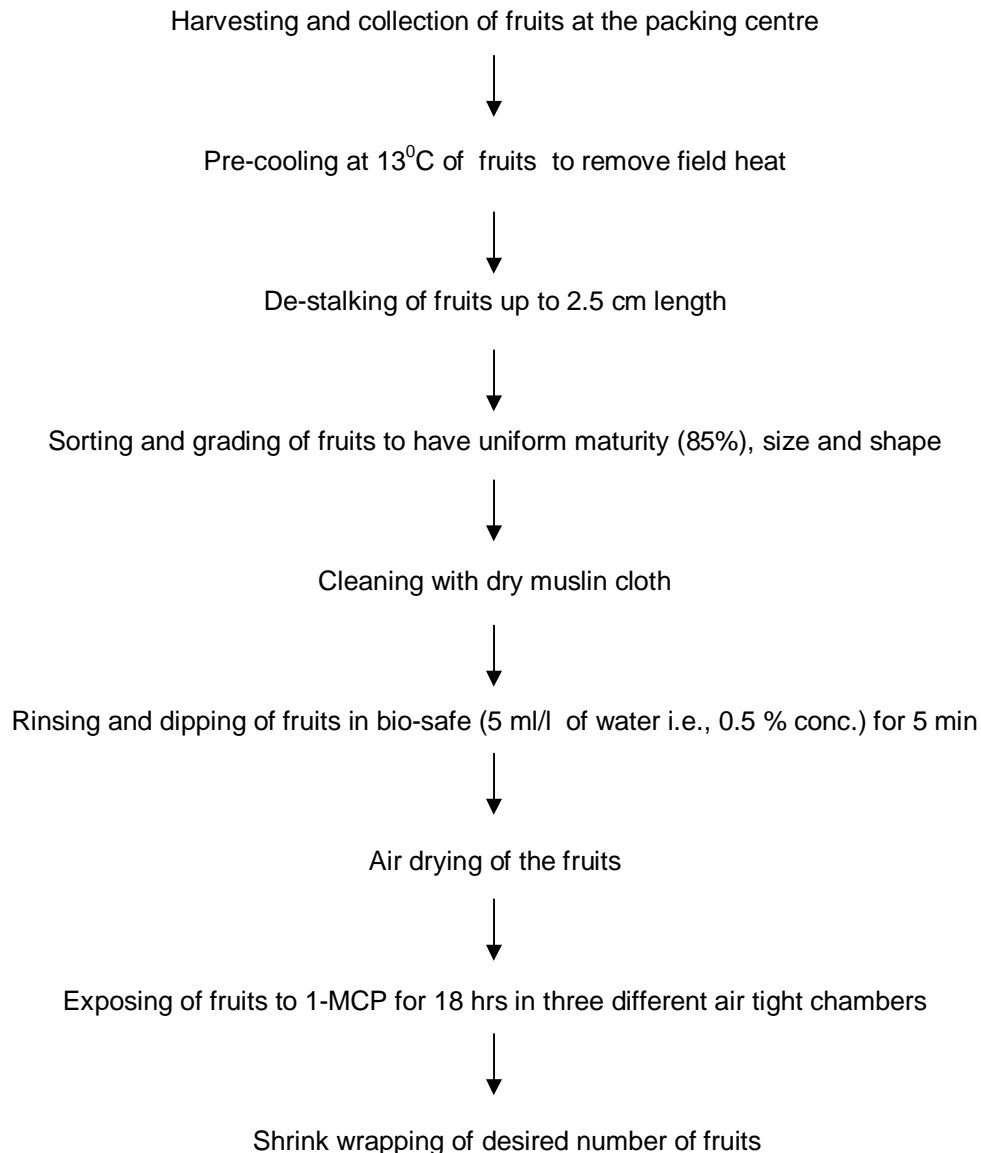


Treatment imposition with 1-MCP

Plate 1 : Steps during imposition of treatments

till 18 hrs in an air-tight fumigation chamber at ambient conditions each accommodating 1800 fruits per dose. Immediately after the 1-MCP treatment, required fruits under shrink wrapper treatment were passed through shrink wrapper machine of PHT laboratory, Department of Horticulture, using pin holes of 15 μ polyolefin film. All the fruits in four batches each with 24 crates were then shifted to the respective storage conditions for studying different aspects of ripening and storage behaviour (Plate 2). For cold storage, blue star make 1000 ft³ vol. walking coolers were used in which the temperature of $13\pm 1^{\circ}\text{C}$ and relative humidity above 85 per cent was maintained till the end of the study period.

Out of 150 fruits per replica, 100 fruits were used for periodical observations in relation to ripening behaviour as mentioned in the observations to be recorded, whereas remaining 50 fruits were used for periodical physical, physiological and physico-chemical observations. The flow chart of the activities carried out is indicated below:



Distribution of crates under various treatment categories to respective storage conditions.

3.3 OBSERVATIONS RECORDED

3.3.1 RIPENING BEHAVIOUR OF FRUITS

3.3.1.1 Ripening pattern

To record the ripening pattern, the batch of 100 fruits in each replica was periodically observed and fruits were categorized into six different groups viz.,



Fumigation of fruits with 1-MCP in enclosed chamber



Shrink wrapper treatment of fruits



Shrink wrapped fruits before cold storage



Fruits without shrink wrapper before cold storage



Trays

Plate 2 ; Storage during imposition of treatments

- 1) Green (harvesting stage)
- 2) Turning yellow (breaking of yellow shades on the skin)
- 3) Half ripe (when 50 per cent of the fruit surface turns yellow)
- 4) Ripe (when fruit fully turns yellow)
- 5) Diseased (when fruits get rotten)
- 6) Shrivelled (when fruit develops wrinkles on the peel)

Above changes as a ripening pattern was studied at 4 days interval under different storage conditions.

3.3.2 PHYSICAL CHANGES

3.3.2.1 Colour change

A colour co-ordinate of fruits was measured using, Hunter Lab calorimeter, manufactured by Hunter Associates Laboratory, USA (Plate 3 and Plate 4). It represents the colour in L*, a* and b* value. Where L* indicates the lightness and extends from 0 (black) to 100 (white). The other two co-ordinates a* and b* indicate redness (+ a) to greenness (- a) and yellowness (+ b) to blueness (-b), respectively. The apparatus was previously calibrated with standard white and black tile.

3.3.2.2 Texture

The Texture of Alphonso mango fruits were measured with QTL Texture Analyser (M/s. Brookfield Engineering Labs, Inc., USA, Plate 5). Fruits were exposed to compression force with Probe No. TA3/100 and pretest speed was 0.5 mm/s, compression depth was 10 mm, and trigger load was 10 kg for each fruit. The peak force for compression was reported. The experiment was repeated for 3 times for each replication and average peak force (g) was reported.

3.3.2.3 Physiological loss in weight (PLW)

Five fruits from each replication per treatment were monitored for physiological loss in weight (PLW) at 2 days interval throughout the period of study. At harvest, the raw (green) mango fruits were weighed and the initial weight of fruits was recorded. The loss in weight was calculated by noting down the progressive loss in weight of the fruit from the day of harvest (initial weight) to ripened day (final weight). It was calculated by following formula:

$$\text{PLW (\%)} = \frac{\text{Initial weight of fruit (g)} - \text{Final weight of fruit (g)}}{\text{Initial weight of fruit (g)}} \times 100$$

3.3.3 PHYSICO-CHEMICAL CHANGES

Following physico-chemical changes were recorded in fruits sampled from different treatment combinations at a 0, 7, 14, 21, 26 days of storage.

3.3.3.1 Total soluble solids (TSS)

The juice extracted by crushing the ripe pulp of each fruit was strained through a muslin cloth and used for measuring total soluble solids using a Erma make hand refractometer (0° to 32° Brix range) and the value was expressed as °Brix.

3.3.3.2 Titratable acidity of pulp

Pulp acidity was determined as per the procedure of Ranganna (1985). A composite pulp of 10 g was blended with distilled water using a pestle and mortar. The volume was made upto 100 ml and filtered through Whatman No. 1 filter paper. From this, 10 ml of aliquot was taken and titrated against 0.1 N NaOH to the phenolphthalein end point and expressed as per cent citric acid.



Plate 3: Measurement of fruits colour using Hunter Lab Colorimeter

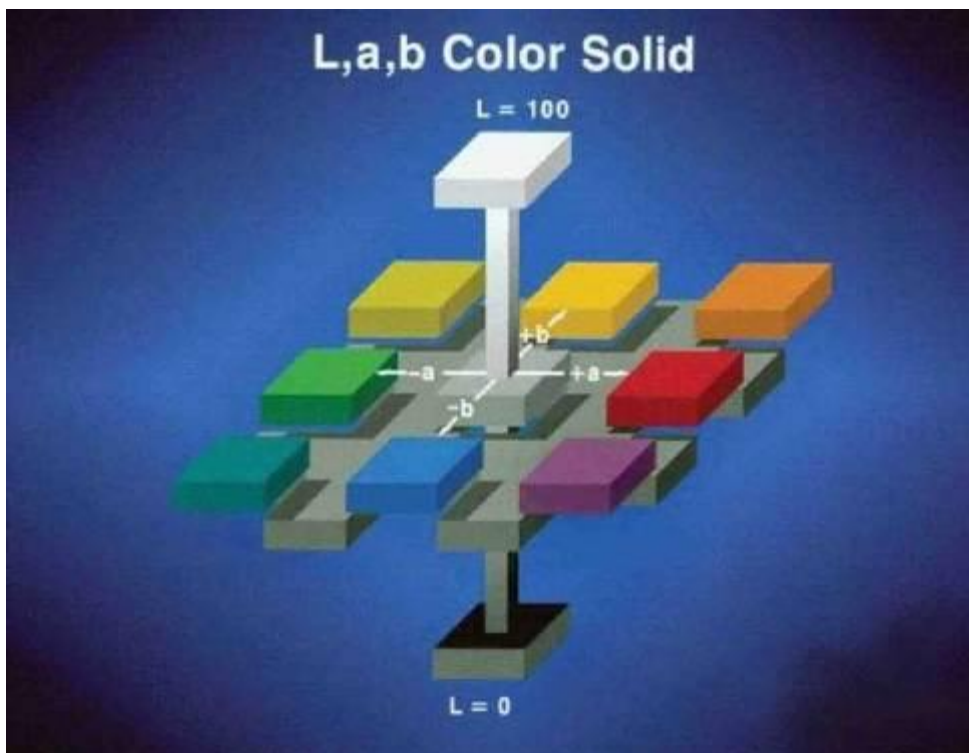


Plate 4 : Hunter Lab colour system



Plate 5 : Measurement of fruit texture using QTL Texture Analyser

3.3.3.3 Estimation of reducing and total sugars

Reducing and total sugars in ripe mango pulp were estimated as per the procedure of Lane and Eynon (1923).

Reagents used

1. Fehling's solution (A): 69.28 g of copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) was dissolved in distilled water and the volume was made upto 1000 ml.
2. Fehling's solution (B): 346 g of Rochelle salt (potassium sodium tartrate, $\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$) and 100 g NaOH was dissolved in distilled water and the volume made upto 1000 ml.
3. Methylene blue indicator: 1g of methylene blue was dissolved in 100 ml of distilled water.
4. Neutral lead acetate solution (45%): 225 g of neutral lead acetate was dissolved in distilled water and the volume was made up to 500 ml.
5. Standard Fehling's solution: Equal quantities of Fehling's solution A and B were mixed.
6. Potassium oxalate solution (22%): 110 g of potassium oxalate ($\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$) was dissolved in distilled water and the volume was made upto 500 ml.
7. Standard invert sugar solution: 9.5 g of AR grade sucrose was weighed into 1.0 litre volumetric flask, to which, 100 ml of distilled water and 5.0 ml of concentrated HCL were added. The contents were allowed to stand for 3 days at 20 - 25°C for inversion to take place and the volume was made upto 1.0 litre. From this, 25 ml of standard invert solution was pipetted out in 100 ml volumetric flask, to which, 50 ml of water and few drops of phenolphthalein indicator were added and neutralized with 20 per cent NaOH until the solution turned pink. It was then acidified by adding drop by drop 1.0 N HCL until the disappearance of pink colour. Volume was made upto 100 ml (1 ml = 2.5 mg of invert sugar).

Procedure for reducing sugars

10 ml of standard Fehling's solution was pipetted in to 250 ml conical flask. A sample solution (mango pulp) was taken in to 50 ml burette and it was titrated against the Fehling's solution in the conical flask until the sugars present are reduced. It is known from the change in colour from blue to dark blue (blue-black). Then, the contents of flask were mixed thoroughly and heated to a boiling point and continued to boil moderately for 2 min. Then, 3 drops of methylene blue solution was added and the titration was continued, until the indicator completely decoloured. At the end point, the boiling liquid turned to brick-red colour due to precipitation of cuprous oxide and the volume of the sample solution (fruit pulp) required was noted for estimation of reducing sugars present in the sample.

Procedure for total sugars

A clarified solution (fruit pulp) was pipetted out in to 250 ml conical flask, to which, 5 g of citric acid and 50 ml of water were added. Then it was boiled gently for 10 minutes to complete the inversion of sucrose and then the contents were cooled. This was then neutralized with 1.0 N NaOH using phenolphthalein indicator.

For inversion at room temperature, a 50 ml aliquot of clarified de-leaded solution was transferred to 250 ml flask, to which, 10 ml of HCL (1N) was added and then allowed to stand at room temperature for 24 hrs. It was then neutralized with NaOH solution. Total sugar content was then estimated by following the same titration procedure adopted for reducing sugars.

Calculations

$$\text{i) Reducing sugars (\%)} = \frac{\text{mg of invert sugar} \times \text{Dilution factor} \times 100}{\text{Titre value} \times \text{weight of sample} \times 100}$$

$$\text{ii) Total sugars invert sugar (\%)} = \frac{\text{mg of invert sugar} \times \text{Dilution factor} \times 100}{\text{Titre value} \times \text{weight of sample} \times 100}$$

$$\text{iii) Sucrose (\%)} = (\% \text{ Total invert sugars} - \% \text{ Reducing sugars}) \times 0.95$$

$$\text{iv) Total sugars (\%)} = (\% \text{ Reducing sugars} + \% \text{ Sucrose})$$

3.3.3.4 Determination of ascorbic acid content

Alphonso mangoes being rich sources of ascorbic acid and are considered as one of the important nutritional quality parameters. Ascorbic acid content in the pulp of ripe mango fruits was estimated by using 2, 6-dichlorophenol-indophenol titration method of Association of Official Analytical Chemists (Anon., 1980).

Reagents

- 3 per cent metaphosphoric acid (HPO_3).
- Ascorbic acid standard: Standard solution of ascorbic acid was prepared by dissolving 100 g of ascorbic acid in 3.0 per cent HPO_3 and the volume was made up to 100 ml.
- Dye solution: Sodium bicarbonate (42 mg) was dissolved in a small volume of glass distilled water, to which, 52 mg of 2, 6 - dichlorophenol indophenol was added and the volume was made upto 200 ml with distilled water. Dye solution was kept in refrigerator before use.

Procedure

Ascorbic acid standard solution (5.0 ml) was pipetted out into a 100 ml conical flask, to which, 5.0 ml of metaphosphoric acid was added. It was titrated against dye solution until the appearance of pink colour which persisted for a few minutes. The dye factor was determined as the amount of dye consumed is equivalent to the amount of ascorbic acid. The ascorbic content in the fruit pulp was estimated by macerating 5.0 g of fresh pulp in 3.0 per cent metaphosphoric acid and filtering through Whatman No. 42 filter paper and the final volume was made upto 100 ml with metaphosphoric acid. From this, 10 ml of the aliquot was pipetted out and titrated with standard dye solution till the pink colour was obtained.

The ascorbic acid content in the sample was calculated by the following formula and expressed as mg/100 g of fresh weight of fruits.

$$\text{Ascorbic acid content (mg/100 g fr.wt.)} = \frac{\text{Titrated value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot taken} \times \text{Weight of sample (g)}} \times 100$$

3.3.3.5 Estimation of Vitamin A

Vitamin A was estimated by working out the procedure for β - carotene and then calculating the vitamin A value as 1 IU (as the biological equivalent of 0.6 μg β - carotene) as given by the Ranganna (1985) as detailed below.

Principle

Carotenoids are generally separated by chromatography. The method is based upon the separation of the biologically active carotenoid pigments from the total carotenoid pigments in an extract by using an adsorbent having varying affinities for different pigments.

Apparatus

1. Pear shaped separating funnels of 500 ml capacity with racks or stands.
2. Adsorption tubes of 150 x 19 mm (inside diameter), made of glass with a constriction at one end to attach a 3-mm glass tubing.
3. Plunger for the preparation of the adsorption column, made of wood, glass or metal disc or the wide end of the cork should be 1 to 2 mm smaller than that of the tube.

Reagents

1. Acetone
2. Petroleum ether
3. Anhydrous sodium sulphate (Na_2SO_4), granular
4. Adsorbent: Mix intimately one part by weight of magnesium oxide (MgO) with three parts of supercel
5. Eluent: 3 per cent acetone in petroleum ether

Procedure

Accurately 25 mg of β - carotene (pure β - carotene ampules are available) weighed and dissolved in 2.5 ml chloroform and made up the volume to 250 ml with petroleum ether. Diluted 10 ml of this solution to 100 ml with petroleum ether and pipetted 5, 10, 15, 20, 25 and 30 ml of this solution to a separate 100 ml volumetric flasks, each containing 3 ml of acetone. Diluted with petroleum ether to make up the volume and the resultant concentration was of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 μg per ml. The colour developed was measured at 452 nm using 3 per cent acetone in petroleum ether as blank. The absorbance was plotted against concentration.

3.3.4 PHYSIOLOGICAL CHANGES

3.3.4.1 Estimation of chlorophyll content

Total chlorophyll of the harvested fruits was determined at 7 days interval during the process of fruit ripening by following the method of Arnon (1949). 250 mg of fresh peel were cut into small pieces and homogenised with pure acetone in a pestle and mortar. The macerate was filtered through Whatman No. 42 filter paper and the extraction was repeated until the residue became colourless.

All the extracts were pooled and the volume was made upto 25 ml with 80 per cent acetone. The absorbance of the extract was measured at 645, 652 and 663 nm in spectrophotometer (Elico, UV-vis, Model CL-254) using 80 per cent acetone as a blank. The chlorophyll content was calculated by using the following formulae;

$$\text{Total chlorophyll} = 20.2 (A_{645}) + 8.02 (A_{663}) \times \frac{V}{1000 \times W \times a}$$

where,

A_{645} = Absorbance of the extract at 645 nm

A_{663} = Absorbance of the extract at 663 nm

a = Path length (1 cm)

V = Final volume of the chlorophyll extract (25 ml)

W = Fresh weight of the sample (250 mg)

The chlorophyll contents were expressed as mg g^{-1} fresh weight

3.3.4.2 Total carotenoids

Total Carotenoids were analysed according to Lime *et al.* (1957) and Umlal and Gabelman (1971), modified by Moretti *et al.* (1998). Pigments were extracted by homogenizing 15 g fresh pulp with 30 ml of acetone in a polytron (PT 1200, Brinkmann Instruments, Westbury, NY) for 1 min at a speed setting of 5. The acetone pigment extract and 45 ml of hexane were mixed in a separatory funnel and, after phase separation, the lower phase was discarded and the pigment-hexane extract was washed three times with 100 ml of deionised water. After the final wash, the extract was transferred to a 100 ml volumetric flask and the volume was made up with hexane. Absorbance was read in a Spectrophotometer 9 Hitachi Model 550 (Japan) at 451 nm and 503 nm. Total carotenoids were expressed as $\mu\text{g}/100\text{g}$ of fresh pulp.

3.3.4.3 Respiration Rate and Release of ethylene

Glass bottles of 3.45 litre capacity with metal lids were used for packing mangoes. A 12-mm-diameter hole was drilled in the lid through which a rubber septum was tightly inserted. This rubber septum served for inserting needles to draw gas samples from the bottles. For the storage study, three Alphonso mango fruits were placed in the bottles. Then the lids were placed and the bottles were made air-tight using siliputin.

While drawing gas samples, care was exercised to discard about 0.5 ml gas to make sure the drawn gas sample was a true representative of the micro-environment gas. The gas samples were analysed using a gas chromatograph (nucon – 5765, AIMIL Ltd, India). The gas chromatograph was equipped with a thermal conductivity detector, a molecular sieve and chromo sob 102 columns

arranged in series. The injector, detector and oven temperatures were maintained at 80, 80 and 60°C, respectively. The gas was analysed till the O₂ concentration in the bottles fell below 1 per cent. All experiments were replicated three times. The changes in O₂ and CO₂ concentration in the jar with time were measured. The rate of respiration of mangoes was calculated using the following equation (Saltveit, 1997):

$$RR = \frac{\left[\frac{C_1 - C_2}{100} \right] \times (V_1 + V_2) + S \left[\frac{W \times M \times 10^{-3}}{100} \right]}{W \times (T_1 - T_2)}$$

where,

RR = Respiration rate (O₂ consumption in ml kg⁻¹hr⁻¹)

C₁ = Initial concentration (ml) of CO₂ or O₂

C₂ = Final concentration (ml) of CO₂ or O₂

V₁ = Volume of the container (ml)

V₂ = Volume of fruit (ml)

W = Weight of the fruit (kg)

M = Moisture present in the fruit (ml)

T₁ = Initial period (hours)

T₂ = Final period (hours)

S = Solubility of gases (Table-1)

To obtain mg kg⁻¹ h⁻¹, multiply ml kg⁻¹hr⁻¹ rate by 2.0 at 0°C (32 °F), 1.9 at 10°C (50 °F) and 1.8 at 20°C (68 °F) as indicated by Karmarkar and Joshi (1941).

The release of the ethylene was measured by the same procedure used for measuring the respiration rate and was expressed as µl kg⁻¹ h⁻¹.

3.3.5 ORGANOLEPTIC EVALUATION

Fruits were examined for their sensory qualities at the optimum ripening for accessing the colour, flavour, texture, aroma and spongy tissue. It was carried out by panel of 5 judges with score on 9 point Hedonic scale (Amerine *et al.*, 1965) as given below (Plate 6).

Organoleptic Score	Rating
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

The overall rating was obtained by averaging score of evaluation. The fruits with score of 5.5 and above were rated as acceptable.

3.4 STATISTICAL ANALYSIS

The data were subjected for pooled analysis of variance following the method of Panse and Sukhatme (1967). The level of significance used in F and t-tests was P=0.01. Critical differences were calculated wherever F-test was found significant.

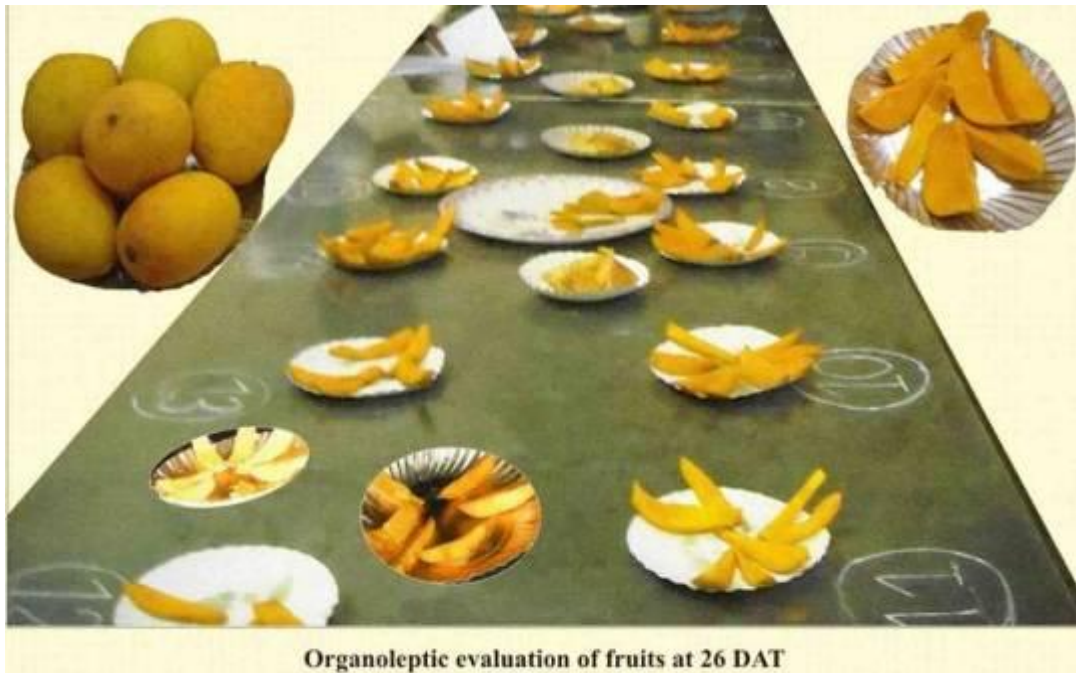


Plate 6 : Fruit ready for organoleptic evaluation

EXPERIMENTAL RESULTS

Mango is an incomparable tasty fruit and its large production in the world (around 29 m tons) makes it known as one of the most relevant tropical fruits. The high esteem with which this fruit has always been held in Asia, where mango has been considered to be the 'King of Fruits', is now apparently true for much of the world. However, to participate in the global market scenario, scientists and producers look for improving basic knowledge and use of modern technology, in order to contribute for increasing the shelf life of fruits. Hence, it is necessary for not only to increase its shelf life, but also maintain the quality. With this background, the present investigations were undertaken to find out the most optimum dose of 1-MCP for prolonging the ripening process and extend the storage of Alphonso mango without affecting fruit quality.

Investigations were carried for two consecutive years (2010-11 and 2011-12) at Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The data were analysed year wise and also pooled analysis for both the years, since the trend was same with respect to storage condition, concentrations of 1-MCP and their interactions in both the years. Results of pooled analysis are presented in this chapter. However, the individual years data is given in Appendices I to XXX.

4.1 RIPENING BEHAVIOUR

The data on the influence of different concentrations of 1-MCP and storage conditions on ripening behaviour in Alphonso mango was collected from 0 days after treatment (DAT) until 26 DAT at 4 days interval and presented in Tables 1a to 1d. Ripening behaviour as indicated by different stages of ripening viz., Green (G), Turning Yellow (TY), Half Ripe (HR), Ripe, Diseased (Di) and Shrivelled (Shrv) was studied from 0 day of treatment to 26 DAT (Plates 7 to 11).

It was observed that at 0 DAT i.e. immediately after the harvest, fruits in all the treatments were 100 per cent green in all the treatments. At 4 DAT, depending on the concentrations and storage conditions, ripening behaviour changed with fruits turning yellow with or without 1-MCP treatment under ambient storage conditions. It was further observed that under cold storage in all the 1-MCP treatments and with shrink wrapper, fruits remained 100 per cent green. There were no fruits which were half ripe and ripe in any of the treatment combinations indicating that 4 DAT is too early to make fruits to ripe. However, under ambient storage condition, there were 2 per cent diseased fruits with 0 ppb 1-MCP (control).

The ripening behaviour at 8 DAT revealed that under cold storage, the fruits still maintained greenness ranging from 95.5 per cent to 100 per cent. The greenness was more with cold storage (S_2) irrespective of the concentration of 1-MCP. Under ambient condition, at 0 ppb of 1-MCP, maximum ripening was observed and less number of fruits was green. It was further observed that the ripening behaviour hastened under ambient storage condition even with 1-MCP and ambient condition with shrink wrapper (S_4), irrespective of the concentration of 1-MCP.

At 12 DAT, it was observed that under ambient storage conditions without 1-MCP, 64.5 per cent of fruits ripened with 0 per cent greenness. Without 1-MCP treatment and storing under ambient storage conditions and with shrink wrapper also resulted in maximum ripeness of 61 per cent ambient condition with shrink wrapper of 0 ppb of 1-MCP (C_1S_4). The fruits stored under cold storage, still maintained greenness and the percentage of greenness increased with an increase in the concentration of 1-MCP upto 2000 ppb. However, further increase in 1-MCP (3000 ppb), there was reduced greenness compared to lower concentrations. At this stage, none of the cold storage treatments with 1-MCP resulted in ripeness. However, there was a trend towards turning yellow and half ripe.

At 16 DAT, none of the fruits under ambient storage conditions even with shrink wrapper were either green or at turning yellow stages. This resulted in almost 50 per cent of the fruits in ripe condition under ambient storage condition and none of the fruits in cold storage ripened at this stage. However, they were turning yellow or in the half ripe stage conditions. The maximum greenness was observed in cold storage with 2000 ppb of 1-MCP (C_3S_2) followed by cold storage with 1000 ppb 1-MCP (C_2S_2) and cold storage with 3000 ppb 1-MCP (C_4S_2) indicating that 2000 ppb concentration of 1-MCP is effective in maintaining greenness compared to other concentrations and storage conditions. More number of diseased fruits was observed under ambient storage conditions with or without 1-MCP and shrink wrapper i.e. ambient condition (S_1) and ambient condition with shrink wrapper (S_4). Similarly, more number of shrivelled fruits were also observed in these two conditions.

Table 1a. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 0 and 4 DAT in Alphonso mango (pooled)

Treatment combinations	0 DAT						4 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	100	0	0	0	0	0	51	47	0	0	2	0
C ₁ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₁ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₁ S ₄	100	0	0	0	0	0	55	44	0	0	1	0
C ₂ S ₁	100	0	0	0	0	0	61	38	0	0	1	0
C ₂ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₂ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₂ S ₄	100	0	0	0	0	0	63	36.5	0	0	0.5	0
C ₃ S ₁	100	0	0	0	0	0	65	34	0	0	1	0
C ₃ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₃ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₃ S ₄	100	0	0	0	0	0	68	32	0	0	0	0
C ₄ S ₁	100	0	0	0	0	0	58	40	0	0	2	0
C ₄ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₄ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₄ S ₄	100	0	0	0	0	0	60	39.5	0	0	0.5	0

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 1b. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 8 and 12 DAT in Alphonso mango (pooled)

Treatment combinations	8 DAT						12 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	9.5	12	20	51	5	2.5	0	2.5	13	64.5	13	7
C ₁ S ₂	97.5	2.5	0	0	0	0	79	18	1	0	2	0
C ₁ S ₃	95.5	4.5	0	0	0	0	76	17.5	2	2.5	2	0
C ₁ S ₄	11.5	14	20	48	4.5	2	2.5	5.5	17	61	9	5
C ₂ S ₁	19	22.5	25.5	31	2	0	9	12.5	27	43.5	6	2
C ₂ S ₂	100	0	0	0	0	0	93	7	0	0	0	0
C ₂ S ₃	98.5	1.5	0	0	0	0	85	13	2	0	0	0
C ₂ S ₄	21.5	25.5	27.5	24.5	1	0	11	13.5	28	40.5	5	2
C ₃ S ₁	27.5	33	31.5	7	1	0	13	14.5	29	38.5	3	2
C ₃ S ₂	100	0	0	0	0	0	97	3	0	0	0	0
C ₃ S ₃	99.5	0.5	0	0	0	0	88	10	2	0	0	0
C ₃ S ₄	31	35	33	0	1	0	16	16.5	31	32.5	3	1
C ₄ S ₁	13.5	16.5	21.5	44.5	3	1	6	8.5	22	52.5	8	3
C ₄ S ₂	99.5	0.5	0	0	0	0	91	9	0	0	0	0
C ₄ S ₃	97.5	2.5	0	0	0	0	82	14	4	0	0	0
C ₄ S ₄	14.5	21	24.5	36	3	1	8	11.5	24	47.5	6	3

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 1c. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 16 and 20 DAT in Alphonso mango (pooled)

Treatment combinations	16 DAT						20 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	0	0	2	39	30	29	0	0	0	23	37	40
C ₁ S ₂	47	29	18.5	0	3.5	2	16	20	33	19	7.5	4.5
C ₁ S ₃	43	31	19.5	0	3.5	3	13	18	34	21	9.5	4.5
C ₁ S ₄	0	0	5	45	27	23	0	0	0	31	34	35
C ₂ S ₁	0	0	15	51	18	16	0	0	0	46	23	31
C ₂ S ₂	71	20.5	8.5	0	0	0	37	33	18	12	0	0
C ₂ S ₃	60	25.5	12	0	1.5	1	22	24	27	16	7.5	3.5
C ₂ S ₄	0	0	15	52	17	16	0	0	0	47	23	30
C ₃ S ₁	0	0	17	54	15	14	0	0	0	54	21	25
C ₃ S ₂	75	18.5	6.5	0	0	0	50	40.5	9.5	0	0	0
C ₃ S ₃	62	24.5	11.5	0	1.5	0.5	31	30	16	15	5.5	2.5
C ₃ S ₄	0	0	20	56	14	10	0	0	0	57	19	24
C ₄ S ₁	0	0	8	48	24	20	0	0	0	40	27	33
C ₄ S ₂	68	22	9.5	0	0.5	0	34	32	11	15	5.5	2.5
C ₄ S ₃	55	27	14.5	0	2.5	1	18	21	34	16	7.5	3.5
C ₄ S ₄	0	0	11	49	18	22	0	0	0	44	24	32

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 1d. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 24 and 26 DAT in Alphonso mango (pooled)

Treatment combinations	24 DAT						26 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	0	0	0	0	43	57	0	0	0	0	0	0
C ₁ S ₂	0	7.5	15.5	30	22	25	0	0	0	42.5	25	32.5
C ₁ S ₃	0	6.5	12.5	31.5	22.5	27	0	0	0	43	26.5	30.5
C ₁ S ₄	0	0	0	0	38	62	0	0	0	0	0	0
C ₂ S ₁	0	0	0	8	29	63	0	0	0	0	30.5	69.5
C ₂ S ₂	27	21.5	23.5	21	4	3	5.5	8.5	21	29	14.5	21.5
C ₂ S ₃	0	10.5	20	26.5	20	23	0	0	0	44	23.5	32.5
C ₂ S ₄	0	0	0	10	28	62	0	0	0	0	30.5	69.5
C ₃ S ₁	0	0	0	12	27	61	0	0	0	0	29.5	70.5
C ₃ S ₂	29	25.5	25.5	15	4	1	11	14	27	24	11.5	12.5
C ₃ S ₃	14	12.5	20.5	24	14	15	0	3	15	39	20.5	22.5
C ₃ S ₄	0	0	0	15	25	60	0	0	0	0	28.5	71.5
C ₄ S ₁	0	0	0	5	32	63	0	0	0	0	35.5	64.5
C ₄ S ₂	18	15.5	21.5	22	11	12	0	4	18	36	19.5	22.5
C ₄ S ₃	0	8.5	18.5	28	21	24	0	0	0	43	24	33
C ₄ S ₄	0	0	0	5	30	65	0	0	0	0	33.5	66.5

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

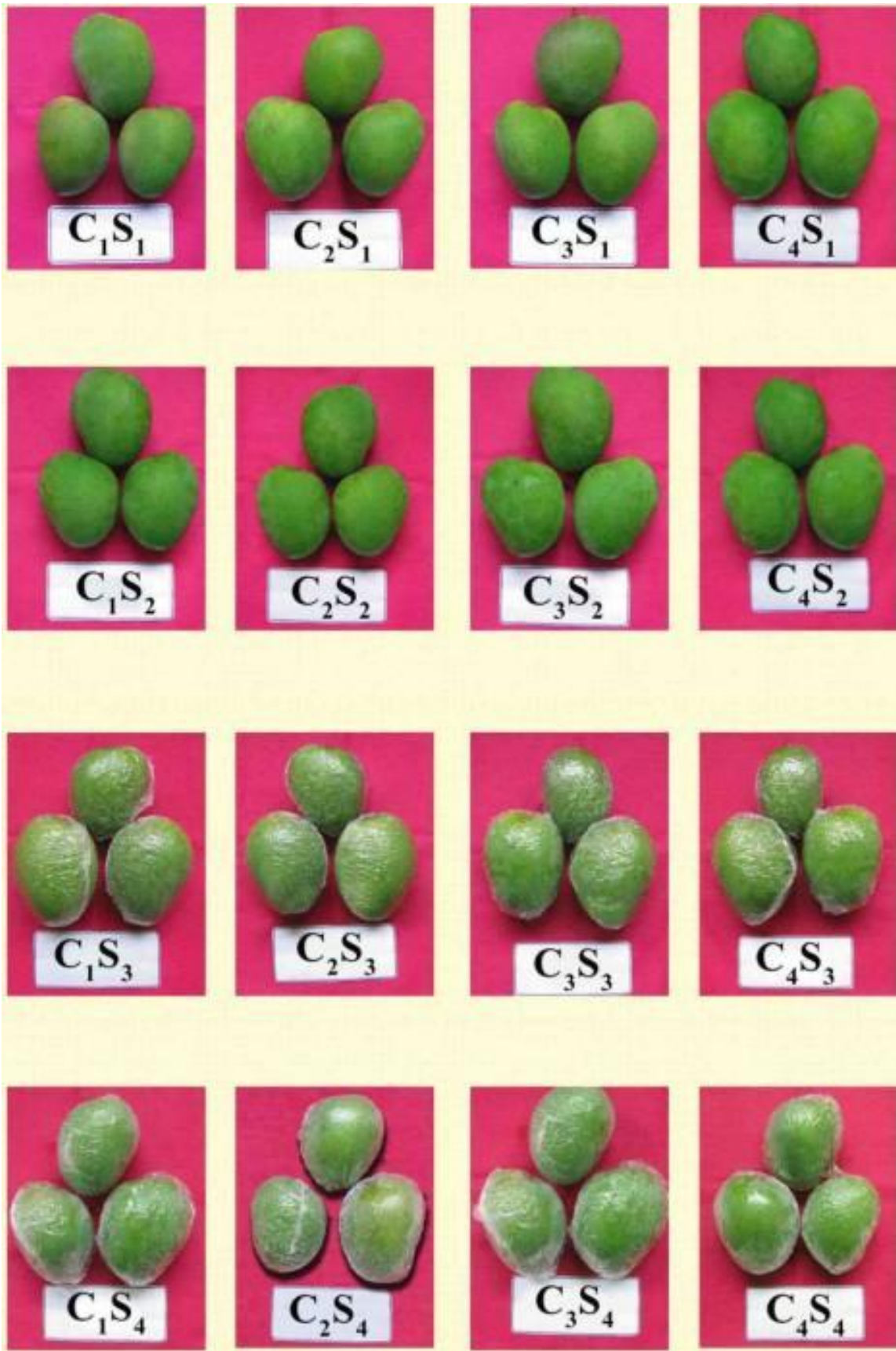


Plate 7 : Influence of different concentrations of 1-MCP and storage conditions at 0 DAT in Alphonso mango

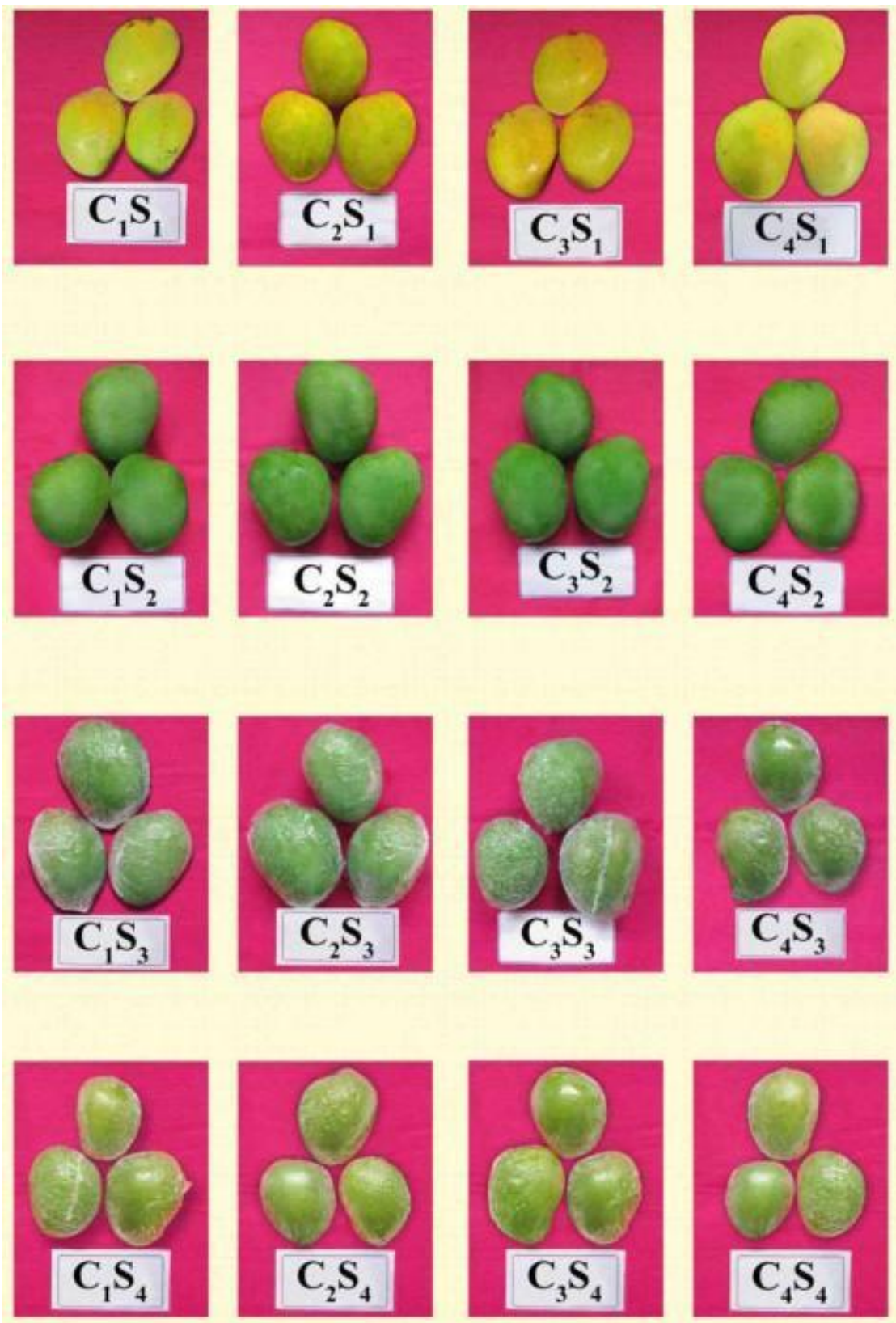


Plate 8 : Influence of different concentrations of 1-MCP and storage conditions at 7 DAT in Alphonso mango

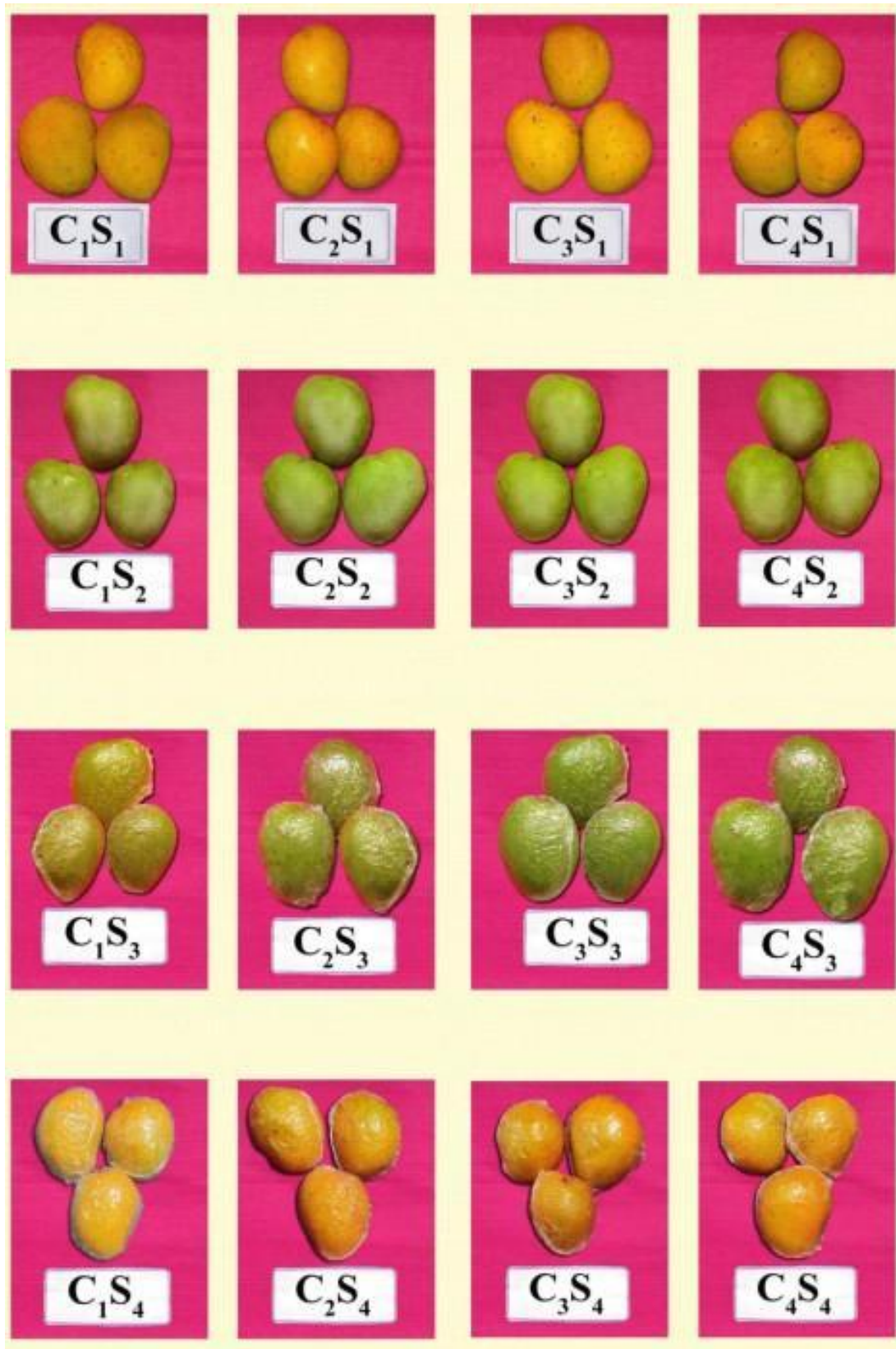


Plate 9 : Influence of different concentrations of 1-MCP and storage conditions at 14 DAT in Alphonso mango

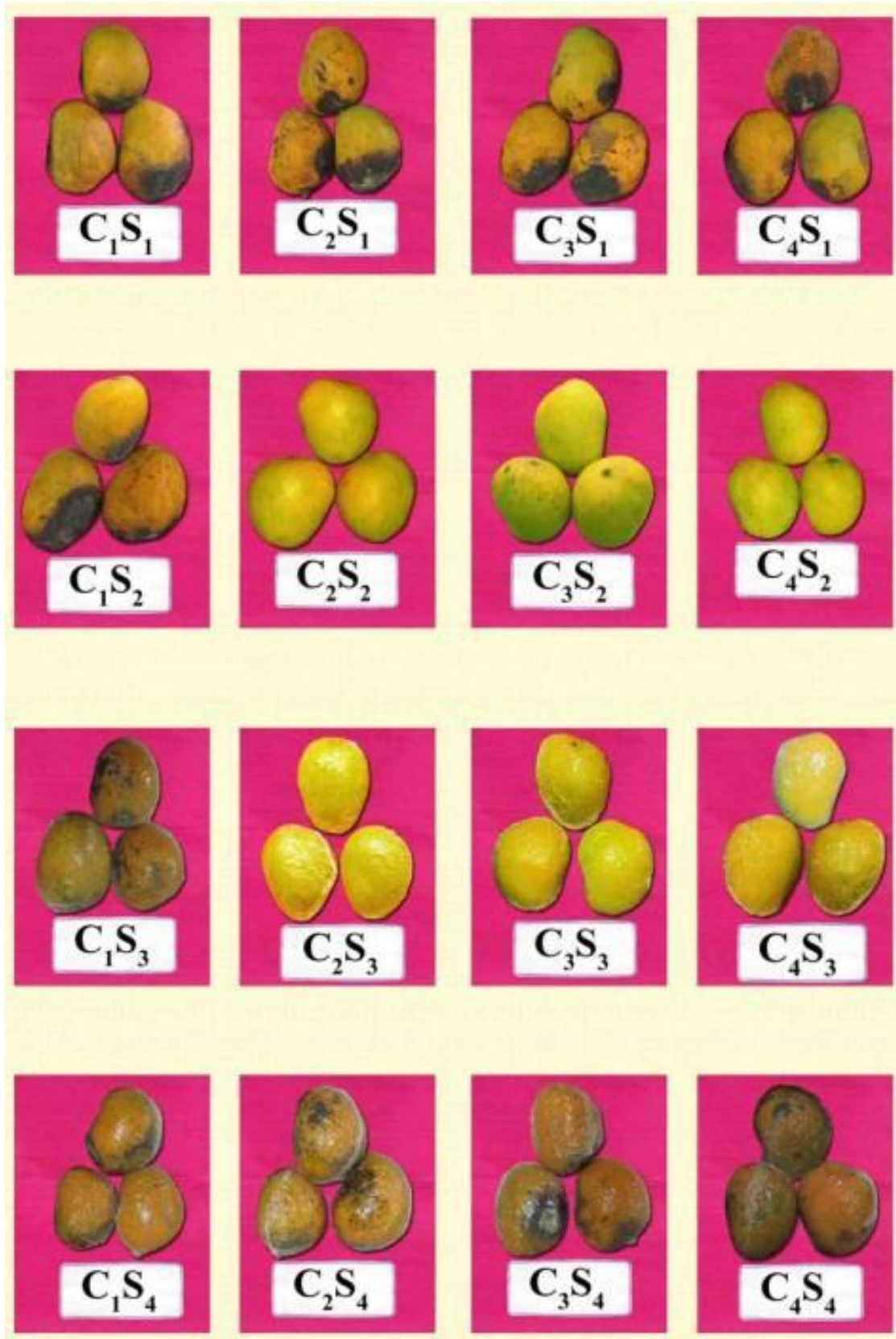


Plate 10 : Influence of different concentrations of 1-MCP and storage conditions at 21 DAT in Alphonso mango

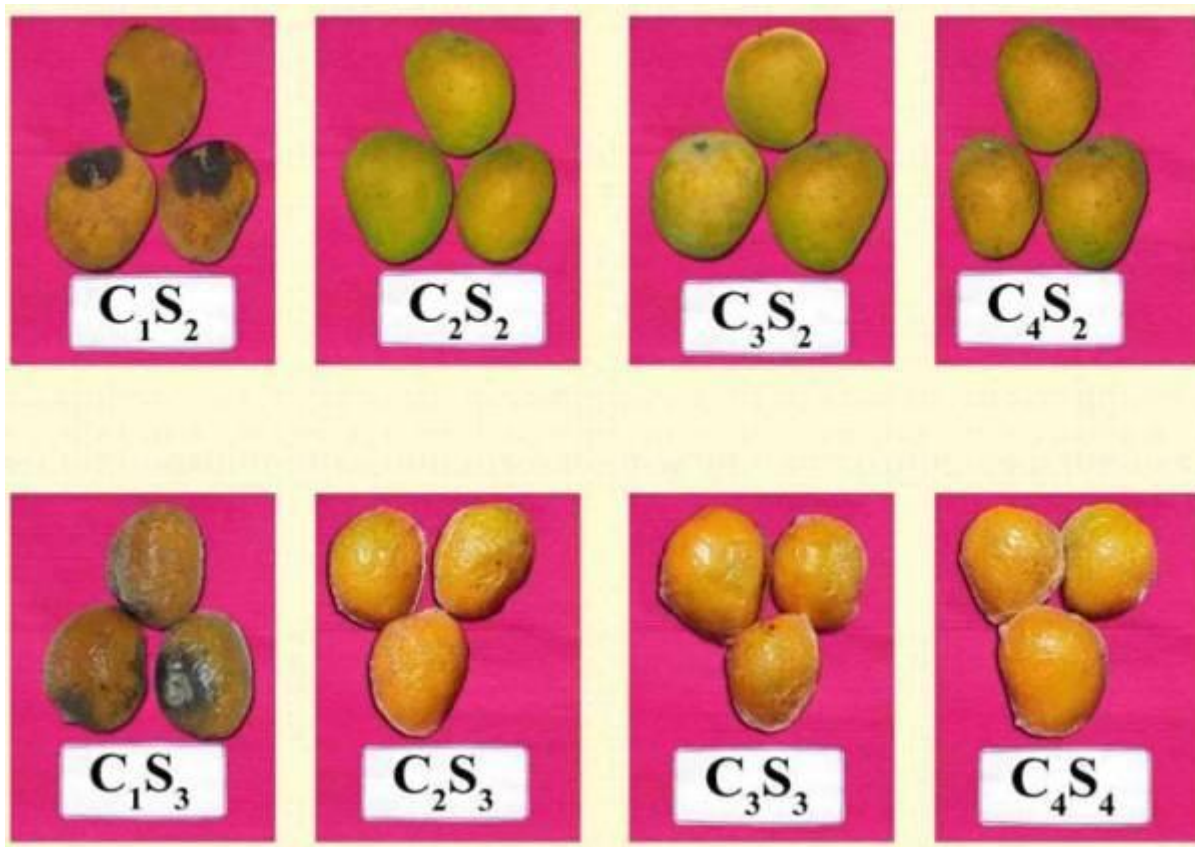


Plate 11 : Influence of different concentrations of 1-MCP and storage conditions at 26 DAT in Alphonso mango

The greenness of the fruits was almost reduced to 50 per cent at 20 DAT under cold storage with 2000 ppb 1-MCP and other 50 per cent of the fruits were either in turning yellow or in half ripe and none of the fruits ripened in this treatment. It was further observed that cold storage with either 1000 ppb or 3000 ppb 1-MCP had higher greenness of fruits. However, cold storage without 1-MCP also had 13 to 16 per cent of greenness. Maximum number of ripened fruits was observed with 2000 ppb 1-MCP under ambient storage with shrink wrapper followed by ambient storage without 1-MCP treatment. The ripening behaviour with 15 to 21 per cent ripe fruits was observed under cold storage, irrespective of the concentration of 1-MCP. The number of diseased and shrivelled fruits was more under ambient storage conditions, irrespective of 1-MCP treatment or shrink wrapper.

Except in cold storage with 1000 ppb of 1-MCP (C_2S_2), cold storage with 2000 ppb of 1-MCP (C_3S_2), cold storage with shrink wrapper + 2000 ppb (C_3S_3) and cold storage with 3000 ppb of 1-MCP (C_4S_2), no treatment indicated green fruits. In these treatments, the greenness was ranging from 14 to 29 per cent. Maximum greenness was observed in S_2 i.e. cold storage with 2000 ppb of 1-MCP. The ripening behaviour was slow in this treatment compared to all other treatments. It was further observed that under ambient storage conditions, all the fruits were either diseased (43 per cent) or shrivelled (57 per cent) without 1-MCP treatment. The percentage of diseased and shrivelled fruits decreased with an increase in the concentrations of 1-MCP from 1000 ppb to 3000 ppb. Cold storage resulted in only about 30 per cent of the fruits under ripened condition and this ripeness decreased with an increase in the concentrations of 1-MCP even upto 3000 ppb. Less number of diseased and shrivelled fruits was observed under cold storage, irrespective of 1-MCP treatment.

4.2 FRUIT COLOUR

The data on the influence of different concentrations of 1-MCP and storage conditions on colour of the fruit was recorded from 1 DAT until 26 DAT at 4 days interval and presented in Table 2. The chroma values in terms of 'L', 'a' and 'b' were measured in all the treatments. 'a' values indicate turning fruits from greenness to redness; +ve values indicate that the fruits are turning to redness and -ve values indicate towards greenness. Similarly, the 'b' values indicate turning fruits yellowness to blueness; +ve values are towards yellowness and -ve values are towards blueness. 'L' indicates lightness which extends from 0 (black) to 100 (white).

The fruits stored under ambient storage were green only at 1 DAT and turning towards yellow and red at successive days after storage and almost turned to yellow indicating the ripeness by 16 DAT and no -ve values was observed in any of the treatments of ambient storage conditions without 1-MCP. While, the fruits stored under cold storage were green even upto 12 DAT and gradually turned towards yellowness thereafter and the values became +ve by 26 DAT in all the cold storage treatments with or without 1-MCP. This indicates that cold storage is more effective in keeping the fruits under unripe condition followed by 1-MCP treatment. With an increase in the concentration of 1-MCP, the chroma values also changed towards yellowness and redness indicating the effect of 1-MCP in inducing ripeness of the fruits. But, turning yellow or green is slow with 1-MCP and with the increase in the concentration of 1-MCP, indicating the effect of 1-MCP in turning the ripening process which can be visualized from all the treatments of 1-MCP.

4.3 FRUIT FIRMNESS

Fruit firmness as influenced by storage conditions and different concentrations of 1-MCP was studied from 0 to 26 DAT and presented in Tables 3a to 3c. The firmness was measured with QTL texture analyzer in which fruits were exposed to a combination force with suitable probe and the peak force for combination was recorded as the fruit firmness.

Higher the value indicates the firmness and lower the value indicates the looseness or softness of the fruits. No significant differences were observed at 0 DAT since all the fruits were of uniform firmness before imposing the treatments. However, at subsequent days of treatment, significant differences were observed between the storage conditions and concentrations of 1-MCP and their interactions in fruit firmness.

At 2 DAT, fruit firmness was more with cold storage irrespective of the concentration of 1-MCP. With an increase in the concentration of 1-MCP, there was a significant increase in fruit firmness upto 2000 ppb of 1-MCP. Further, increase in the concentration of 1-MCP i.e. 3000 ppb resulted in reduced fruit firmness compared to 2000 ppb of 1-MCP. Among the treatment combinations, ambient condition of 3000 ppb 1-MCP (C_3S_1) had significantly higher fruit firmness, but it did not differ with any of the cold storage treatments and other concentrations of 1-MCP. However, it

Table 2. Influence of different concentrations of 1-MCP and storage conditions on chroma values at 1, 4, 8, 12, 16, 20, 24 and 26 DAT in Alphonso mango (pooled)

Treatment combinations	Chroma value	1 DAT	4 DAT	8 DAT	12 DAT	16 DAT	20 DAT	24 DAT	26 DAT
C ₁ S ₁	a	-6.94	0.52	5.46	9	13.09	16.07	—*	—
	b	16.83	16.31	15.66	15.54	14.24	18.61	—	—
	L	44.04	39.53	43.6	42.77	30.18	42.12	—	—
C ₁ S ₂	a	-7.71	-6.06	-4.56	-1.11	0.52	1.71	3.76	7.45
	b	15.61	16.58	15.68	18.32	16.31	14.49	19.38	12.44
	L	39.56	39.86	39.63	46.36	39.53	39.3	45.27	35.73
C ₁ S ₃	a	-7.27	-5.86	-4.23	-0.3	0.96	2.95	4.3	9.05
	b	14.8	21.88	16.54	19.71	15.87	16.62	16.69	15.15
	L	40.88	46.96	42.5	47.11	42.18	42.65	49.56	41.79
C ₁ S ₄	a	-7.56	0.15	44.61	9.8	13.39	17.23	—	—
	b	16.03	16.69	20.08	26.49	35.02	26.6	—	—
	L	40.99	38.99	20.09	49.27	62.73	54.04	—	—
C ₂ S ₁	a	-7.52	-3.81	0.03	8.3	11.15	15.16	—	—
	b	17.21	17.22	20.85	16.63	19.68	26.34	—	—
	L	43.66	40.94	46.79	42.23	38.46	51.29	—	—
C ₂ S ₂	a	-8.25	-7.42	-6.62	-5.15	-4.33	-3.15	-1.24	0.35
	b	18.16	19.35	18.92	19.67	19.38	22.3	18.07	16.61
	L	40.11	43.11	42.5	41.87	42.57	44.46	45.5	45.78
C ₂ S ₃	a	-7.63	-6.71	-5.4	-3.15	-1.45	-0.08	1.03	4.26
	b	20.94	20.96	20.02	22.3	15.67	24.51	16.54	17.91
	L	44.7	42.69	43.99	44.46	38.95	48.12	40.74	45.67
C ₂ S ₄	a	-7.39	-4.39	-1.11	7.18	10.59	14.99	16.88	—
	b	15.58	19.52	18.32	11.72	19.81	22.58	28.98	—
	L	41.43	41.52	46.36	35.16	40.25	41.62	51.35	—

Contd.....

Table 2. (Contd.....) Influence of different concentrations of 1-MCP and storage conditions on chroma values at 1, 4, 8, 12, 16, 20, 24 and 26 DAT in Alphonso mango (pooled)

Treatment combinations	Chroma value	1 DAT	4 DAT	8 DAT	12 DAT	16 DAT	20 DAT	24 DAT	26 DAT
C ₃ S ₁	a	-7.34	-4.8	-2.9	6.97	10.3	13.63	16.49	—
	b	18.07	23.23	18.45	20.57	23.41	27.91	21.20	—
	L	43.71	45.4	44.85	47.76	43.55	49.42	41.35	—
C ₃ S ₂	a	-8.89	-8.24	-7.53	-6.44	-5.91	-4.21	-2.2	-0.3
	b	18.54	18.63	17.44	16.86	20.06	14.92	18.85	19.71
	L	42.88	43.07	44.62	41.19	47.43	36.95	45.73	47.11
C ₃ S ₃	a	-7.92	-6.82	-5.62	-4.57	-2.07	-0.63	0.69	2.5
	b	15.53	20.71	16.72	15.3	15.45	16.03	22.55	15.29
	L	39.08	44.4	42.85	37.35	42.1	44.01	45.47	40.41
C ₃ S ₄	a	-7.38	-5.25	-3.82	6.34	9.22	12.65	16.3	—
	b	15.29	17.8	18.07	16.97	29.81	29.21	28.17	—
	L	42.03	42.35	43.05	43.71	53.59	53.82	53.65	—
C ₄ S ₁	a	-7.26	-2.01	2.72	3.22	11.89	16.49	—	—
	b	16.43	12.39	12.85	29.87	25.49	21.2	—	—
	L	43.11	35.2	37.08	53.59	46.31	41.35	—	—
C ₄ S ₂	a	-8.17	-7.45	-6.05	-4.87	-3.16	-0.98	-0.98	1.25
	b	17.49	15.65	18.22	19.42	18.68	15.05	15.05	14.12
	L	43.14	39.07	44.49	41.8	44.95	40.44	40.44	39.92
C ₄ S ₃	a	-7.53	-6.38	-5.12	-2.86	-4.6	0.96	2.89	6.51
	b	17.44	17.24	16.04	19.34	13.6	15.87	15.2	11.38
	L	44.62	50.25	41.99	44.45	38.33	42.18	39.75	38.08
C ₄ S ₄	a	-7.42	-3.21	1.86	8.4	11.78	15.88	—	—
	b	17.06	16.36	22.47	27.04	28.68	24.7	—	—
	L	42.03	40.81	52.26	50.66	53.7	44.71	—	—

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

a : Redness (+ a) to greenness (- a)

b : Yellowness (+ b) to blueness (-b)

L : Lightness and extends from 0 (black) to 100 (white)

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1^oC) + 1-MCP

S₃ : Cold storage (13±1^oC) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

differed significantly with all the treatment combinations involving storage under ambient condition, irrespective of the concentration of 1-MCP (Table 3a).

Similar trend continued at 4 DAT, where all the cold storage treatments recorded higher fruit firmness compared to storage under ambient condition. Again increase in the concentration of 1-MCP, there was a significant increase in fruit firmness upto 2000 ppb and declined thereafter. At 6 DAT, fruit firmness was maximum in cold storage (S_2) followed by cold storage with shrink wrapper (S_3) and least in ambient condition (S_1) among the storage conditions; while it was maximum in 2000 ppb (C_3) among 1-MCP concentrations and declined at 3000 ppb concentration. A similar trend continued at 8 and 10 DAT with cold storage treatments recording higher values of fruit firmness compared to ambient storage and increase in the concentration of 1-MCP upto 2000 ppb. There was a drastic decline in the fruit firmness at 3000 ppb of 1-MCP under ambient storage, but not with cold storage at this concentration (Table 3a).

The data of fruit firmness measured at 12, 14, 16 and 18 DAT as influenced by storage conditions and 1-MCP treatments presented in Table 3b indicated that the fruit firmness was more under cold storage (S_2) at all the DAT followed by cold storage with shrink wrapper (S_3). However, low fruit firmness was observed under ambient condition (S_1) at all the days after treatment. Similarly, increase in the concentration of 1-MCP upto 2000 ppb resulted in enhanced fruit firmness and declined thereafter at all the DAT. It clearly indicates that cold storage is more effective in maintaining the fruit firmness compared to 1-MCP concentrations and ambient storage.

Influence of different concentrations of 1-MCP and storage conditions of fruit firmness measured at 20, 22, 24 and 26 DAT presented in Table 3c indicated significant differences between the storage conditions, irrespective of 1-MCP and their interactions. It was further observed that maximum fruit firmness was seen under cold storage (S_2) followed by cold storage with shrink wrapper (S_3) and least in ambient condition (S_1) at 20, 22 and 24 DAT. At 26 DAT, it was not possible to measure the fruit firmness in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were totally rotten, hence not indicated. However, the fruits stored under cold storage (S_2) and cold storage with shrink wrapper (S_3) still had firmness through at much less compared to 2 DAT. In general, it was observed that there was a decline in the fruit firmness from 0 DAT to 26 DAT, but the extent of decline was much less under cold storage followed by 1-MCP treatment. Maximum decline in fruit firmness was observed under ambient storage with or without 1-MCP and shrink wrapper.

4.4 PHYSIOLOGICAL LOSS IN WEIGHT

Physiological loss in weight as influenced by storage conditions and 1-MCP treatments was measured from 2 to 26 DAT and presented in Tables 4a to 4c. The data indicated that at 2 DAT, no significant differences were observed due to storage condition and concentration of 1-MCP and their interaction, since it was too early to induce any physiological change leading to loss in weight (Table 4a).

At 4 DAT, the physiological loss in weight was almost doubled compared to 2 DAT in the treatments with ambient storage. However, though physiological loss in weight increased at this stage compared to 2 DAT under cold storage, but the extent of increase was less compared to ambient storage and with an increase in the concentration of 1-MCP. Among the storage conditions, minimum physiological loss in weight was observed in cold storage with shrink wrapper (S_3) and with an increase in the concentration of 1-MCP upto 2000 ppb.

A similar trend continued at 6 and 8 DAT that cold storage with shrink wrapper (S_3) recording lower physiological loss in weight compared to other treatments especially ambient storage conditions. The physiological loss in weight was almost 25 per cent of the ambient storage indicating the effectiveness of cold storage in reducing the physiological loss in weight. Similarly, increase in the concentration of 1-MCP upto 2000 ppb resulted in reducing physiological loss in weight and it is slightly increased at 3000 ppb of 1-MCP compared to lower concentration, but however, it was less compared to control.

The physiological loss in weight increased further with enhanced duration of storage, irrespective of the cold storage or ambient conditions and with or without 1-MCP treatment as indicated at 10 to 12 DAT (Table 4a). The extent of increase in physiological loss in weight was almost 4 to 5 times under ambient storage compared to cold storage. While, the physiological loss in weight was doubled in control compared to 1-MCP treatments. Among treatments, maximum physiological loss in weight was observed in cold storage with 0 ppb of 1-MCP (C_1S_1) and the lowest

Table 3a. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 0, 2, 4, 6, 8 and 10 DAT in Alphonso mango (pooled)

0 DAT						2 DAT					4 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	9.021	8.905	8.900	8.902	8.932	7.104	7.105	7.702	7.102	7.253	6.305	6.455	6.903	6.305	6.492	
S ₂	8.906	8.903	8.903	8.902	8.904	8.202	8.202	8.203	8.201	8.202	7.553	7.703	7.704	7.702	7.665	
S ₃	8.903	8.906	8.902	8.905	8.904	8.200	8.203	8.201	8.202	8.202	7.551	7.555	7.701	7.554	7.590	
S ₄	8.903	8.906	8.901	8.902	8.903	7.103	7.106	7.702	7.104	7.254	6.305	6.456	7.053	6.453	6.567	
Mean	8.933	8.905	8.902	8.903		7.652	7.654	7.952	7.652		6.928	7.042	7.340	7.003		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.010	NS				C	0.010	0.026			C	0.006	0.015			
S	0.010	NS				S	0.010	0.019			S	0.007	0.011			
S X C	0.021	NS				S X C	0.021	0.051			S X C	0.014	0.030			

6 DAT						8 DAT					10 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	3.907	5.157	6.004	3.907	4.744	2.417	3.509	4.132	2.536	3.149	1.858	2.704	3.327	2.021	2.477	
S ₂	6.806	7.105	7.106	7.104	7.030	6.328	6.605	6.897	6.552	6.596	5.171	5.448	5.740	5.395	5.438	
S ₃	6.803	6.957	7.103	6.955	6.955	6.228	6.419	6.517	6.403	6.392	5.071	5.262	5.360	5.246	5.234	
S ₄	3.907	5.459	6.155	4.256	4.944	2.516	3.603	4.372	2.610	3.276	1.961	2.798	3.567	1.918	2.561	
Mean	5.356	6.169	6.592	5.555		4.373	5.034	5.480	4.526		3.515	4.053	4.498	3.645		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.004	0.015				C	0.003	0.01			C	0.002	0.01			
S	0.004	0.012				S	0.003	0.007			S	0.003	0.007			
S X C	0.008	0.031				S X C	0.005	0.019			S X C	0.005	0.019			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 3b. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 12, 14, 16 and 18 DAT in Alphonso mango (pooled)

12 DAT						14 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.567	2.109	2.732	1.686	2.023	1.412	1.572	1.759	1.472	1.554
S ₂	3.876	4.153	4.445	4.100	4.143	2.520	2.708	3.019	2.705	2.738
S ₃	3.776	3.967	4.065	3.951	3.940	2.516	2.652	2.662	2.574	2.601
S ₄	1.666	2.203	2.972	1.690	2.133	1.439	1.630	1.869	1.510	1.612
Mean	2.721	3.108	3.553	2.857		1.972	2.141	2.327	2.065	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.002	0.009				C	0.003	0.010		
S	0.003	0.007				S	0.002	0.007		
S X C	0.005	0.019				S X C	0.005	0.019		

16 DAT						18 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.358	1.464	1.621	1.418	1.465	1.302	1.399	1.486	1.362	1.387
S ₂	2.107	2.295	2.771	2.292	2.366	1.918	2.106	2.582	2.103	2.178
S ₃	2.103	2.239	2.249	2.161	2.188	1.914	2.050	2.060	1.972	1.999
S ₄	1.385	1.522	1.731	1.465	1.526	1.329	1.412	1.596	1.400	1.434
Mean	1.738	1.880	2.093	1.834		1.616	1.742	1.931	1.709	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.003	0.012				C	0.004	0.017		
S	0.003	0.009				S	0.004	0.012		
S X C	0.006	0.023				S X C	0.009	0.033		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 3c. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 20, 22, 24 and 26 DAT in Alphonso mango (pooled)

20 DAT						22 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.230	1.342	1.368	1.299	1.310	1.108	1.243	1.289	1.194	1.208
S ₂	1.697	1.885	2.361	1.882	1.956	1.453	1.716	1.907	1.626	1.676
S ₃	1.693	1.829	1.839	1.751	1.778	1.429	1.536	1.599	1.489	1.513
S ₄	1.260	1.352	1.463	1.336	1.353	1.143	1.287	1.368	1.220	1.254
Mean	1.470	1.602	1.758	1.567		1.283	1.445	1.541	1.382	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.007	0.028				C	0.004	0.016		
S	0.008	0.021				S	0.004	0.012		
S X C	0.015	0.056				S X C	0.008	0.031		

24 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.039	1.165	1.246	1.113	1.140	—*	—	—	—	—
S ₂	1.360	1.541	1.715	1.477	1.523	1.203	1.382	1.507	1.325	1.354
S ₃	1.347	1.419	1.460	1.385	1.403	1.191	1.258	1.301	1.236	1.247
S ₄	1.071	1.206	1.295	1.129	1.175	—	—	—	—	—
Mean	1.204	1.333	1.429	1.276						
	S.Em.±	C.D. (1%)								
C	0.002	0.008								
S	0.002	0.006								
S X C	0.004	0.015								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

in cold storage with shrink wrapper + 3000 ppb of 1-MCP (C_4S_3) at 12 DAT. Significant differences between the storage conditions, concentrations of 1-MCP and their interaction was evident at all the DAT.

Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight measured at 14, 16, 18 and 20 DAT indicated significant differences between the treatments and their interaction (Table 4b). There was a gradual increase in the physiological loss in weight from 14 to 20 DAT in all the treatments. However, the extent of increase was more under ambient storage condition compared to cold storage, irrespective of the 1-MCP treatment. With an increase in the concentration of 1-MCP, there was a decrease in physiological loss in weight upto 2000 ppb and further increase in 1-MCP concentration at 3000 ppb resulted in a slight increase of physiological loss in weight, but this increase was much less compared to no 1-MCP treatment. Among different treatment combinations, the lowest physiological loss in weight was observed in cold storage with shrink wrapper + 3000 ppb of 1-MCP (C_4S_3) followed by cold storage with 3000 ppb of 1-MCP (C_4S_2) at all the DAT.

Physiological loss in weight enhanced further with an increase in the storage period at 22, 24 and 26 (Table 4c). The magnitude of physiological loss in weight was much higher under ambient storage at all the concentrations of 1-MCP compared to cold storage and ambient condition with shrink wrapper (S_4). Though the physiological loss in weight increased, the increase was marginal in all the cold storage treatments. It is noticed that the physiological loss in weight was only ranging from 3.7 (C_3S_3) to 7.84 (C_1S_2) at 26 DAT under cold storage conditions. It was not possible to record the physiological loss in weight at 26 DAT in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), because the fruits were totally rotten at this stage. In general, it was observed that the physiological loss in weight ranged from 7.93 in ambient condition with 0 ppb of 1-MCP (C_1S_1) at 4 DAT to 29.83 again in ambient condition with 0 ppb of 1-MCP (C_1S_1) at 24 DAT which was maximum.

4.5 TOTAL SOLUBLE SOLIDS

Total soluble solids measured from 0 to 26 DAT indicated significant differences between storage conditions and 1-MCP treatments at all the stages except at 0 DAT as the treatments were not imposed (Tables 5a and 5b).

At 7 DAT, total soluble solids was maximum in ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4) in all the concentrations of 1-MCP. Cold storage (S_2) and cold storage with shrink wrapper (S_3) recorded significantly lower total soluble solids at this stage. It was further observed that total soluble solids decreased with an increase in the concentration of 1-MCP. A similar trend continued at 14 DAT as was observed at 7 DAT with ambient condition (S_1) and ambient condition with shrink wrapper (S_4) recording significantly higher total soluble solids over cold storage (S_2) and cold storage with shrink wrapper (S_3) treatments. Significantly lower total soluble solids was observed in cold storage (S_2) over all other treatments. With an increase in the concentration of 1-MCP, total soluble solids decreased upto 2000 ppb 1-MCP (C_3) and increased further at 3000 ppb of 1-MCP (C_4).

Total soluble solids was maximum in cold storage with shrink wrapper (S_3) followed by cold storage (S_2) at 21 DAT, which were significantly superior over ambient condition (S_1) and ambient condition with shrink wrapper (S_4). Similarly, with an increase in the concentration of 1-MCP, there was an increase in the total soluble solids but the increase was maximum upto 1000 ppb 1-MCP (C_2) and declined slightly thereafter at 2000 ppb 1-MCP (C_3) and 3000 ppb 1-MCP (C_4). Among different treatment combinations, maximum total soluble solids was observed in cold storage with shrink wrapper + 3000 ppb of 1-MCP (C_4S_3) which was significantly superior over all other treatments, except cold storage with shrink wrapper + 1000 ppb of 1-MCP (C_2S_3) and cold storage with 2000 ppb of 1-MCP (C_3S_2).

Similar trend continued at 26 DAT with higher total soluble solids in cold storage (S_2) and cold storage with shrink wrapper (S_3) as was observed at 21 DAT. However, it was not possible to record total soluble solids in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were rotten and were unfit for sampling. It is observed in general, from the data that total soluble solids was initially higher under ambient storage and lower in cold storage treatments. However, this trend reversed at 21 and 26 DAT.

Table 4a. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 2, 4, 6, 8, 10 and 12 DAT in Alphonso mango (pooled)

2 DAT						4 DAT					6 DAT							
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean			
S ₁	3.38	2.65	2.07	3.12	2.80	7.93	4.60	3.41	4.61	5.14	10.16	5.58	4.00	5.21	6.24			
S ₂	1.84	1.53	1.39	1.32	1.52	3.05	2.51	2.52	1.90	2.49	3.37	2.39	2.82	1.92	2.63			
S ₃	1.28	1.23	1.26	1.26	1.26	1.93	1.81	1.77	1.69	1.80	1.84	1.69	1.50	1.47	1.62			
S ₄	1.86	1.79	1.36	1.84	1.71	2.57	2.51	1.91	2.64	2.41	2.96	2.67	1.89	2.95	2.62			
Mean	2.09	1.80	1.52	1.88		3.87	2.85	2.40	2.71		4.58	3.08	2.55	2.89				
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em. ±	C.D. (1%)				
C	0.03	NS					C	0.12	0.47				C	0.16	0.61			
S	0.03	NS					S	0.13	0.35				S	0.17	0.45			
S X C	0.53	0.20					S X C	0.25	0.94				S X C	0.33	1.22			

8 DAT						10 DAT					12 DAT							
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean			
S ₁	11.66	6.89	4.89	6.18	7.40	13.15	8.02	5.97	7.06	8.55	16.93	11.17	8.44	9.84	11.59			
S ₂	3.91	2.77	3.15	2.10	2.99	4.46	3.25	3.49	2.74	3.48	5.54	4.11	4.32	3.40	4.34			
S ₃	2.06	1.82	1.62	1.66	1.79	2.49	2.25	1.93	1.96	2.15	2.62	2.61	2.40	2.09	2.43			
S ₄	3.76	3.07	2.26	3.50	3.15	4.55	3.55	2.74	4.27	3.78	4.28	3.82	3.19	4.41	3.92			
Mean	5.35	3.64	2.98	3.36		6.157	4.27	3.53	4.01		7.34	5.42	4.59	4.94				
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				
C	0.20	0.77					C	0.23	0.87				C	0.31	1.14			
S	0.21	0.58					S	0.24	0.65				S	0.30	0.86			
S X C	0.41	1.54					S X C	0.47	1.74				S X C	0.61	2.29			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 4b. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 14, 16, 18 and 20 DAT in Alphonso mango (pooled)

14 DAT						16 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	18.58	11.16	8.81	11.12	12.42	22.83	12.59	10.21	12.33	14.49
S ₂	5.37	3.99	4.02	3.35	4.18	5.86	4.51	4.48	3.83	4.67
S ₃	3.07	2.90	2.57	2.55	2.77	3.62	3.46	3.02	3.03	3.28
S ₄	6.58	4.48	3.91	6.25	5.30	7.77	5.00	4.67	7.46	6.22
Mean	8.40	5.63	4.83	5.82		10.02	6.39	5.60	6.66	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.35	1.32				C	0.40	1.51		
S	0.36	0.99				S	0.40	1.13		
S X C	0.71	2.64				S X C	0.81	3.02		

18 DAT						20 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	24.60	13.68	11.86	13.98	16.03	25.86	15.14	13.02	15.18	17.30
S ₂	6.35	4.97	4.71	4.12	5.04	6.63	5.18	4.97	4.13	5.23
S ₃	4.11	3.82	3.27	3.38	3.65	4.21	3.81	3.27	3.58	3.72
S ₄	8.94	5.62	5.17	8.11	6.96	9.88	5.83	5.45	8.76	7.48
Mean	10.998	7.024	6.251	7.399		11.645	7.487	6.679	7.911	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.44	1.65				C	0.49	1.85		
S	0.44	1.24				S	0.50	1.39		
S X C	0.89	3.31				S X C	0.99	3.70		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 4c. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 22, 24 and 26 DAT in Alphonso mango (pooled)

22 DAT						24 DAT					26 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	27.70	16.34	13.88	16.27	18.55	29.83	17.76	15.02	18.03	20.16	—*	—	—	—	—	
S ₂	6.95	5.24	5.18	4.21	5.39	7.45	5.62	5.59	4.52	5.79	7.84	6.13	6.21	4.72	6.23	
S ₃	4.56	3.90	3.39	3.70	3.88	4.97	4.20	3.78	4.23	4.30	4.63	4.06	3.70	3.78	4.04	
S ₄	10.56	6.44	5.87	9.51	8.09	11.72	6.96	6.40	10.53	8.90	—	—	—	—	—	
Mean	12.44	7.98	7.08	8.42		13.49	8.64	7.70	9.33							
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)								
C	0.53	2.01				C	0.59	2.22								
S	0.54	1.51				S	0.59	1.67								
S X C	1.07	4.03				S X C	1.19	NS								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 5a. Influence of different concentrations of 1-MCP and storage conditions on total soluble solids (⁰Brix) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	8.75	8.56	8.43	8.69	8.61	15.95	14.89	14.85	14.97	15.17	18.81	16.86	15.77	17.64	17.27	
S ₂	8.35	8.56	8.31	8.37	8.40	12.99	11.01	10.81	11.21	11.51	13.74	12.74	12.50	12.80	12.94	
S ₃	8.59	8.67	8.46	8.40	8.53	12.49	11.21	11.21	11.53	11.61	13.78	13.03	12.95	13.25	13.25	
S ₄	8.67	8.81	8.42	8.60	8.62	15.85	14.87	13.56	14.90	14.80	17.94	16.75	14.00	17.46	16.54	
Mean	8.59	8.65	8.40	8.51		14.32	13.00	12.61	13.15		16.07	14.85	13.81	15.28		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.068	NS				C	0.055	0.208			C	0.015	0.057			
S	0.068	NS				S	0.055	0.156			S	0.015	0.042			
S X C	0.136	NS				S X C	0.110	0.416			S X C	0.030	0.113			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 5b. Influence of different concentrations of 1-MCP and storage conditions on total soluble solids (⁰Brix) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	12.62	15.10	14.95	14.87	14.38	—*	—	—	—	—
S ₂	16.90	17.49	18.45	17.60	17.61	13.74	16.57	17.90	15.50	15.93
S ₃	16.60	18.71	18.04	18.81	18.04	13.64	13.90	15.29	13.51	14.09
S ₄	14.72	15.62	14.91	15.00	15.06	—	—	—	—	—
Mean	15.21	16.73	16.59	16.57						
	S.Em.±	C.D. (1%)								
C	0.016	0.062								
S	0.016	0.046								
S X C	0.033	0.124								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

4.6 PULP ACIDITY

Pulp acidity decreased with an increase in the duration of treatment imposition under all storage conditions and concentrations (Tables 6a and 6b). Pulp acidity was maximum at 0 DAT i.e. before the imposition of the treatment and it decreased at 7 DAT where the pulp acidity was maximum in cold storage treatments (Table 6a). Pulp acidity was significantly lower in ambient condition (S_1) and ambient condition with shrink wrapper (S_4) compared to other treatments. Further, with an increase in the concentration of 1-MCP, pulp acidity increased upto 2000 ppb of 1-MCP (C_3) and decreased thereafter at 3000 ppb of 1-MCP (C_4).

Similar trend continued at 14 DAT also, but the pulp acidity almost decreased to half at this stage compared to 7 DAT in all the treatments. However, cold storage treatments maintained significantly higher pulp acidity over ambient storage either with or without 1-MCP. Interaction effect was non-significant and increase in the concentration of 1-MCP slightly increased the pulp acidity upto 2000 ppb of 1-MCP (C_3).

The pulp acidity further reduced to half in all the ambient storage conditions treatments at 21 DAT and 26 DAT (Table 6b). Similarly, the pulp acidity declined by 5 times in the cold storage treatments at both the DAT. In fact, there was not much difference in the pulp acidity of ambient condition (S_1) and ambient condition with shrink wrapper (S_4); cold storage (S_2) and cold storage with shrink wrapper (S_3). However, cold storage treatments still maintained higher pulp acidity at both the stages compared the ambient storage. Increase in the concentration of 1-MCP increased pulp acidity upto 2000 ppb of 1-MCP (C_3) and declined at 3000 ppb of 1-MCP (C_4).

4.7 TOTAL SUGARS

Total sugars as influenced by storage conditions and 1-MCP treatments were recorded from 0 to 26 DAT and presented in Tables 7a and 7b. No significant differences were observed between the treatments at 0 DAT as the treatments were not imposed at this stage. However, treatments differed significantly thereafter at 7, 14, 21 and 26 DAT with respect to storage conditions, concentrations of 1-MCP and their interactions.

At 7 DAT, maximum total sugars was observed in ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4) in all the concentrations of 1-MCP (Table 7a). Cold storage alone (S_2) and cold storage with shrink wrapper (S_3) recorded significantly lower total sugars compared to ambient condition (S_1) and ambient condition with shrink wrapper (S_4). It was further observed that total sugars decreased with an increase in the concentration of 1-MCP with lower values at 2000 ppb 1-MCP (7.35%) under cold storage (C_3S_2).

A similar trend continued at 14 DAT as was observed at 7 DAT with ambient condition (S_1) and ambient condition with shrink wrapper (S_4) recording significantly higher total sugars over cold storage (S_2) and cold storage with shrink wrapper (S_3). Significantly lower total sugars was observed in cold storage (S_2) over all other treatments. With an increase in the concentration of 1-MCP, total sugars decreased upto 2000 ppb (C_3) and increased further at 3000 ppb of 1-MCP (C_4). Among all the treatment combinations, significantly higher total sugars was observed in the ambient condition at 0 ppb of 1-MCP (15.04%) followed by ambient condition with shrink wrapper + 0 ppb 1-MCP (14.38%); whereas, the lowest value of total sugars was recorded in cold storage at 2000 ppb of 1-MCP (C_3S_2 , 10.30%).

At 21 DAT (Table 7b), total sugars reached the peak in cold storage with shrink wrapper (S_3) followed by cold storage (S_2), recording significantly higher values over ambient condition (S_1) and ambient condition with shrink wrapper (S_4). Similarly, with an increase in the concentration of 1-MCP, there was a decrease in the total sugars upto 2000 ppb of 1-MCP (C_3). Among different treatment combinations, maximum total sugars was observed in cold storage 2000 ppb of 1-MCP (C_3S_2) which was significantly superior over all other treatments, except cold storage with shrink wrapper +1000 ppb of 1-MCP (C_2S_3).

Similar trend continued at 26 DAT with cold storage (S_2) and cold storage with shrink wrapper (S_3) recording higher total sugars. However, it was not possible to record total sugars in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were discarded due to rotting and were unfit for sampling. Generally, the data suggested that the total sugars were initially higher under ambient storage upto 14 DAT and lower in cold storage treatments. However, this trend changed at 21 and 26 DAT. Among different combinations studied, significantly higher values of total sugars were recorded in cold storage with 2000 ppb 1-MCP (13.93% and 12.50%, respectively).

Table 6a. Influence of different concentrations of 1-MCP and storage conditions on pulp acidity (%) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	3.105	3.108	3.145	3.208	3.142	0.950	1.190	1.240	1.100	1.120	0.400	0.460	0.520	0.420	0.450		
S ₂	3.123	3.083	3.113	3.120	3.110	2.550	2.690	3.000	2.640	2.720	1.320	1.600	1.780	1.510	1.553		
S ₃	3.213	3.098	3.133	3.217	3.165	2.480	2.630	2.580	2.600	2.573	1.300	1.420	1.440	1.410	1.393		
S ₄	3.180	3.043	3.162	3.038	3.106	1.097	1.240	1.240	1.120	1.174	0.409	0.520	0.560	0.460	0.487		
Mean	3.155	3.083	3.138	3.146		1.769	1.938	2.015	1.865		0.857	1.000	1.075	0.950			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.039	NS				C	0.014	0.054				C	0.017	0.065			
S	0.039	NS				S	0.014	0.04				S	0.017	0.049			
S X C	0.079	NS				S X C	0.028	0.108				S X C	0.034	NS			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 6b. Influence of different concentrations of 1-MCP and storage conditions on pulp acidity (%) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	0.22	0.29	0.32	0.24	0.27	—*	—	—	—	—
S ₂	0.32	0.54	0.58	0.54	0.50	0.28	0.35	0.38	0.35	0.34
S ₃	0.32	0.35	0.48	0.35	0.38	0.22	0.31	0.31	0.31	0.29
S ₄	0.24	0.32	0.34	0.27	0.29	—	—	—	—	—
Mean	0.28	0.38	0.43	0.35						
	S.Em.±	C.D. (1%)								
C	0.009	0.037								
S	0.009	0.027								
S X C	0.019	0.073								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 7a. Influence of different concentrations of 1-MCP and storage conditions on total sugars (%) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	2.48	2.64	2.47	2.56	2.54	10.21	9.41	9.38	9.47	9.62	15.04	13.59	12.76	14.16	13.89		
S ₂	2.58	2.54	2.53	2.34	2.50	8.53	7.50	7.35	7.65	7.76	11.23	10.48	10.30	10.53	10.63		
S ₃	2.52	2.63	2.60	2.64	2.60	8.61	7.65	7.65	7.89	7.95	11.28	10.71	10.64	10.86	10.87		
S ₄	2.81	2.70	2.58	2.72	2.70	10.13	9.40	9.42	9.42	9.59	14.38	13.50	11.44	14.02	13.33		
Mean	2.59	2.63	2.54	2.57		9.37	8.49	8.45	8.61		12.98	12.07	11.28	12.39			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.138	NS				C	0.018	0.07				C	0.018	0.07			
S	0.138	NS				S	0.018	0.05				S	0.018	0.053			
S X C	0.277	NS				S X C	0.037	0.14				S X C	0.037	0.142			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 7b. Influence of different concentrations of 1-MCP and storage conditions on total sugars (%) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	12.95	11.73	11.62	11.56	11.97	—*	—	—	—	—
S ₂	13.75	13.52	13.93	13.60	13.70	11.76	12.42	12.50	12.12	12.20
S ₃	13.69	13.79	12.20	13.63	13.33	11.42	11.82	11.96	11.80	11.75
S ₄	11.44	12.12	11.58	11.65	11.70	—	—	—	—	—
Mean	12.96	12.79	12.33	12.61						
	S.Em.±	C.D. (1%)								
C	0.026	0.099								
S	0.026	0.079								
S X C	0.052	0.197								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

4.8 REDUCING SUGARS

Changes in reducing sugars as influenced by storage conditions and 1-MCP treatments were recorded from 0 to 26 DAT and presented in Tables 8a and 8b. No significant differences were observed between the treatments at 0 DAT as the treatments were not imposed at this stage. However, treatments differed significantly at all the other DAT with respect to storage conditions, concentrations of 1-MCP and their interactions.

Reducing sugars was maximum under ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4) in all the concentrations of 1-MCP at 7 DAT (Table 8a). Cold storage (S_2) and cold storage with shrink wrapper (S_3) recorded significantly lower reducing sugars at this stage. It was further observed that reducing sugars decreased with an increase in the concentration of 1-MCP upto 2000 ppb and increased further at 3000 ppb 1-MCP (C_4).

At 14 DAT, a similar trend continued as observed at 7 DAT with ambient condition (S_1) and ambient condition with shrink wrapper (S_4) in all the concentrations of 1-MCP recording significantly higher reducing sugar over cold storage (S_2) and cold storage with shrink wrapper (S_3). Significantly lower reducing sugars was observed in cold storage (S_2) over all other treatments. With an increase in the concentrations of 1-MCP, reducing sugars decreased upto 2000 ppb (C_3) and increased further at 3000 ppb (C_4).

Reducing sugars was maximum in cold storage (S_2) followed by cold storage with shrink wrapper (S_3) at 21 DAT (Table 8b), which were significantly superior over ambient condition (S_1) and ambient condition with shrink wrapper (S_4). Similarly, increase in the concentration of 1-MCP, there was decrease in reducing sugars upto 2000 ppb and increased slightly thereafter at 3000 ppb. Among different treatment combinations, maximum reducing sugars was observed in cold storage of 2000 ppb of 1-MCP (C_3S_2) which was significantly superior over all other treatments, except cold storage of 0 ppb 1-MCP (C_1S_2) and cold storage with shrink wrapper at 0 ppb 1-MCP (C_1S_3).

Similar trend continued at 26 DAT with higher reducing sugars in cold storage (S_2) and cold storage with shrink wrapper (S_3) as was observed at 21 DAT. However, it was not possible to record reducing sugars in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were rotten and were unfit for sampling. It was observed in general from the data that reducing sugars was initially high under ambient storage condition and lower in cold storage treatments. However, this trend reversed at 21 and 26 DAT.

4.9 VITAMIN A CONTENT

The data on changes in vitamin A content during storage as influenced by 1-MCP treatment revealed significant differences between the treatments and their interaction at all stages, except at 0 DAT (Tables 9a and 9b).

At 7 DAT, vitamin A content was maximum in ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4) in all the concentrations of 1-MCP (Table 9a). Cold storage (S_2) and cold storage with shrink wrapper (S_3) recorded significantly lower vitamin A content at this stage. It was further observed that vitamin A content decreased with an increase in the concentration of 1-MCP upto 2000 ppb and increased slightly at 3000 ppb.

A similar trend continued at 14 DAT as was observed at 7 DAT with ambient condition (S_1) and ambient condition with shrink wrapper (S_4) recording significantly higher vitamin A content over cold storage (S_2) and cold storage with shrink wrapper (S_3). Significantly lower vitamin A content was observed in cold storage (S_2) over all other treatments. With an increase in the concentration of 1-MCP, vitamin A content decreased upto 2000 ppb and increased thereafter at 3000 ppb of 1-MCP (C_4).

Vitamin A content was maximum in ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4) at 21 DAT (Table 9b), which were significantly superior over cold storage (S_2) and cold storage with shrink wrapper (S_3). Similarly, with an increase in the concentration of 1-MCP, there was a decrease in vitamin A content upto 2000 ppb and increased further at 3000 ppb of 1-MCP (C_4). Among different treatment combinations, maximum vitamin A content was observed in ambient condition at 0 ppb 1-MCP (C_1S_1) which was significantly superior over all other treatments.

Similar trend continued at 26 DAT with higher vitamin A content in cold storage with shrink wrapper (S_3) and cold storage (S_2). However, it was not possible to record vitamin A content in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were rotten and

Table 8a. Influence of different concentrations of 1-MCP and storage conditions on reducing sugars (%) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	1.285	1.243	1.294	1.328	1.287	3.262	3.023	3.014	3.041	3.085	4.312	3.875	3.628	4.046	3.965	
S ₂	1.250	1.349	1.217	1.245	1.265	2.759	2.450	2.105	2.495	2.452	3.169	2.944	2.890	2.957	2.990	
S ₃	1.254	1.284	1.218	1.246	1.251	2.783	2.495	2.495	2.567	2.585	3.182	3.011	2.991	3.058	3.061	
S ₄	1.294	1.343	1.273	1.287	1.299	3.239	3.019	3.024	3.025	3.077	4.114	3.848	3.232	4.006	3.800	
Mean	1.271	1.305	1.251	1.276		3.011	2.747	2.659	2.782		3.694	3.419	3.185	3.517		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.025	NS				C	0.012	0.046			C	0.011	0.044			
S	0.025	NS				S	0.012	0.035			S	0.011	0.033			
S X C	0.051	NS				S X C	0.024	0.092			S X C	0.023	0.087			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 8b. Influence of different concentrations of 1-MCP and storage conditions on reducing sugars (%) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	3.875	3.510	3.426	3.458	3.567	—*	—	—	—	—
S ₂	4.115	4.045	4.225	4.070	4.114	3.484	3.679	3.717	3.588	3.617
S ₃	4.097	4.076	3.435	4.050	3.915	3.379	3.509	3.544	3.495	3.482
S ₄	3.422	3.625	3.465	3.485	3.499	—	—	—	—	—
Mean	3.877	3.814	3.638	3.766						
	S.Em.±	C.D. (1%)								
C	0.018	0.069								
S	0.018	0.052								
S X C	0.036	0.137								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 9a. Influence of different concentrations of 1-MCP and storage conditions on vitamin A (IU) content at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	434	436	436	436	435	5197	4523	4368	5191	4820	6679	4903	4802	6127	5628
S ₂	436	437	435	436	436	1007	903	858	906	919	1594	1306	1264	1331	1374
S ₃	434	436	437	435	436	1012	971	960	990	983	1596	1382	1345	1455	1445
S ₄	435	436	437	436	436	5197	4370	4330	5191	4772	6402	4870	4798	5920	5497
Mean	435	436	436	436		3103	2692	2629	3069		4068	3115	3052	3708	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)		
C	0.51	NS				C	3.83	14.38			C	3.21	12.05		
S	0.51	NS				S	3.83	10.82			S	3.21	9.07		
S X C	1.03	NS				S X C	7.66	28.76			S X C	6.42	24.10		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 9b. Influence of different concentrations of 1-MCP and storage conditions on vitamin A (IU) content at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	5668	4827	4802	5247	5136	—*	—	—	—	—
S ₂	3744	3302	3302	3305	3413	4292	4114	4113	4117	4159
S ₃	3868	3426	3327	3447	3517	4325	4238	4139	4258	4240
S ₄	5544	4805	4802	4926	5019	—	—	—	—	—
Mean	4706	4090	4058	4231						
	S.Em.±	C.D. (1%)								
C	3.01	11.33								
S	3.01	8.53								
S X C	6.03	22.66								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

were unfit for sampling. It is observed in general, from the data that vitamin A content was initially lower under all storage treatments and increased almost ten folds at 7 DAT in all the ambient storage treatments and doubled under cold storage treatments. There was further increase at 14 DAT under both ambient storage and cold storage in all 1-MCP treatments. The trend reversed at 21 and 26 DAT with cold storage treatments almost doubling vitamin A content and ambient storage condition reducing vitamin A content.

4.10 ASCORBIC ACID CONTENT

Influence of storage conditions and 1-MCP treatments on ascorbic acid content recorded significant differences between the treatments and their interaction at all the storage periods, except at 0 DAT (Tables 10a and 10b). Ascorbic acid content was maximum at 0 DAT and then started declining upto the end of the storage period (26 DAT).

At 7 DAT, ascorbic acid content differed significantly with respect to storage conditions, concentrations of 1-MCP and their interactions. It was maximum in cold storage (S_2) followed by cold storage with shrink wrapper (S_3). Ambient condition (S_1) and ambient condition with shrink wrapper (S_4) recorded significantly lower ascorbic acid content at this stage (Table 10a). It was further observed that ascorbic acid content increased with an increase in the concentration of 1-MCP upto 2000 ppb and declined slightly thereafter at 3000 ppb.

A similar trend continued at 14 DAT, but the ascorbic acid content decreased at this stage compared to 7 DAT in all the treatments. However, cold storage (S_2) and cold storage with shrink wrapper (S_3) recording significantly higher ascorbic acid content over ambient condition (S_1) and ambient condition with shrink wrapper (S_4). Significantly lower ascorbic acid content was observed in ambient condition (S_1) over all other treatments. With an increase in the concentration of 1-MCP, there was increase in the ascorbic acid content upto 2000 ppb (C_3) and declined slightly thereafter at 3000 ppb.

Again, ascorbic acid content was maximum in cold storage (S_2) followed by cold storage with shrink wrapper (S_3) at 21 DAT (Table 10b), which were significantly superior over ambient condition (S_1) and ambient condition with shrink wrapper (S_4). Similarly, with an increase in the concentrations of 1-MCP, there was increase in the ascorbic acid content upto 2000 ppb and declined slightly thereafter at 3000 ppb. Among different treatment combinations, maximum ascorbic acid content was observed in cold storage of 2000 ppb of 1-MCP (C_3S_2) which was significantly superior over all other treatments except cold storage with 1000 ppb (C_2S_2).

Similar trend continued at 26 DAT with higher ascorbic acid content in cold storage (S_2) and cold storage with shrink wrapper (S_3) as was observed at 21 DAT. However, it was not possible to record ascorbic acid content in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were rotten and were unfit for sampling.

4.11 TOTAL CHLOROPHYLL CONTENT OF PEEL

Total chlorophyll content decreased with an increase in the duration of treatment imposition under all storage conditions and 1-MCP concentrations (Tables 11a and 11b). It was maximum at 0 DAT i.e. after the harvest and before the imposition of treatments and no significant differences between the treatments and their interaction was observed at this stage.

At 7 DAT, total chlorophyll content was significantly lower in ambient condition (S_1) and ambient condition with shrink wrapper (S_4) compared to other treatments. However, these two treatments did not differ significantly with each other. Further, with an increase in the concentration of 1-MCP, total chlorophyll content increased upto 2000 ppb (C_3) and decreased thereafter at 3000 ppb (C_4). The treatment 2000 ppb (C_3) had significantly higher total chlorophyll content over all other concentrations.

Similar trend continued at 14 DAT, but the total chlorophyll content almost decreased to half at this stage compared to 7 DAT in all the treatments (Table 11a). Cold storage treatments maintained significantly higher total chlorophyll content over ambient storage either with or without 1-MCP with cold storage (S_2) maintaining significantly higher total chlorophyll content over all other treatments. With an increase in the concentration of 1-MCP, there was an increase in the total chlorophyll content upto 2000 ppb (C_3) and declined slightly thereafter at 3000 ppb (C_4). Among different treatment combinations, maximum total chlorophyll content was observed in cold storage at 2000 ppb of 1-MCP (C_3S_2) which was significantly superior over all the treatments. Significantly lower

Table 10a. Influence of different concentrations of 1-MCP and storage conditions on ascorbic acid content (mg / 100 g fr. wt.) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	76.03	74.64	75.47	75.61	75.44	69.61	70.38	71.01	70.28	70.32	65.39	65.66	66.30	65.57	65.73		
S ₂	75.46	75.35	75.05	75.28	75.28	73.93	74.34	74.37	74.32	74.24	68.22	70.65	70.78	69.54	69.80		
S ₃	75.25	76.28	76.00	76.50	76.01	73.86	74.02	74.14	73.97	73.99	67.66	69.42	69.45	69.10	68.91		
S ₄	75.55	74.95	75.38	76.30	75.54	70.20	70.95	71.93	70.29	70.84	65.49	66.23	67.22	65.58	66.13		
Mean	75.57	75.30	75.48	75.92		71.90	72.42	72.86	72.21		66.69	67.99	68.44	67.45			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.47	NS				C	0.072	0.27				C	0.079	0.298			
S	0.47	NS				S	0.072	0.20				S	0.079	0.225			
S X C	0.94	NS				S X C	0.144	0.54				S X C	0.159	0.596			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 10b. Influence of different concentrations of 1-MCP and storage conditions on ascorbic acid content (mg / 100 g fr. wt.) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	56.46	56.73	57.36	56.64	56.80	—*	—	—	—	—
S ₂	64.29	66.72	66.85	65.61	65.87	56.28	58.71	58.84	57.60	57.86
S ₃	63.73	65.48	65.52	65.17	64.98	55.72	57.47	57.51	57.16	56.97
S ₄	56.55	57.30	58.28	56.65	57.20	—	—	—	—	—
Mean	60.26	61.56	62.00	61.02						
	S.Em.±	C.D. (1%)								
C	0.080	0.300								
S	0.080	0.230								
S X C	0.160	0.600								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 11a. Influence of different concentrations of 1-MCP and storage conditions on total chlorophyll content of peel (mg 100⁻¹ g) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	17.01	17.07	16.77	16.57	16.85	10.17	10.47	10.67	10.24	10.39	5.27	5.94	6.13	5.67	5.75		
S ₂	16.57	16.73	16.72	16.71	16.68	11.19	13.10	13.54	12.63	12.62	6.96	8.34	9.81	8.01	8.28		
S ₃	16.65	16.77	16.86	17.07	16.84	10.96	11.93	12.00	11.44	11.58	6.53	7.34	7.62	7.19	7.17		
S ₄	16.65	16.67	16.72	16.57	16.65	10.19	10.51	10.75	10.33	10.45	5.43	6.00	6.21	5.82	5.86		
S ₁	16.72	16.81	16.77	16.73		10.63	11.50	11.74	11.16		6.05	6.90	7.44	6.67			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.064	NS				C	0.027	0.103				C	0.024	0.092			
S	0.064	NS				S	0.027	0.078				S	0.024	0.069			
S X C	0.128	NS				S X C	0.055	0.207				S X C	0.049	0.180			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 11b. Influence of different concentrations of 1-MCP and storage conditions on total chlorophyll content of peel (mg 100⁻¹ g) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	0.96	1.56	1.72	1.04	1.32	—*	—	—	—	—
S ₂	3.23	5.00	6.21	4.54	4.75	0.86	1.98	2.28	1.62	1.69
S ₃	3.04	3.54	4.01	3.41	3.50	0.75	0.99	1.29	0.92	0.99
S ₄	1.00	1.67	1.80	1.23	1.43	—	—	—	—	—
Mean	2.06	2.94	3.44	2.56						
	S.Em.±	C.D. (1%)								
C	0.018	0.068								
S	0.018	0.051								
S X C	0.036	0.135								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

total chlorophyll content was observed in ambient condition with 0 ppb of 1-MCP (C_1S_1) which was on par with ambient condition with shrink wrapper + 0 ppb of 1-MCP (C_1S_4).

The total chlorophyll content further reduced to half at 21 DAT compared to 14 DAT in all the treatments. It was significantly lower in all the ambient storage conditions compared to cold storage at all the concentrations of 1-MCP. In fact, there was not much difference in total chlorophyll content of ambient condition (S_1) and ambient condition with shrink wrapper (S_4). Among different treatment combinations, significantly higher total chlorophyll content was recorded in cold storage with 2000 ppb of 1-MCP (C_3S_2) which was significantly superior over all other treatments. However, cold storage treatments still maintained higher total chlorophyll content compared to ambient storage. Increase in the concentration of 1-MCP, there was increase in the total chlorophyll content upto 2000 ppb (C_3) and declined at 3000 ppb (C_4).

A similar trend continued at 26 DAT in all the cold storage treatments except that it declined by four folds compared to 21 DAT. However, it was not possible to record total chlorophyll content under ambient storage treatments as there was total rotting of fruits.

4.12 TOTAL CAROTENOIDS

The data on total carotenoids as influenced by storage conditions and 1-MCP treatments recorded from 0 to 26 DAT and presented in Table 12a and 12b indicated no significant differences between the treatments at 0 DAT as the treatments were not imposed at this stage. However, treatments differed significantly at all other DAT with respect to storage conditions, concentrations of 1-MCP and their interactions.

Total carotenoids increased at 7 DAT compared to 0 DAT and was maximum in ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4) which did not differ significantly among themselves. Cold storage (S_2) and cold storage with shrink wrapper (S_3) recorded significantly lower total carotenoids at this stage. It is further observed that total carotenoids decreased with an increase in the concentration of 1-MCP upto 2000 ppb and increased slightly thereafter at 3000 ppb.

Total carotenoids increased more than ten times at this stage at ambient condition (S_1) and ambient condition with shrink wrapper (S_4) and only by two times in the cold storage treatments.

At 14 DAT, total carotenoids increased further compared to 7 DAT in all the treatments with cold storage (S_2) and cold storage with shrink wrapper (S_3) maintaining significantly higher values compared to cold storage treatments. Total carotenoids were almost $\frac{1}{4}$ th in these treatments compared to ambient condition. Significantly lower total carotenoids was observed in cold storage (S_2) over all other treatments. With an increase in the concentration of 1-MCP, total carotenoids decreased upto 2000 ppb (C_3) and increased further at 3000 ppb (C_4).

Total carotenoids decreased under ambient storage and increased under cold storage at 21 DAT as compared to 14 DAT (Table 12b). The increase was almost 2.5 times in cold storage (S_2) and cold storage with shrink wrapper (S_3). Total carotenoids was maximum in ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4), both of which did not differ significantly with each other, but were significantly superior over cold storage (S_2) and cold storage with shrink wrapper (S_3) treatments. With an increase in the concentration of 1-MCP, total carotenoids decreased upto 2000 ppb (C_3) and increased further at 3000 ppb (C_4).

At 26 DAT, total carotenoids increased in cold storage (S_2) and cold storage with shrink wrapper (S_3) compared to 21 DAT. However, it was not possible to record total carotenoids in ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were totally spoiled and were unfit for sampling. Maximum total carotenoids were recorded in cold storage with shrink wrapper + 0 ppb of 1-MCP (C_1S_3) followed by cold storage with 0 ppb of 1-MCP (C_1S_2).

It is observed in general, from the data that total carotenoid content increased during storage, attained a peak value during ripening followed by slow decline in ambient condition (S_1) and ambient condition with shrink wrapper (S_4).

4.13 RATE OF RESPIRATION

The rate of respiration increased continuously from 0 to 21 DAT in all the treatments, irrespective of storage conditions and the concentration of 1-MCP (Tables 13a and 13b). It was further observed that the rate of respiration differed significantly between the storage conditions, concentration of 1-MCP and their interaction at all the stages except at 0 DAT, since at this stage no treatments were imposed.

Table 12a. Influence of different concentrations of 1-MCP and storage conditions on total carotenoids ($\mu\text{g} / 100 \text{ g fr.wt.}$) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	752	753	754	756	753	8664	7542	7283	8655	8036	11132	8172	8003	10211	9379	
S ₂	755	759	755	756	756	1681	1509	1434	1514	1534	2657	2177	2107	2218	2290	
S ₃	752	756	758	754	755	1690	1622	1603	1653	1642	2661	2303	2242	2426	2408	
S ₄	753	753	756	754	754	8664	7286	7220	8654	7956	10670	8116	7997	9866	9162	
Mean	753	755	756	755		5175	4490	4385	5119		6780	5192	5087	6180		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.89	NS				C	2.63	9.87				C	4.13	15.52		
S	0.89	NS				S	2.63	7.43				S	4.13	11.68		
S X C	1.79	NS				S X C	5.26	19.75				S X C	8.26	31.03		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 12b. Influence of different concentrations of 1-MCP and storage conditions on total carotenoids ($\mu\text{g} / 100 \text{ g fr.wt.}$) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT					26 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	9445	8043	8002	8743	8558	—*	—	—	—	—
S ₂	6238	5502	5501	5507	5687	7148	6851	6849	6856	6926
S ₃	6445	5709	5543	5743	5860	7202	7057	6892	7092	7061
S ₄	9238	8007	8001	8209	8363	—	—	—	—	—
Mean	7841	6815	6762	7050						
	S.Em.±	C.D. (1%)								
C	3.28	12.33								
S	3.28	9.28								
S X C	6.56	24.66								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

At 7 DAT, irrespective of 1-MCP concentrations, the rate of respiration was maximum in ambient condition (S_1) followed by ambient condition with shrink wrapper (S_4); whereas, cold storage (S_2) and cold storage with shrink wrapper (S_3) recorded significantly lower rates of respiration (Table 13a). Among different concentrations of 1-MCP, maximum rate of fruit respiration was recorded in the treatment without 1-MCP; whereas, the lower rate of respiration was observed in 1-MCP at 2000 ppb. Among different treatment combinations, maximum rate of fruit respiration was recorded in ambient condition without 1-MCP (75.4%) and the lowest rate of respiration was recorded in cold storage with 2000 ppb 1-MCP (46.0%).

Irrespective of 1-MCP concentrations, ambient condition (S_1) and ambient condition with shrink wrapper (S_4) maintained significantly higher rates of fruit respiration over cold storage (S_2) and cold storage with shrink wrapper (S_3) at 14 DAT. Under all storage conditions, the 0 ppb concentration of 1-MCP (111.5%) maintained significantly higher values; whereas, cold storage at 2000 ppb 1-MCP maintained the lowest rate of fruit respiration (60.8%) at 14 DAT.

The rate of respiration was maximum in both ambient condition (S_1) and ambient condition with shrink wrapper (S_4) which did not differ significantly among themselves compared to cold storage treatment at 21 DAT (Tables 13a and 13b). Among the cold storage treatments, significantly higher rate of respiration was recorded in cold storage with shrink wrapper (S_3) over cold storage (S_2). The rate of respiration decreased continuously from 0 ppb to 2000 ppb of 1-MCP and slightly increased thereafter at 3000 ppb. The maximum rate of respiration at this stage was observed in ambient condition with 0 ppb 1-MCP (C_1S_1) which was significantly superior over all other treatment combinations. However, the minimum values were noticed with cold storage with 2000 ppb of 1-MCP (C_3S_2), which was significantly lower over all other treatments.

A similar trend continued at 26 DAT with cold storage with shrink wrapper (S_3) maintaining significantly higher rate of respiration over cold storage (S_2). However, it was not possible to record the rate of respiration in both ambient condition (S_1) and ambient condition with shrink wrapper (S_4), since the fruits were totally rotten and were unfit of making measurement. With an increase in the concentration of 1-MCP, there was significant decrease in rate of respiration upto 2000 ppb and further increase in the concentration at 3000 ppb, increased the rate of respiration.

4.14 RELEASE OF ETHYLENE

Ethylene released from the fruit was monitored right from the harvest (0 DAT) to 26 DAT under both ambient storage and cold storage with or without 1-MCP treatment (Tables 14a and 14b). The data revealed that the ethylene release increased continuously from 0 DAT to 14 DAT in all the ambient storage conditions, irrespective of the concentration of 1-MCP (Table 14a). Among the treatments, significantly higher ethylene was observed in ambient condition (S_1) followed by ambient storage with shrink wrapper (S_4) which were on par with each other and significantly superior over cold storage treatments. Similarly, increase in the concentration of 1-MCP, release of ethylene decreased upto 2000 ppb and increased slightly thereafter at 3000 ppb at 7 DAT. Among the cold storage treatments, maximum ethylene was observed in cold storage with shrink wrapper (S_3) followed by cold storage (S_2) in all the 1-MCP treatments. Among different treatment combinations, significantly higher ethylene release was observed in ambient condition with 0 ppb 1-MCP (C_1S_1) which was significantly superior over all other treatment combinations. Significantly lower ethylene release was observed in cold storage with 2000 ppb of 1-MCP (C_3S_2) at this stage.

Similar trend continued at 14 DAT with ambient storage maintaining significantly higher ethylene release over cold storage. Increase in the concentration of 1-MCP, significantly declined the ethylene release upto 2000 ppb. The ethylene release was higher at this stage compared to previous stage of measurement in all the treatments including cold storage treatments. Among different treatments combinations, maximum ethylene release was observed in ambient condition with 0 ppb 1-MCP (C_1S_1), which was significantly superior over all other treatments and significantly lower ethylene was observed in cold storage with 2000 ppb of 1-MCP (C_3S_2) at this stage.

At 21 DAT, the ethylene release was slightly reduced in all the ambient storage treatments. While, there was a marginal increase in the ethylene release compared to previous stage. Among the MCP concentrations, ethylene release increased significantly with an increase in the concentration of 1-MCP upto 2000 ppb and declined slightly thereafter at 3000 ppb. The interaction effect was non-significant at this stage.

The ethylene release was reduced at 26 days in all the cold storage treatments compared to 21 DAT. While, ambient storage treatments, there was no ethylene release, since the fruits were

Table 13a. Influence of different concentrations of 1-MCP and storage conditions on rate of respiration (%) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	41.0	41.4	41.2	41.2	41.2	75.4	71.4	71.2	73.2	72.8	111.5	89.7	81.5	100.5	95.8		
S ₂	40.3	40.0	40.8	40.4	40.4	55.4	53.0	46.0	53.4	52.0	77.7	63.8	60.8	65.7	67.0		
S ₃	40.3	40.2	40.2	40.4	40.3	55.7	54.8	54.2	55.1	54.9	79.1	76.7	76.5	76.7	77.3		
S ₄	41.3	41.1	40.8	40.9	41.0	74.1	71.3	69.7	71.6	71.7	102.7	81.8	80.6	93.0	89.5		
Mean	40.7	40.7	40.8	40.7		65.1	62.6	60.3	63.3		92.8	78.0	74.8	84.0			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.27	NS				C	0.28	1.05				C	0.20	0.76			
S	0.27	NS				S	0.28	0.79				S	0.20	0.57			
S X C	0.55	NS				S X C	0.56	2.11				S X C	0.40	1.51			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 13b. Influence of different concentrations of 1-MCP and storage conditions on rate of respiration (%) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	109.5	105.2	102.6	105.8	105.8	—*	—	—	—	—
S ₂	101.5	97.8	81.8	99.3	95.1	99.7	95.6	80.1	95.8	92.8
S ₃	101.7	100.2	99.6	100.8	100.6	99.8	99.2	97.8	99.5	99.1
S ₄	106.1	104.8	102.6	105.6	104.8	—	—	—	—	—
Mean	104.7	102.0	96.7	102.9						
	S.Em.±	C.D. (1%)								
C	0.21	0.82								
S	0.22	0.61								
S X C	0.43	1.63								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 14a. Influence of different concentrations of 1-MCP and storage conditions on release of ethylene (ppm) at 0, 7 and 14 DAT in Alphonso mango (pooled)

0 DAT						7 DAT					14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	1.07	1.02	1.04	1.05	1.05	1.18	1.01	1.00	1.07	1.07	1.39	1.23	1.21	1.29	1.28	
S ₂	1.02	0.98	0.97	0.99	0.99	0.95	0.88	0.83	0.91	0.90	1.18	1.08	1.00	1.11	1.09	
S ₃	1.04	1.00	0.99	1.00	1.01	0.96	0.93	0.89	0.93	0.93	1.19	1.14	1.12	1.16	1.15	
S ₄	1.06	1.03	1.05	1.03	1.04	1.08	0.98	0.96	1.08	1.03	1.31	1.22	1.20	1.25	1.24	
Mean	1.05	1.01	1.01	1.02		1.05	0.95	0.92	1.00		1.27	1.17	1.13	1.20		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.07	NS				C	0.005	0.021				C	0.006	0.023		
S	0.07	NS				S	0.005	0.016				S	0.006	0.017		
S X C	0.14	NS				S X C	0.011	0.042				S X C	0.012	0.045		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 14b. Influence of different concentrations of 1-MCP and storage conditions on release of ethylene (ppm) at 21 and 26 DAT in Alphonso mango (pooled)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.05	1.04	1.08	0.96	1.03	—*	—	—	—	—
S ₂	1.13	1.25	1.27	1.23	1.22	0.88	1.04	1.08	0.97	1.00
S ₃	1.12	1.20	1.22	1.14	1.17	0.87	0.91	0.93	0.90	0.91
S ₄	0.95	1.06	1.10	1.01	1.03	—	—	—	—	—
Mean	1.06	1.13	1.16	1.08						
	S.Em.±	C.D. (1%)								
C	0.006	0.024								
S	0.006	0.018								
S X C	0.013	NS								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

rotten and it was not possible to measure the ethylene release. Among cold storage treatments, maximum ethylene release was observed in cold storage (S₂) followed by cold storage with shrink wrapper (S₃). Significant increase in ethylene release was also observed with an increase in the concentration of 1-MCP upto 2000 ppb.

4.15 ORGANOLEPTIC EVALUATION

The data on organoleptic evaluation of Alphonso mango was done at the end of the storage period and presented in Tables 15a and 15b. It was observed that fruit colour enhanced with an increase in the concentration of 1-MCP upto 2000 ppb and declined slightly at 3000 ppb. Among the storage conditions, maximum fruit colour was observed in cold storage (S₂) followed by cold storage with shrink wrapper (S₃) and least under ambient condition (S₁).

With respect to Aroma, maximum aroma was recorded under cold storage (S₂) followed by ambient storage with shrink wrapper (S₄) and least under cold storage with shrink wrapper (S₃). While, the aroma increased from 0 to 1000 ppb and declined further at 2000 ppb of 1-MCP (C₃). The fruit taste was better in ambient condition (S₁) compared to all other storage conditions. Similarly, 0 ppb 1-MCP (C₁) recorded higher values for taste and least in 3000 ppb 1-MCP (C₄).

Flavour component indicated that the values were maximum under cold storage (S₂) followed by cold storage with shrink wrapper (S₃). However, ambient condition (S₁) and ambient storage with shrink wrapper (S₄) had the same values. With respect to 1-MCP, it was observed that 2000 (C₃) and 3000 ppb 1-MCP (C₄) had the maximum values and similar values, followed by 0 ppb 1-MCP (C₁) and least in 1000 ppb 1-MCP (C₂).

The data on spongy tissue revealed that the values were maximum in ambient condition (S₁) followed by ambient storage with shrink wrapper (S₄) and least in cold storage (S₂) among the storage conditions. With an increase in the concentration of 1-MCP, the values declined upto 2000 ppb and slightly increased at 3000 ppb.

Table 15a. Influence of different concentrations of 1-MCP and storage conditions on organoleptic evaluation of colour and aroma at optimum ripening in Alphonso mango (pooled)

Colour						Aroma				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	7.25	7.30	7.30	7.28	7.28	7.80	7.86	7.60	7.72	7.74
S ₂	7.38	7.54	7.62	7.56	7.52	7.75	7.92	7.76	7.88	7.82
S ₃	7.36	7.52	7.58	7.32	7.44	7.60	7.64	7.75	7.80	7.69
S ₄	7.27	7.28	7.40	7.32	7.31	7.82	7.82	7.66	7.70	7.75
Mean	7.31	7.41	7.47	7.37		7.74	7.81	7.69	7.77	

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Table 15b. Influence of different concentrations of 1-MCP and storage conditions on organoleptic evaluation of taste, flavour and spongy tissue at optimum ripening in Alphonso mango (pooled)

	Taste					Flavour					Spongy tissue				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	8.60	7.93	7.90	7.88	8.07	7.20	7.16	7.23	7.24	7.20	7.75	7.70	7.41	7.65	7.62
S ₂	8.00	8.04	8.04	7.92	8.00	7.34	7.34	7.36	7.34	7.34	6.36	6.48	6.40	6.46	6.42
S ₃	8.00	8.02	7.88	7.90	7.95	7.32	7.32	7.32	7.36	7.33	7.70	6.44	6.46	6.43	6.75
S ₄	8.02	7.94	7.96	7.86	7.94	7.22	7.14	7.24	7.20	7.20	7.50	7.32	7.53	7.72	7.51
Mean	8.15	7.98	7.94	7.89		7.27	7.24	7.28	7.28		7.32	6.98	6.95	7.06	

C₁ : 0 ppb 1-MCP
C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP
C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP
S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper
S₄ : Ambient storage + 1- MCP + Shrink wrapper

DISCUSSION

Mango is one of the oldest and most important tropical fruits that has been in cultivation for over 4000 years. It has its origin in the Indo-Burma region (Mendoza Jr. and Wills, 1984). It is the national fruit of India and is designated as king of fruits owing to attractive colour, excellent taste, exotic flavour, exemplary nutritive value and its delicacy. It is gaining popularity in various parts of the world due to its wide adaptability, high yield and attractive fruit colour. Among different varieties being cultivated in India, Alphonso is the choicest variety because of its flavour and keeping quality compared to several varieties. Konkan region of India is known for extensive cultivation of Alphonso mango which is being exported to Middle-east, Japan, Indonesia, European Union, USA, Canada, etc. The quality of fruits produced in this region is much superior in terms of shelf-life, attractive size and colour and nutritive value and thus gaining importance day-by-day. Unfortunately, this variety suffers from two major physiological disorders, viz., Alternate bearing and spongy tissue. In addition, the shelf-life of this fruit is not more than 14 to 15 days under ambient storage conditions and thus early perishability post a great threat for export to long distance destinations.

Fruit quality is affected by genetic makeup and environmental, cultural and developmental preharvest factors. One of the most important factors determining at-harvest fruit quality and storability is the stage of maturity. Harvested mango fruits are still living biological systems with an active metabolism and since they are removed from the supplies of water, photosynthates and minerals from the tree, they are depending on their stored water and carbohydrate reserves. Between harvest and consumption fruits undergo many biochemical changes. Some of these changes are desirable for consumption, such as development of flavour, conversion of starch to sugars and reduction in organic acid contents, while others (mainly transpiration and respiration) may lead to inevitable postharvest losses (physical loss and loss of fruit quality) (Lee *et al.*, 1995; Giovannoni, 2001; Wills *et al.*, 2007). However, the plant hormone ethylene influences many of the ripening processes in fruits. Therefore, the main aim of postharvest technologies is to reduce metabolism, such as respiration, transpiration and ethylene production of harvested produce by means of low temperatures, high relative humidity and supplementary controlled atmospheres (reduced oxygen and elevated carbon dioxide concentrations). However, senescence and deterioration of harvested fruit can not be stopped, but delayed and slowed down by appropriate postharvest management.

A highly potent inhibitor of ethylene action, 1-methylcyclopropene (1-MCP), was developed (Sisler and Serek, 1997), and has been registered as a preservative of fresh fruit and vegetables in the United States. It is thought to bind irreversibly to ethylene receptors and protect plants from ethylene. Many reports on efficacy of 1-MCP are available for horticultural crops. 1-Methylcyclopropene (1-MCP) has been shown to improve the postharvest and shelf-life quality of various fruits such as apples, pears and kiwifruit by inhibiting ethylene-related senescence (Watkins and Miller, 2003). Therefore, we hypothesized that post harvest 1-MCP treatment would extend the shelf life by delaying the ripening of mango fruits. The objectives of this study were to determine storage conditions and appropriate concentrations of 1-MCP required to extend the shelf life of mango fruits cv. Alphonso. Results obtained from the present investigation are discussed in this chapter.

5.1 RIPENING BEHAVIOUR OF FRUITS

Mango being a climacteric fruit is characterised by a sharp increase in ethylene production and respiratory climacteric followed by series of biochemical changes during ripening. Progression in ripening brings about the degradation of cell wall components along with structural changes (Parikh *et al.*, 1990).

Fruit softening is accompanied with reduction in the size of hemicelluloses, loss of galactose side chains and solubilisation and depolymerisation of pectin. The enzymes responsible for softening, such as polygalactouronase (PG) and pectin methyl esterase (PME) have been reported to increase during ripening of fruits (Tucker and Grierson, 1987). A treatment which can inhibit the rapid softening in fruits after harvest is of paramount importance to increase the storage life.

India being the largest producer of mangoes in the world, its export is very much limited mainly due to poor shelf-life. It is well determinate that a fruit softening is partially controlled by ethylene and the exogenous application of ethylene to fruit causes faster softening.

Ethylene (C₂H₄) is well documented as being the ripening hormone of climacteric fruits. At a certain maturation stage, ethylene is linked to its binding-site in the cell and promotes several

alterations which culminate in the ripening and senescence of fruits (Burg and Burg, 1967; Lelievre *et al.*, 1997a).

Such ethylene actions can be blocked by some compounds, such as 2,5-norbornadiene (NDB) and diazocyclopentadiene (DACP), which, when linked to the ethylene binding-site, avoid its action. Blankenship and Sisler (1989 and 1993) and Gong and Tian (1998) observed that NDB and DACP delayed the softening and ripening in mangoes. However, none of these products are commercially acceptable due to toxicity and manufacturing concerns (Fan *et al.*, 1999).

The 1-methylcyclopropene (1-MCP or C₄H₆) is a potent inhibitor of the ethylene binding-site, acting as an antagonist (Sisler and Serek, 1997). The 1-MCP has been formulated into a powder that releases its active ingredient when mixed with water at 40-60°C. This nontoxic compound can be used at low concentrations (nLL⁻¹).

It has been reported that 1-MCP improved the shelf life of cut flowers and potted plants (Serek *et al.*, 1994 and 1995; Porat *et al.*, 1995; Sisler *et al.*, 1996) and retarded the ripening of several climacteric fruits (Lelievre *et al.*, 1997b; Sisler and Serek 1997; Abdi *et al.*, 1998; Golding *et al.*, 1998; Fan *et al.*, 1999; Feng *et al.*, 2000; Jiang *et al.*, 1999a).

Various maturity indices for harvesting mangoes have been suggested for several varieties, but on the whole little effort has been made to determine indices that have practical significance (Medlicott *et al.*, 1998). Mango fruits are usually harvested unripe (mature green); before the onset of the climacteric, but physiologically mature or 15-16 weeks after fruit set (Lakshminarayana *et al.*, 1970). Due to differences among mango types (Indian, monoembryonic vs. Polyembryonic), varieties, production conditions and locations, there is no consensus on maturity indices. Physical, chemical and physiological parameters have been examined to define the optimum state of maturity for harvest. Useful physical parameters include shape, size, surface colour, lenticels, shoulder growth (shoulder rise above the stem end), pit around the pedicel and specific gravity (Popenoe and Long, 1957; Krishnamurthy and Subramanyam, 1970; Ketsa *et al.*, 1991). Most mango varieties on reaching physiological maturity show changes in the pulp colour, breaking to yellow, which can easily be determined by slicing the pulp of a few fruits before harvest and which may incidentally serve as a guiding factor for harvest. Generally fruit intended for local markets or shipments by air (a three-day marketing frame) are harvested after the colour break. Fruit destined for longer transportation distances or storage (8-10 days) should be harvested firm and green, but physiologically mature.

Among various changes taking place during ripening, physical changes *viz.* colour, texture and physiological loss in weight (PLW) are the most obvious signals for fruit ripening. During ripening, fruit generally show a rapid loss of green colour, which results from the degradation of chlorophyll structures (Tromp, 2005; Wills *et al.*, 2007). The yellow colour of carotenoids and red colour of anthocyanins becomes visible with diminishing green colour due to chlorophyll decline (Kingston, 1992; Tromp, 2005; Wills *et al.*, 2007).

In present investigation, as expected, mature green Alphonso mango fruits ripened under ambient condition without 1-MCP treatment (C₁S₁), following the normal trend of ripening as observed in respect of early degradation of green colour (Fig. 1 to 3), loss in physiological weight and texture. Whereas, fruits under cold storage with different concentrations of 1-MCP in general and treatment under cold storage with 2000 ppb of 1-MCP (C₃S₂), exhibited significantly longer retention of green colour (97% fruits green on 12 DAT against 0.0 % in C₁S₁), firm texture (Fig. 4) and slower rate of loss in physiological weight (Fig. 5), thereby registering minimum of 7 days delay in normal ripening. They also maintained acceptable levels of these physical parameters till 26 DAT. The data further indicated that at 16 DAT, when 98 per cent of fruits completed the ripening in control, at the same stage, none of the fruits from the cold storage alone or cold storage with 1-MCP (2000 ppb) completed the ripening. In control more than 50 per cent fruits had developed the diseased and shrivelled symptoms on 16 DAT, whereas on the same day none of the fruits from cold storage alone or cold storage with 2000 ppb 1-MCP had developed the disease or shrivelling symptoms.

This clearly establishes that the 1-MCP under the influence of cold storage, at all the subsequent stages *i.e.*, green, turning yellow, half ripe, ripe, diseased and shrivelled delayed ripening as compared to control. This could be attributed to the fact that, during the normal ripening process, the ethylene is received by the receptor binding sites, but with the early induction of 1-MCP, these receptors get occupied by 1-MCP and hence, role of ethylene is held up till the new receptors are synthesized in the cell, which normally takes 7-8 days depending upon the type of the fruit, temperature and storage conditions. This could be the most convincing reason for delay in the

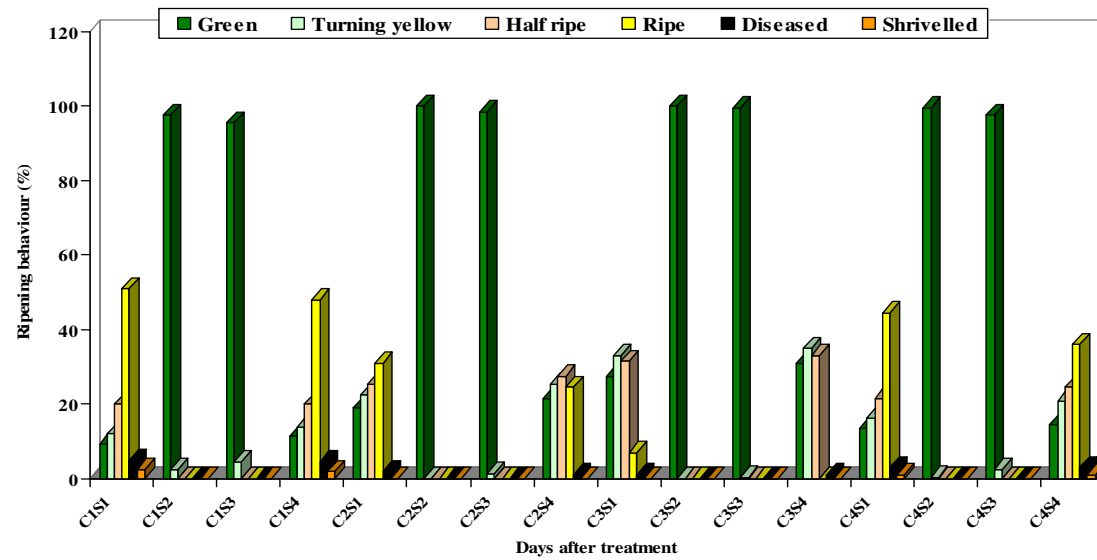


Fig 1 : Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 8 DAT in Alphonso mango (pooled)

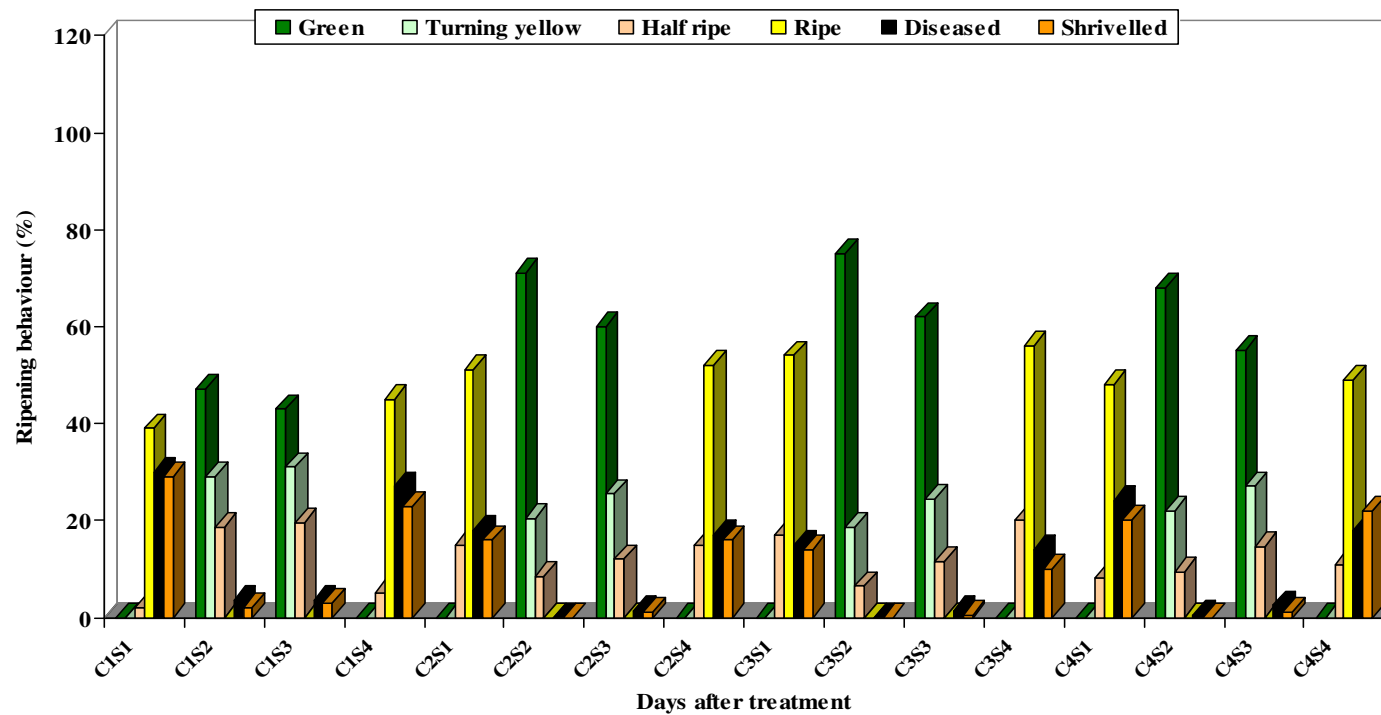


Fig 2 : Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 16 DAT in Alphonso mango (pooled)

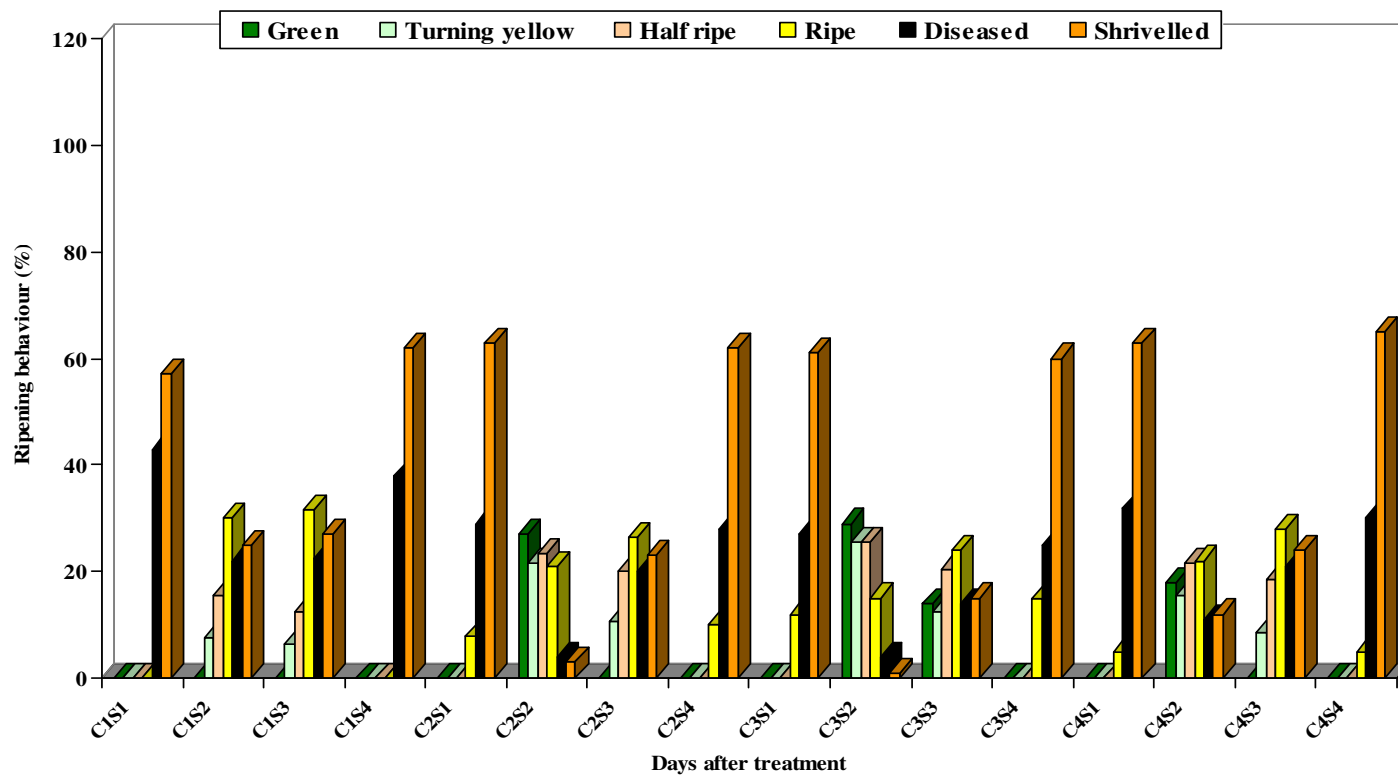


Fig 3 : Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 24 DAT in Alphonso mango (pooled)

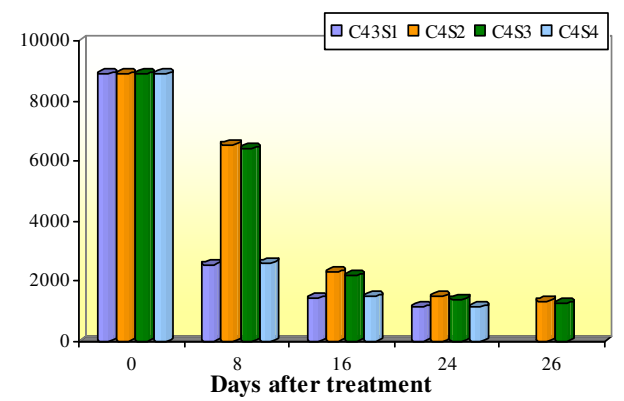
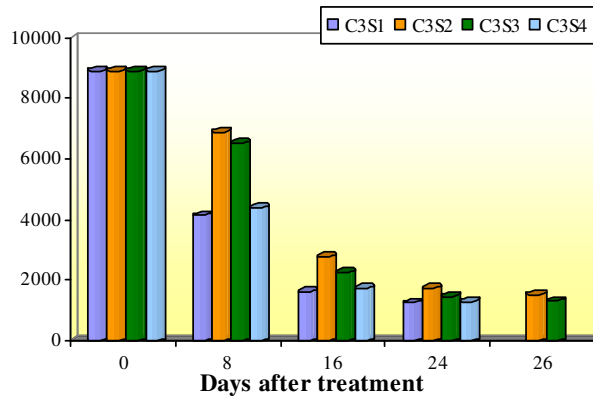
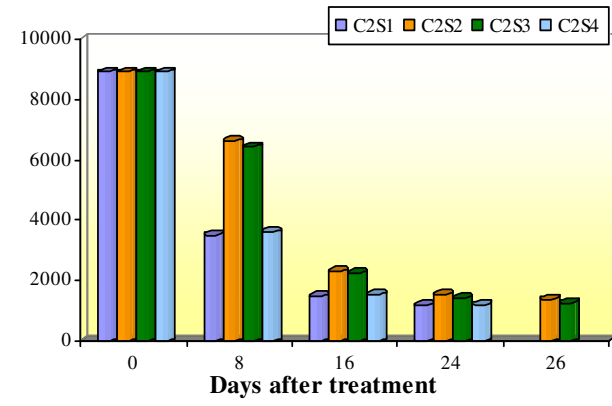
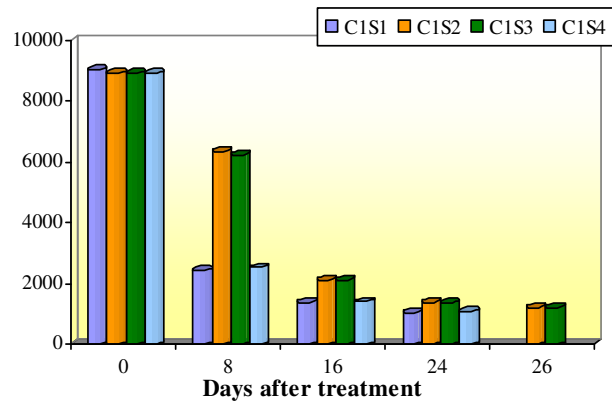


Fig 4 : Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at different days after treatment in Alphonso mango (pooled)

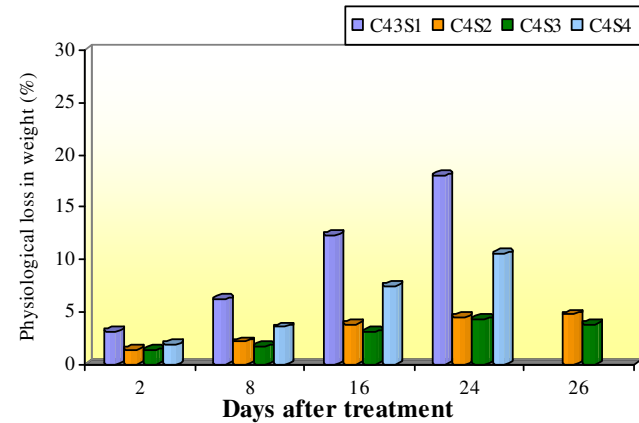
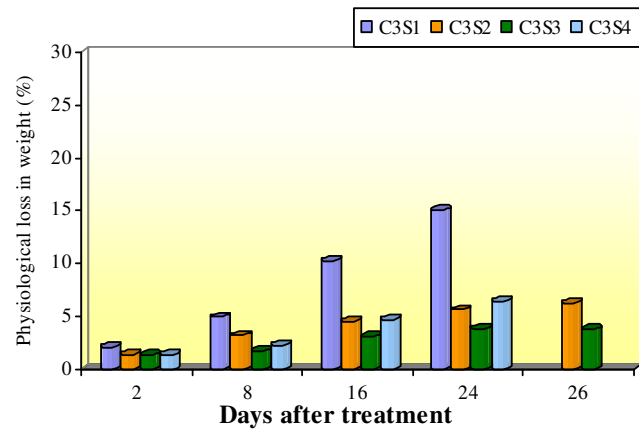
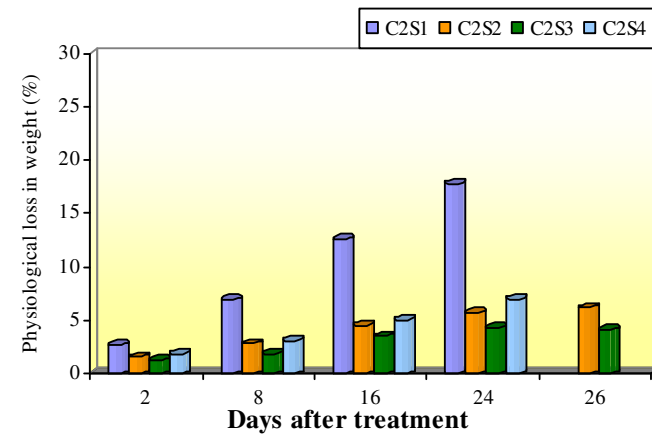
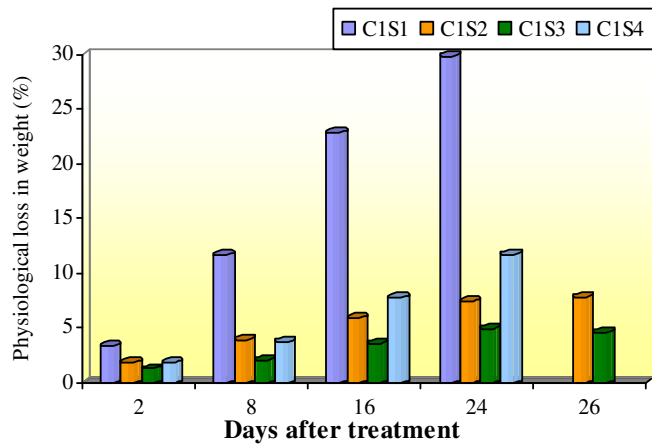


Fig 5 : Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at different days after treatment in Alphonso mango (pooled)

initiation of ripening (Sisler *et al.*, 1996), which ultimately reduces the physiological loss in weight, firmness and green colour of the fruit.

Several other reports on the effect of 1-MCP on maintenance of skin greenness and flesh firmness during storage are consistent with our findings (Fan *et al.*, 1999; Watkins *et al.*, 2000; Morais, 2001; Saftner *et al.*, 2003; Silva *et al.*, 2004; Mao *et al.*, 2007; Tatsuki *et al.*, 2007; Chaiprasart and Hansawasdi, 2009). Similarly, several studies (e.g., Kays, 1999; Alves *et al.*, 2004; Subramanyam *et al.*, 1972; Hofman *et al.*, 2001; Jiang and Joyce, 2000; Lalel *et al.*, 2003; Penchaiya *et al.*, 2006) have shown that the number of days required to ripen mangoes can be delayed by up to several days through the use of 1-MCP. However, our results are inconsistent with these findings regarding the level of 1-MCP concentration required to achieve the desired ripening delay.

Alves *et al.* (2004) were successful in using low concentrations (30 and 120 ppb) of 1-MCP to delay ripening of 'Tommy Atkins' mangoes, while others (Hofman *et al.*, 2001; Jiang and Joyce, 2000; Lalel *et al.*, 2003) reported concentrations much higher (25 to 100 ppm) than is typically required for other crops in order to be effective. Wang *et al.*, (2006) found when applying 1-MCP using vacuum infiltration technique, a 5-ppm concentration of 1-MCP provided an increase in shelf life of 8 to 12 days. Singh *et al.* (2007) compared 1-MCP treatments to silver nitrate, gibberellic acid, sodium metabisulphite and ascorbic acid treatments on 'Dashehari' mangoes and found that 1-MCP treatment was the most effective in delaying ripening. Cocozza *et al.* (2004) found that sensory judges detected no difference in aroma, colour or firmness between untreated and 1-MCP treated 'Tommy Atkins' mangoes. However, Lalel *et al.* (2003) observed that 1-MCP treatment of 'Kensington Pride' mangoes suppressed the development of aromatic volatiles during ripening. Hofman *et al.* (2001) observed that 1-MCP doubled the decay incidence (stem rots) due to *Colletotrichum* spp. or *Dothiorella* spp. in mangoes when compared to untreated fruits.

5.2 PHYSICO-CHEMICAL CHANGES

The normal ripening marks with the upsurge of ethylene in mango fruits. With the release of ethylene, various metabolic activities activate under the influence of different enzymes. Among these, conversion of starch to sugars is one of the critical processes. Temperature plays a critical role in controlling the ethylene production and reducing the overall starch metabolism (Lee *et al.*, 1995; Wills *et al.*, 2007). It is described that both the enzymes involved in ethylene biosynthesis pathway i.e. 1-aminocyclopropane-1-carboxylic acid synthase (ACC-S) and 1-aminocyclopropane-1-carboxylic acid oxidase (ACC-O) are sensitive to low temperature (Larrigaudiere *et al.*, 1997). At low temperature, fruits are less sensitive to ethylene and at a given ethylene concentration it takes longer time for ripening initiation (Lurie, 2002; Watkins, 2002). Hence, it is well established that low temperatures significantly delay the initiation of ripening and clearly decrease all metabolic activities including starch metabolism, which could have attributed to 7 days delay in reaching the peak values of total soluble solids, total sugars and reducing sugars.

In the present investigation, all the physico-chemical attributes which determine the fruit quality *viz.*, TSS (Fig. 6), pulp acidity (Fig. 7), total sugars (Fig.8), reducing sugars (Fig. 9), vitamin A (Fig. 10) and ascorbic acid (Fig. 11) content were found to be significantly influenced by storage conditions and concentrations of 1-MCP. The trend of change in these attributes reveal that regardless of storage conditions and 1-MCP treatments, the values obtained for total soluble solids, total sugars and reducing sugar were found to increase rapidly from the 1st day of treatment till 14 days after treatment in absolute control (S₁C₁) and till 21st day under the influence of cold storage with 2000 ppb of 1-MCP treatment (S₂C₃). Although, the peak values of total soluble solids, reducing sugar and total sugar were obtained on 21st day after treatment in cold storage with 2000 ppb 1-MCP, these values were comparable to those achieved under ambient condition on 14 DAT. Trend further indicated that after reaching the peak values, there was a sharp decrease in TSS (32.90%), total sugars (13.89%) and reducing sugars (10.13%) in control; whereas, the similar trend of decrease in TSS (2.98%), total sugars (10.26%) and reducing sugars (12.02%) at the slow rate was observed in cold storage with 2000 ppb 1-MCP at 21 DAT with relatively high consumer acceptable values of sugars till 26 DAT.

Burondkar *et al.* (2013) also observed considerable delay in ripening of Alphonso mango due to 1-MCP at 1000 ppb without significant differences in total soluble solids between control (17.61^oBrix) and in 1-MCP treatments (17.93^oBrix). Delayed but increased values of TSS over only cold storage under the influence of cold storage and 1-MCP might be due to delayed but effective hydrolytic changes due to alteration of all wall structure and effective breakdown of complex carbohydrates into simple sugars (Rathore *et al.*, 2007).

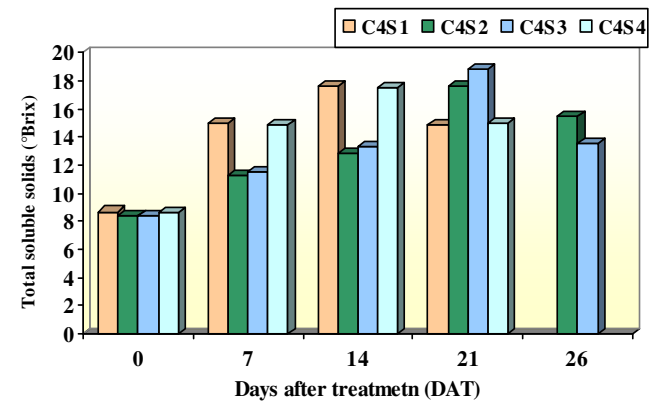
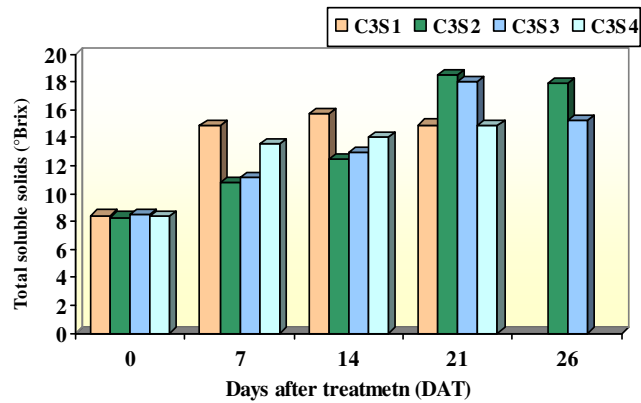
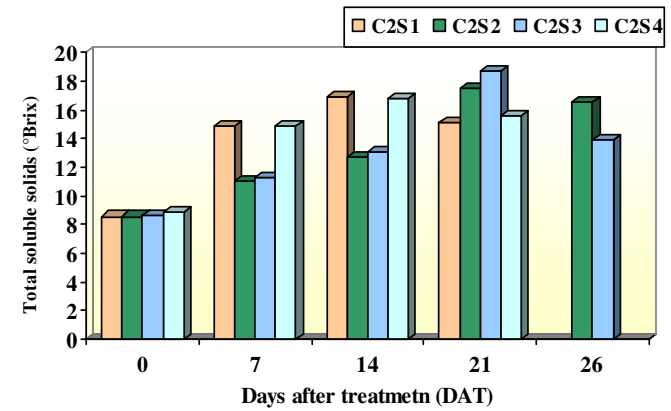
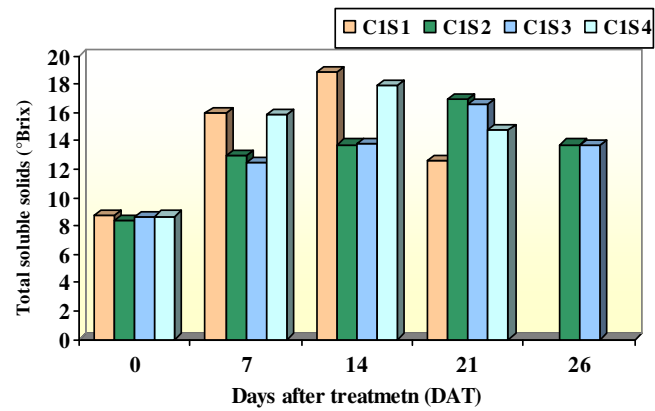


Fig 6 : Influence of different concentrations of 1-MCP and storage conditions on total soluble solids (° Brix) at different days after treatment in Alphonso mango (pooled)

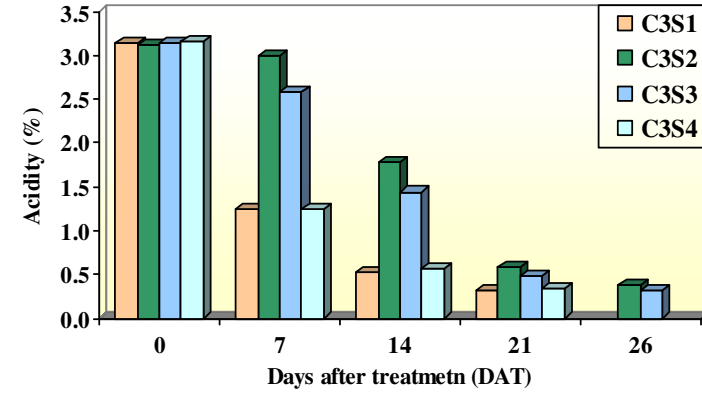
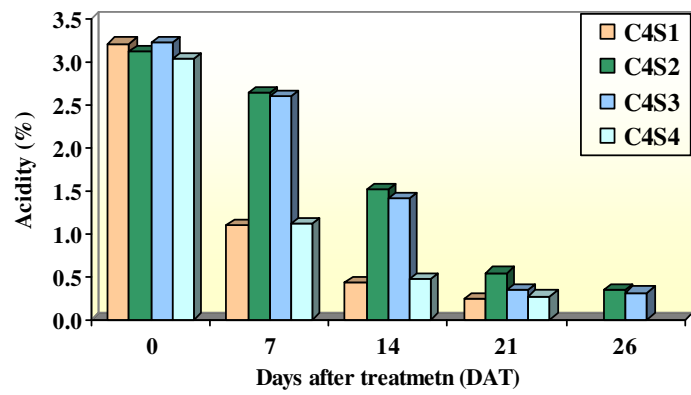
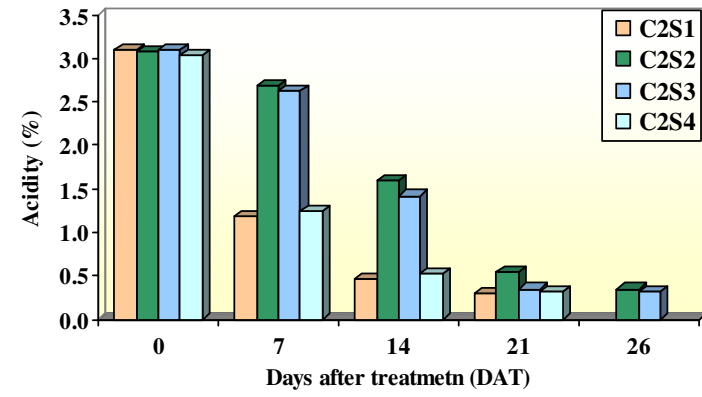
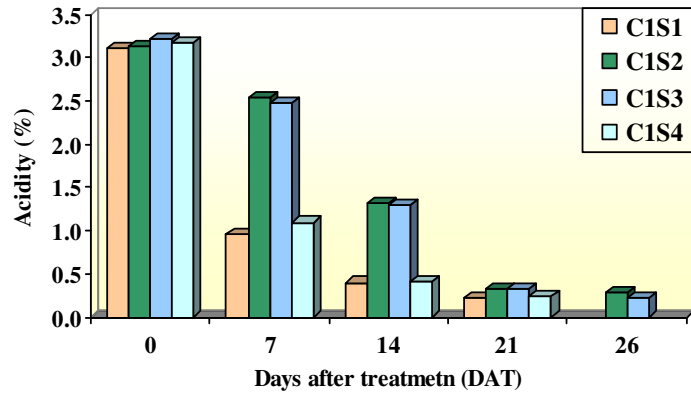


Fig 7 : Influence of different concentrations of 1-MCP and storage conditions on pulp acidity (%) at different days after treatment in Alphonso mango (pooled)

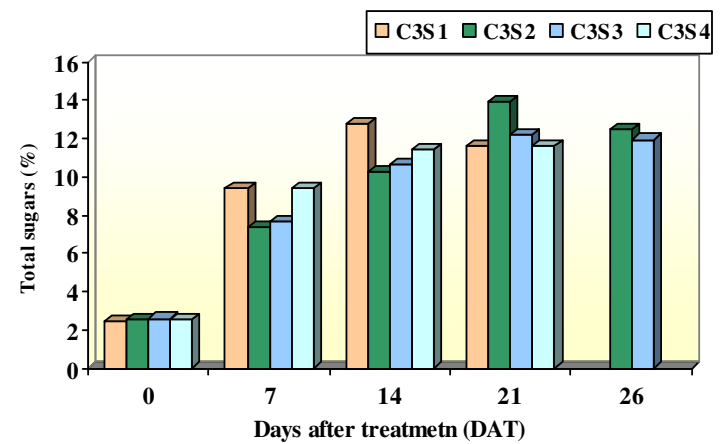
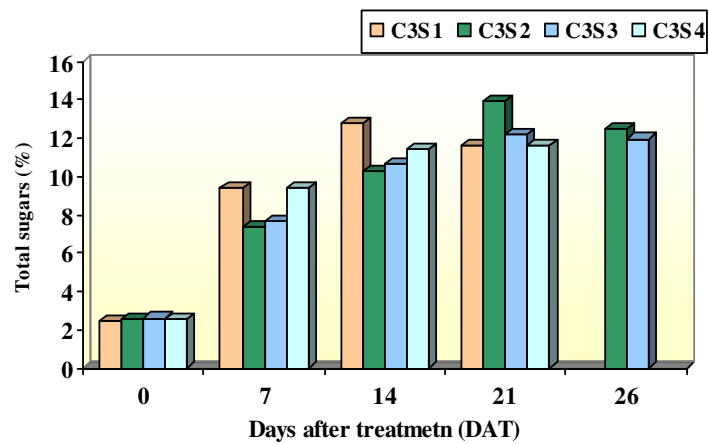
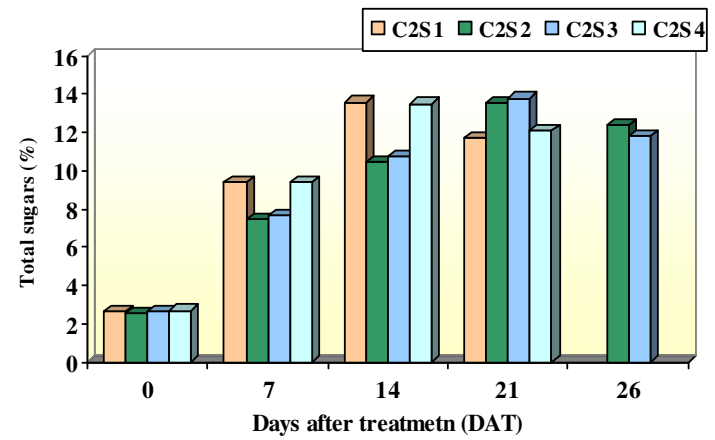
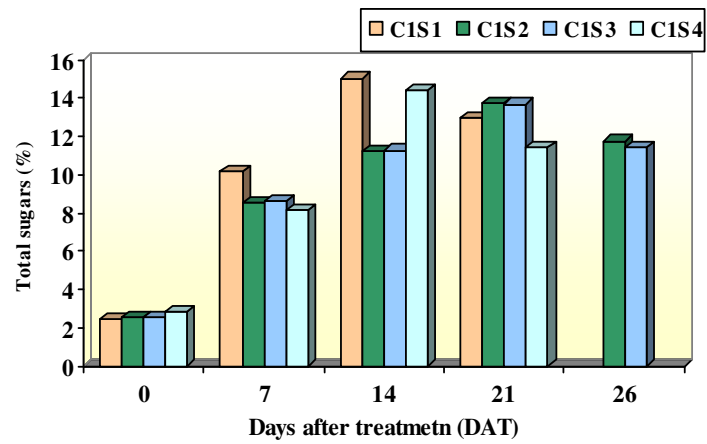


Fig 8 : Influence of different concentrations of 1-MCP and storage conditions on total sugars (%) at different days after treatment in Alphonso mango (pooled)

Similar effect of cold storage on delaying the sugar metabolism is reported in mango (Burondkar *et al.*, 2013; Rathore *et al.*, 2007; Silva *et al.*, 2004; Santos *et al.*, 2004; Alves *et al.*, 2004; Morais, 2001; Pandey and Singh, 2007; Liu *et al.*, 2010; Cocozza *et al.*, 2004) and other fruit crops viz., apple (Fan *et al.*, 1999; Jomari *et al.*, 2003; Calvo *et al.*, 2002). It is further observed that cold storage when coupled with 1-MCP (2000 ppb) was found to be most effective treatment as it not only delayed the metabolism but also maintained the same level of sugar synthesis on 21 DAT and was at par with the values of TSS, reducing sugar and total sugars attained on 14 DAT in ambient control. The effect of 1-MCP on changes in total soluble solids, reducing sugars and total sugars has also been reported in mango (Silva *et al.*, 2004; Santos *et al.*, 2004; Alves *et al.*, 2004; Morais, 2001; Pandey and Singh, 2007; Liu *et al.*, 2010; Cocozza *et al.*, 2004) and in other fruits crops such as apple (Fan *et al.*, 1999), pear (Calvo, 2002), custard apple (Benassi *et al.*, 2003) and lime (Jomari *et al.*, 2003).

Although the development of sweetness is an important attribute, organic acids also influence the overall fruit flavour. Acids help in maintaining the desirable sugar acid balance, which is necessary for a pleasant taste. The acidity of fruits generally decreases during the ripening. Organic acids present in fruit vary with different fruits, with malate and citrate being the most common of all acids in mango. A decrease in starch is accompanied by decrease in organic acids during ripening. Three major organic acids which imparts the acidity to pulp are succinate, citrate and malate and the decreasing level of these acids reduces the titratable acidity in the fruits (Lazan *et al.*, 1993).

In the present investigation, regardless of storage conditions and 1-MCP treatments, the values obtained for titratable acidity and ascorbic acid content were found to be reduced considerably from the 1st day till 21st day under ambient conditions (S₁C₁) and till 26th day under cold storage with 2000 ppb of 1-MCP treatment (S₂C₃). It was further observed that throughout the storage period, fruits at ambient conditions maintained significantly lower values as compared to cold storage alone and cold storage with 1-MCP (2000 ppb). Considerable decline in the acidity and ascorbic acid content during ripening can be attributed mainly to decrease in citrate and malate, which are present in high amount in unripe fruits but decrease towards ripening (Medlicott and Thompson, 1985). Generally, low temperatures reduce the decrease in titratable acidity (Hidalgo *et al.*, 1997).

Slow decrease in titratable acidity under the influence of cold storage and 1-MCP has also been reported in mango (Burondkar *et al.*, 2013, Dubery *et al.*, 1984) and other fruits like apple (Fan *et al.*, 1999) and pear (Calvo, 2002; Argenta *et al.*, 2003; Botondi *et al.*, 2003; Santos *et al.*, 2004; Silva *et al.*, 2004; Bassetto *et al.*, 2005a, b; Qiuping *et al.*, 2006; Rathore *et al.*, 2007; Ozkaya and Dundar, 2009; Chaiprasart and Hansawasdi, 2009; Liu *et al.*, 2010). Vitamin C content as expressed in terms of ascorbic acid indicated that, higher values of ascorbic acid content at initial stages is due to the large accumulation of glucose through the reduction of respiration rate favouring vitamin C synthesis (Selvarajah *et al.*, 2001; Evangelista, 1999) in mango. Whereas, Lee and Kader (2000) reported that the L-ascorbic acid concentrations during storage can be substantial and is affected by a number of factors such as extended storage duration or adverse storage temperatures. Similar results have been reported by Davey *et al.* (2004) and Heyn (2009) in apple, sapota, Qiuping *et al.* (2006) in sapodilla, Sankhla *et al.* (2010) in ber and Wang *et al.* (2009) in mango.

However, another attribute *i.e.*, vitamin A content contrastingly to acidity or ascorbic acid content, maintained the significantly higher values in control (S₁C₁) throughout the storage period over rest of the treatments. The ambient condition also registered maximum value of vitamin A (6679 IU) at 14 DAT and there was a significant decline by 16 per cent at 21 DAT. As compared to the control, in cold storage alone and cold storage with 1-MCP (2000 ppb) showed increase in vitamin A content at a slow rate but with a gradual rise up to the end of the study period (26 days) without any drop. Similar results have been reported by Plotto *et al.* (2003). However, very less work has been carried out in estimation of vitamin A content, which would be focused in future research.

5.3 PHYSIOLOGICAL CHANGES

Ripening is the process by which physiologically mature but inedible fruits attain its characteristic quality. Generally, during the process of ripening, changes such as loss of chlorophyll, synthesis of carotenoids, increased rate of respiration and ethylene takes place (Liu *et al.*, 2010). Since harvested fruits are still living biological systems, the respiration rate and ethylene production are important metabolic activities taking place during the ripening and it is inversely related to storability of fruits (Liu *et al.*, 1995; Wertheim, 2005). The change in physiology of climacteric fruit from maturation to ripening is initiated when cellular quantities of ethylene reach a threshold level (Yang and Hoffman, 1984; Yang, 1985).

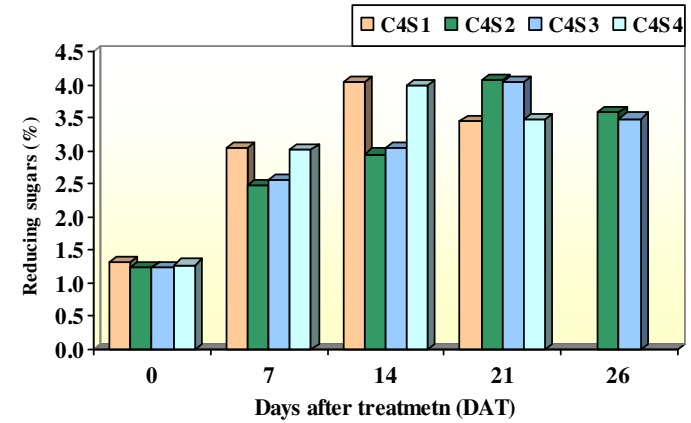
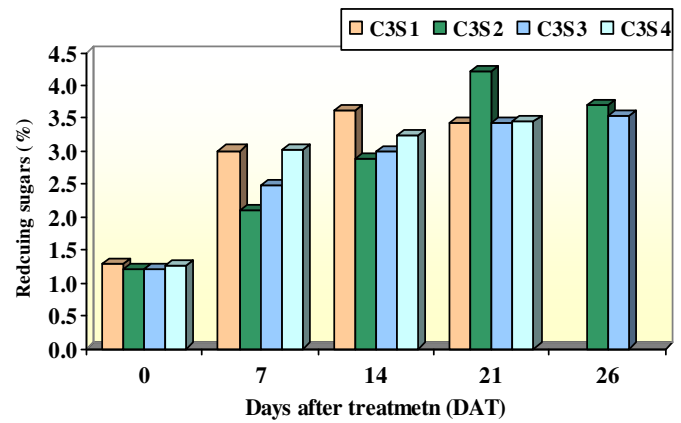
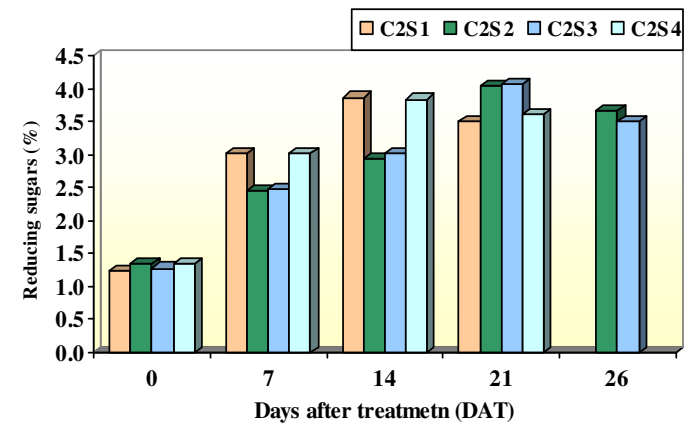
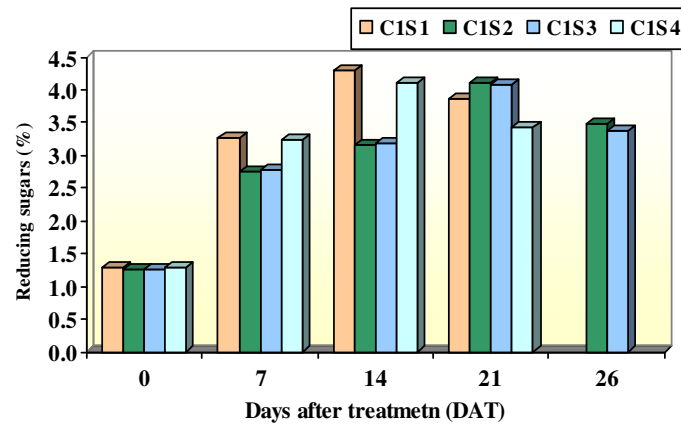


Plate 9 : Influence of different concentrations of 1-MCP and storage conditions on reducing sugars (%) at different days after treatment in Alphonso mango (pooled)

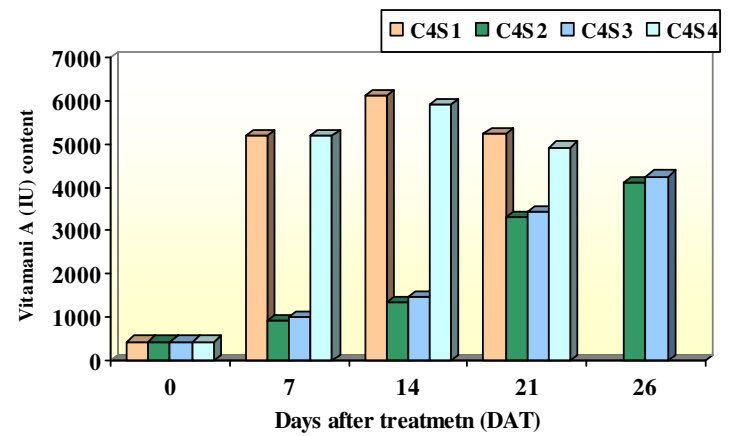
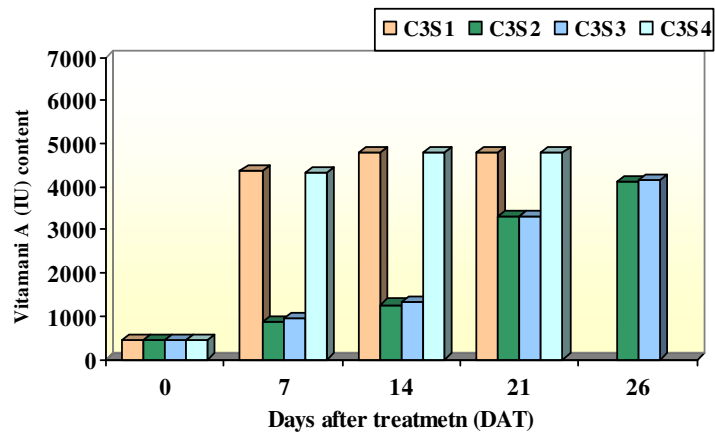
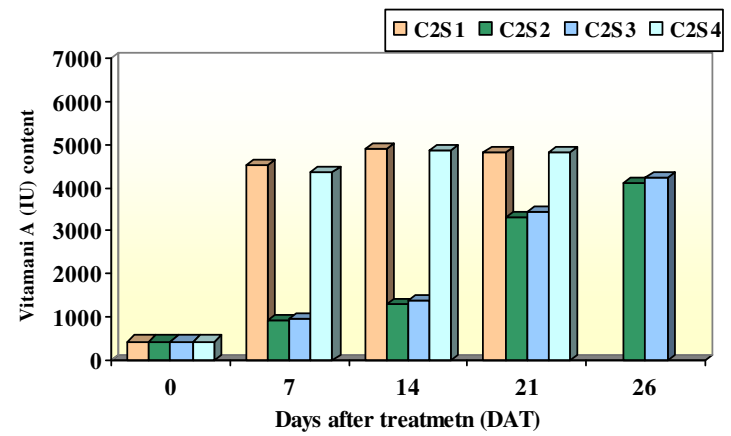
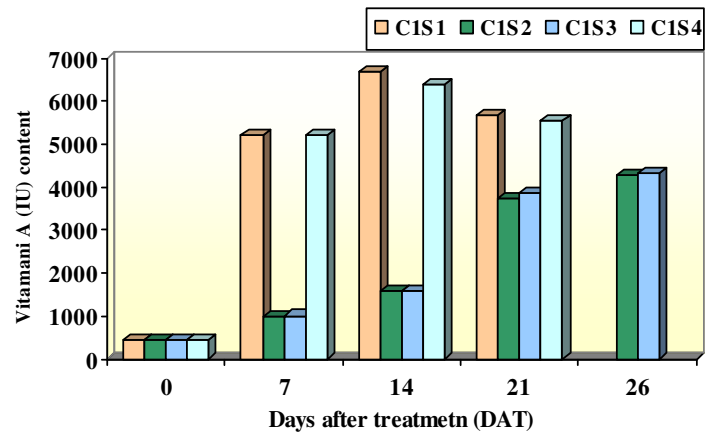


Plate 10 : Influence of different concentrations of 1-MCP and storage conditions on vitamin A (IU) content at different days after treatment in Alphonso mango (pooled)

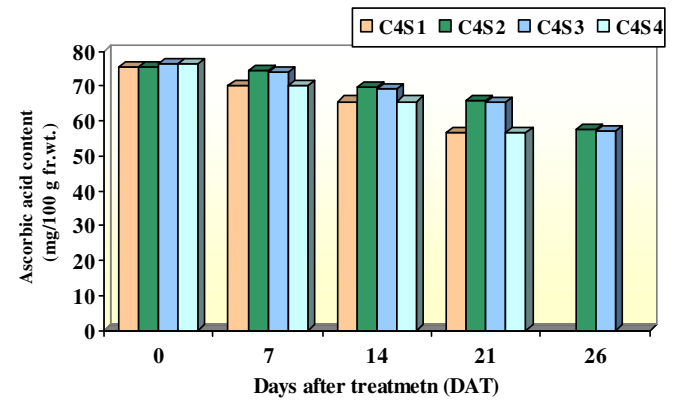
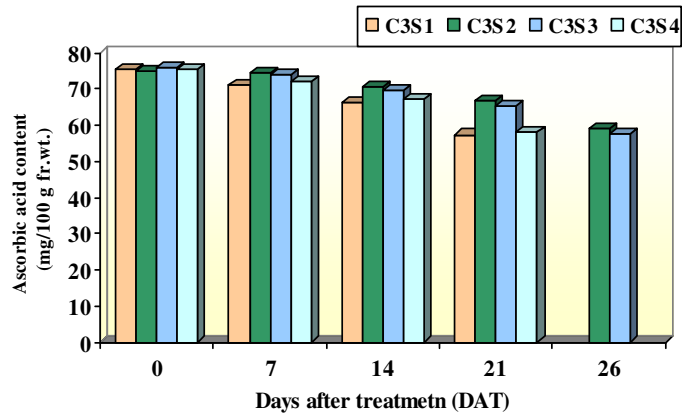
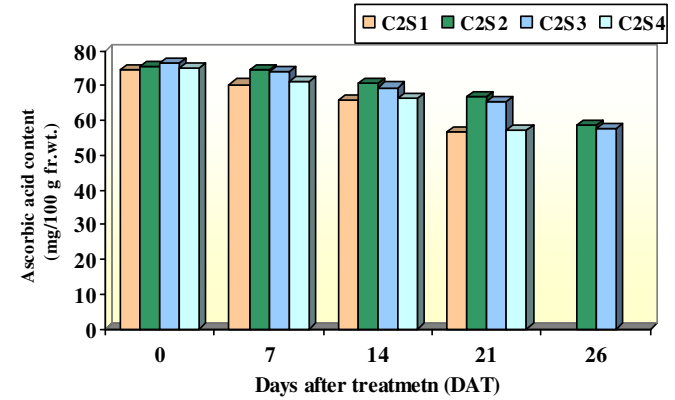
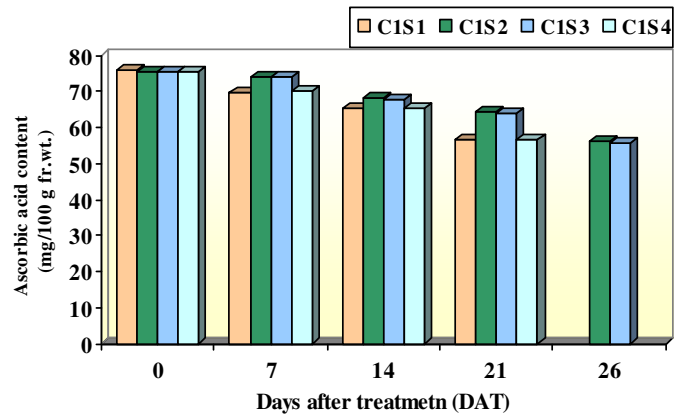


Plate 11 : Influence of different concentrations of 1-MCP and storage conditions on ascorbic acid content (mg/100 g fr.wt.) at different days after treatment in Alphonso mango (pooled)

Most obvious change during ripening in many fruits is their external colour. Pigments, which are chemicals responsible for skin and flesh colours, undergo changes during ripening of fruits. These include loss of chlorophyll, which is influenced by pH changes, oxidative conditions and chlorophyllase action, synthesis and/or revelation of carotenoids and development of anthocyanins which are fruit specific. These colour changes occur immediately following climacteric respiration peak during the fruit ripening. During senescence or storage, chlorophyll is degraded to colourless products and exposes carotenoid pigments. Factors like temperature, duration of storage and composition of storage atmosphere influence retention of green colour and thus rate of yellowing (Paull and Chen, 2004). During ripening, most of the fruits show a rapid loss of green colour, which is due to the degradation of chlorophyll structures (Wills *et al.*, 2007). The peel colour of fruits changes on ripening from dark green to olive-green; sometimes reddish, orange-yellow or yellowish hues appear from the base colour, depending on the cultivar. Chloroplasts in the peel are transformed into chromoplasts containing red and yellow pigments (John *et al.*, 1979; Lakshminarayana, 1980; Parikh *et al.*, 1990; Lizada, 1993).

The estimated total chlorophyll content (Fig. 12) in the present study under different interactions of storage and 1-MCP treatments suggested that there was a constant loss or degradation of chlorophyll in ambient condition (S_1C_1) throughout the study period, maintaining decreased chlorophyll from 0 DAT (17.01 mg /100 g of fruit weight) till 21 DAT (0.96 mg /100 g of fruit weight). However, cold storage and cold storage with 2000 ppb 1-MCP showed a similar trend of loss of chlorophyll at much reduced rates as compared to control, where, the cold storage with 2000 ppb 1-MCP maintained the higher level of readings over rest of the treatments from 0 DAT (16.72 mg /100 g of fruit weight) till 26 DAT (2.28 mg /100 g of fruit weight). The lower rate of chlorophyll degradation may be attributed due to lower temperature under cold storage accompanied by 1-MCP treatments, although the rate of chlorophyll content declines during the storage duration regardless of storage condition and 1-MCP treatments.

In the experiments conducted by Fan and Matheis (1999) they reported that the loss of chlorophyll content can be prevented or at least delayed after treatment with 1-MCP. Similarly, Jomari *et al.*, (2003) reported that the 1-MCP treated fruits maintained the green colouration with delay in ethylene production and chlorophyll degradation which makes skin yellow and low activity of chlorophyllase enzyme that degrades the chlorophyll. Similar results in mango were also reported by Johnson (2003), Saftner *et al.* (2003), Blankenship (1987), Janave and Sharma (2006) and other fruits such as cherry tomato (Opiyo and Ying, 2005), sapodilla (Qiuping *et al.*, 2006) and ber (Sankhla *et al.*, 2010).

The change in the peel and colour of the fruit is due to synthesis of carotenoids, which becomes visible with chlorophyll decline (Kays, 1999; Niemann, 2005; Wills *et al.*, 2007). Whereas, progressive loss of chlorophyll and increase in carotenoids indicating the transition from a green to yellow colour not only involve unmasking of the carotenoids, but synthesis of these pigments as well (Medlicott *et al.*, 1986). Several authors have studied the qualitative and quantitative changes in the carotenoid pigments during the ripening (Jungwala and Cama, 1963; John *et al.*, 1979). Parikh *et al.*, (1990) and observed that well arranged grana and osmiophilic globules appear in the chloroplasts of the cells in the peel of unripe mangoes, this granal membrane loses integrity during the ripening and osmiophilic globules appear, indicating the transformation of the chloroplast to chromoplast containing red and yellow carotenoid pigments. Carotenoid synthesis occurs *de novo* during ripening, which might be an ethylene dependent process Knee (1988).

It was further observed in the present study that in contrast to total chlorophyll content, total carotenoids increased (Fig. 13) considerably under ambient storage (control) till 14 DAT (11132 $\mu\text{g}/100\text{g}$ fruit weight) with a sharp decline (16% of peak values) at 21 DAT (9445 $\mu\text{g}/100\text{g}$ fruit weight). However, the total carotenoids under ambient conditions maintained significantly higher values over rest of the treatments till 21 DAT. Whereas, the cold storage alone and cold storage with 1-MCP (2000 ppb) showed a steady increase in total carotenoids till the end of the storage period i.e., 26 DAT (7148 and 6849 $\mu\text{g}/100\text{g}$ fruit weight) and running parallel to each other. Cold storage with 2000 ppb 1-MCP showed significantly lower values of total carotenoids as compared to control and other treatments. The reason of low synthesis of carotenoids could be the low degradation of chlorophyll content caused by cold storage and 1-MCP treatments.

Krishnamurthy and Subramanyam (1973) reported that mangoes stored at room temperature and subsequently ripened at room temperatures failed to synthesize as much carotenoids as do fruits held continuously at room temperature. Similar results were also reported by different researchers in mango (Thomas, 1975; Masalkar *et al.*, 2006; Mattoo and Modi, 1969; Janave and Sharma, 2006)

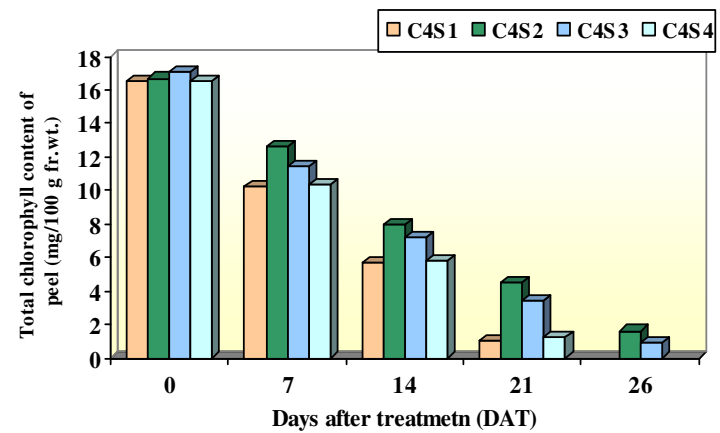
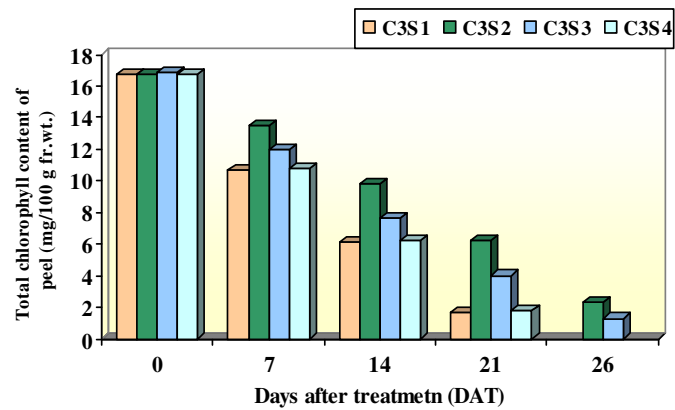
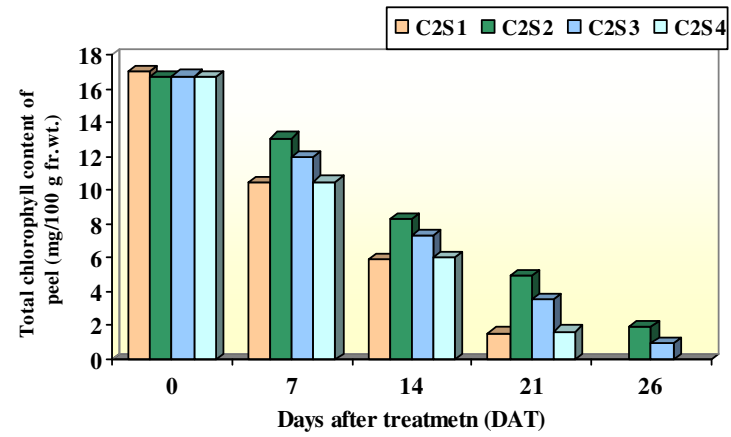
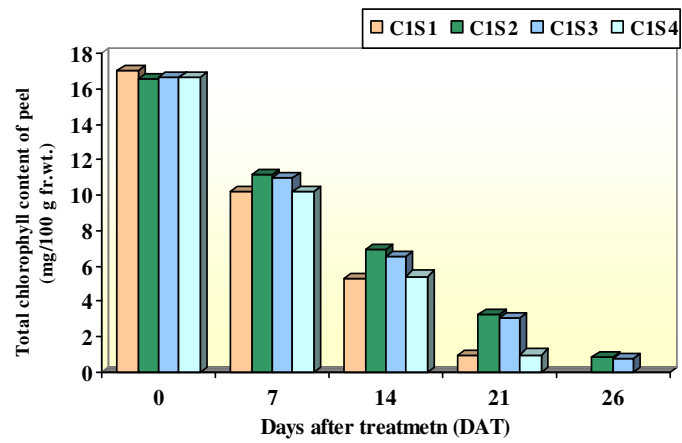


Plate 12 : Influence of different concentrations of 1-MCP and storage conditions on total chlorophyll content of peel (mg/100 g fr. wt.) at different days after treatment in Alphonso mango (pooled)

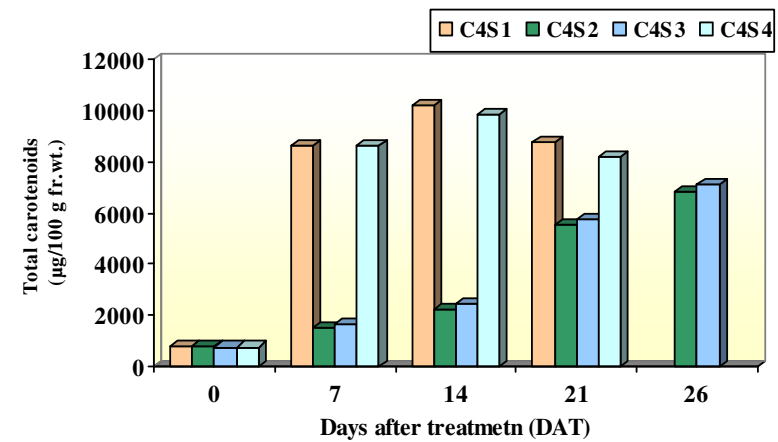
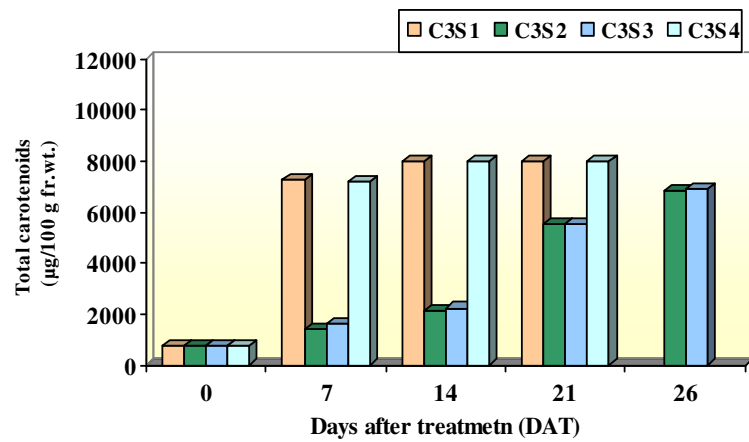
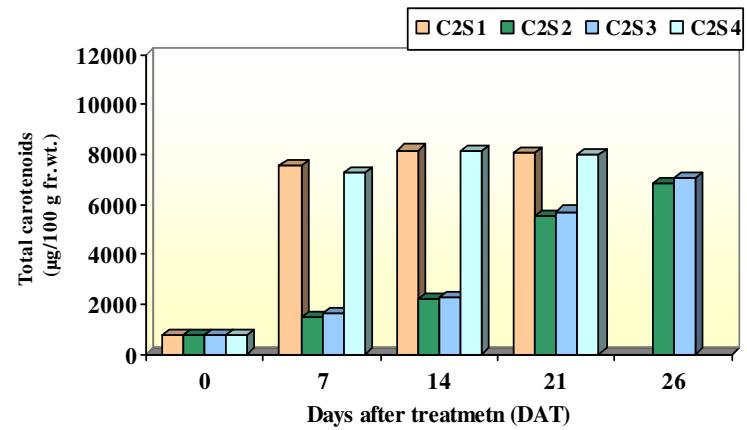
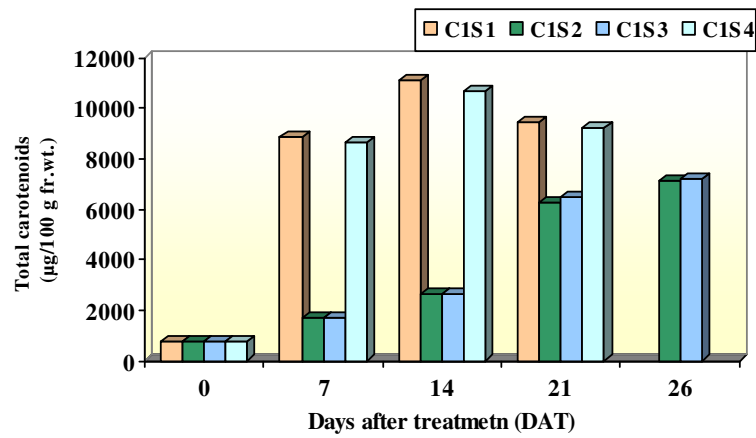


Plate 13 : Influence of different concentrations of 1-MCP and storage conditions on total carotenoids (µg/100 g fr.wt.) at different days after treatment in Alphonso mango (pooled)

and other crops such as carrot (Weier and Stocking, 1946 and Park, 1999) and tomatoes (Lichtenthaler, 1987).

Mango being a climacteric fruit, as such undergoes (autocatalytic) ethylene production (Mattoo and Modi, 1969), alongwith a breakdown in carotenoids in the peel (yellowing), enhanced ripitation and softening (Krishnamurthy and Subramanyam, 1970; Akamine and Goo, 1973; Salunkhe and Desai, 1984). Together with ethylene evolution and respiratory climacteric in mangoes, the catalase and peroxidase activities were found to increase considerably, due to the disappearance of the heat-labile and non-dialyzable inhibitor of these enzymes (Mattoo and Modi, 1970). The pattern of respiration vary among varieties, climatic conditions and the places where the fruit is grown (Krishnamurthy and Subramanyam, 1970).

Irrespective of the storage or 1-MCP treatments, the physiological characters such as, rate of fruit respiration, rate of ethylene production and total carotenoids show a trend of considerable increase up to their peak values with a sudden decline with the progress of the storage period. Whereas, unlike the above characters, the total chlorophyll content of the fruit follow the trend of consistent decrease as the storage period progresses.

In the present study, the rate of fruit respiration showed a sharp increase till 14 DAT in the ambient control (111.5%), where it reached to significantly higher peak values as compared to other treatments (Fig. 14). However, the cold storage alone and cold storage with 1-MCP (2000 ppb) showed a slow rise in the rate of fruit respiration by maintaining low values up to 21 DAT (101.5% and 81.8%, respectively) lesser than ambient and declining very slowly till the end of the storage period (26 DAT), thus, increasing the shelf life of the treated fruits. The slow and steady rise in respiration rate of the fruits could be attributed to the low temperature under cold storage which reduces the oxygen level required for aerobic respiration by maintaining the anaerobic conditions i.e., depletion of oxygen levels (Burg and Burg, 1967). Generally, the rate of respiration increases or decreases based upon changes in storage conditions and the physiological status of the produce (Kader 1992; Fennir *et al.*, 2003). Reduced oxygen and increase CO₂ levels will reduce the rate of respiration and results into slow ripening (Mathooko, 1996).

Karmarkar and Joshi (1941) reported that the respiratory peak in Alphonso mangoes was observed at five days after harvest and fruits ripen within eight to ten days under ambient conditions. However, Nakamura *et al.* (2004) observed changes in respiration rate at different storage temperatures under normal conditions. They found that usually after the harvest of mango fruits, ripening process in mature green fruits takes within 9 to 14 days under ambient conditions. Whereas, the ethylene inhibitor, 1-MCP performs a role of inhibiting the ethylene action thereby reducing respiration rate and ATP concentration required to provide energy used in catabolic process during ripening (Abeles *et al.*, 1992). Similar results were also found by Manzano *et al.* (1997) and Herianus *et al.* (2003).

Ethylene production by mango fruit tissue, as in many climacteric fruits, is maximal at the onset of the climacteric phase of fruit ripening (Burg and Burg, 1967; Mattoo and Modi, 1969). However, a small amount of ethylene present in the fruit at harvest is sufficient for the initiation of ripening (Burg and Burg, 1967). The metabolic pathway within the cells of the plant that result in ethylene production is complex, which involves a series of steps culminating in the synthesis of SAM (S-adenosylmethionine), which is converted to ACC (1-aminocyclopropane-1-carboxylic acid) by the action of ACC synthase. ACC is immediate precursor of ethylene biosynthesis in plants and ACC oxidase is required to convert ACC to ethylene (Hamilton *et al.*, 1990). It is a labile enzyme and is sensitive to oxygen and can be inhibited at temperatures above 35°C and under anaerobic conditions. During the ripening process, the availability of oxygen catalyzes the ethylene biosynthesis (Larrigaudiere *et al.*, 1997).

Ethylene production rate in this study was investigated and the results obtained showed that under the influence of ambient conditions without 1-MCP, the rate of ethylene increased gradually till 14 DAT (1.39 ppm) and further it declined till 21 DAT (1.05 ppm) (Fig. 15). Cold storage alone and cold storage with 1-MCP (2000 ppb) showed a similar trend of ethylene production rate in the fruits with peak values occurring at 21 DAT (1.13 ppm and 1.27 ppm, respectively) and further slow decline in the ethylene production till the end of the storage period at 26 DAT (0.88 ppm and 1.08 ppm, respectively). The delay in ethylene production under cold storage conditions with 1-MCP treatments could be due to the sensitivity of enzymes (ACC-S and ACC-O) responsible for ethylene production to low temperatures (Larrigaudiere *et al.*, 1997). Hence, reduced rate of ethylene production can be achieved by storage of fruits under low oxygen levels at low temperatures and 1-MCP being an

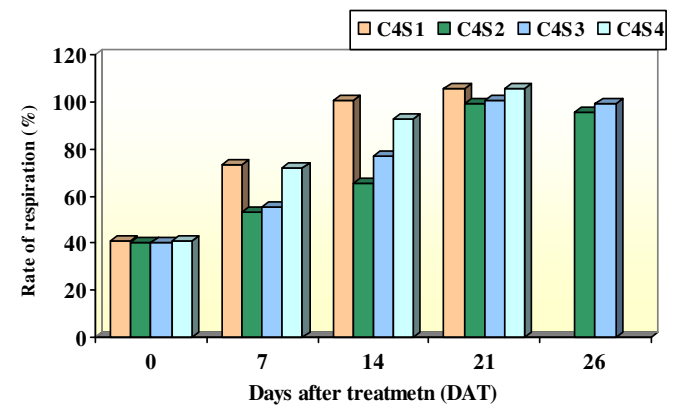
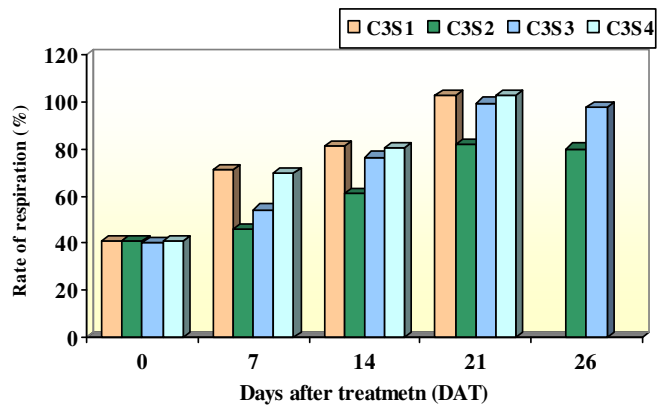
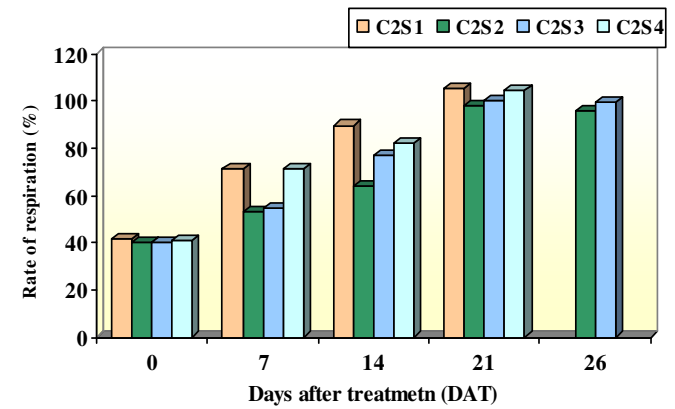
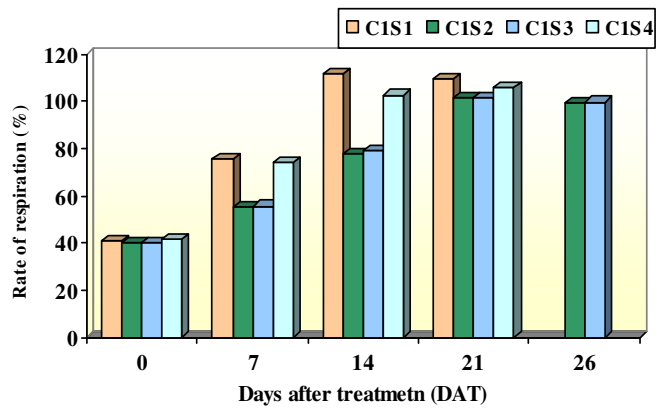


Plate 14 : Influence of different concentrations of 1-MCP and storage conditions on rate of respiration (%) at different days after treatment in Alphonso mango (pooled)

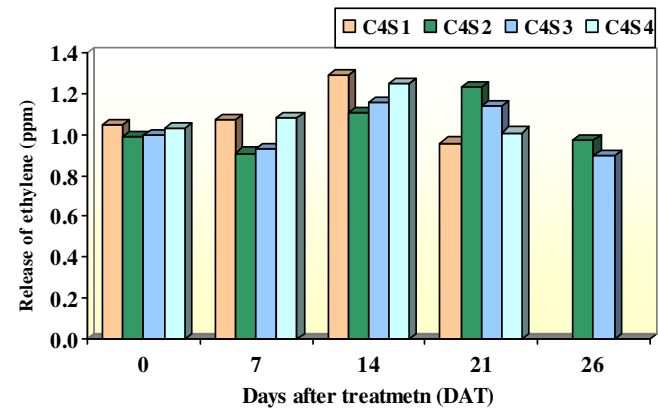
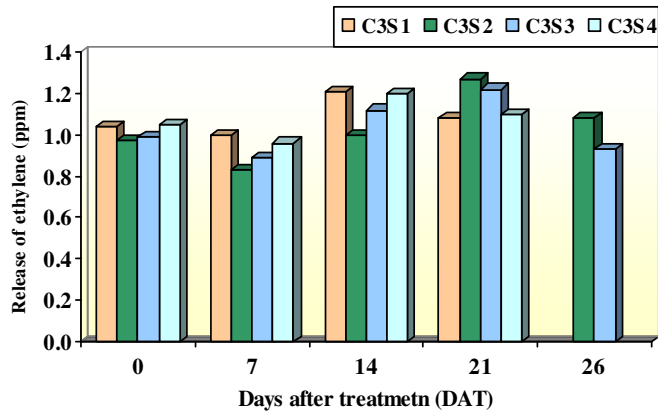
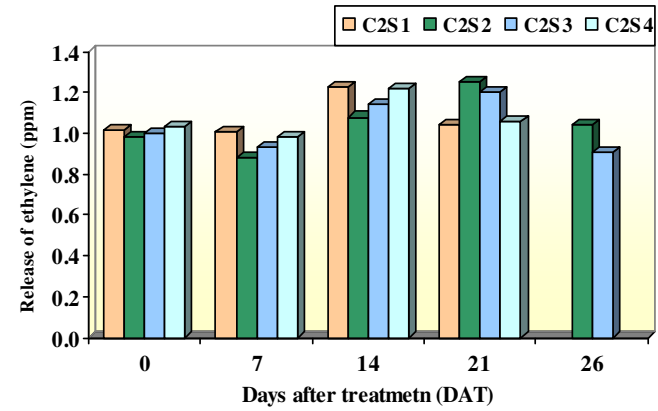
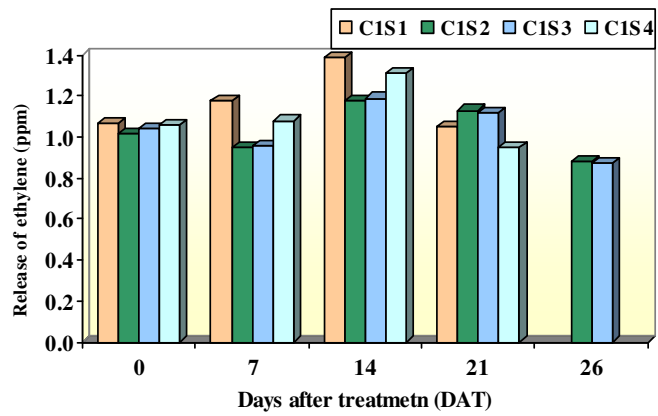


Plate 15 : Influence of different concentrations of 1-MCP and storage conditions on release of ethylene (ppm) at different days after treatment in Alphonso mango (pooled)

effective ethylene inhibitor acts on the receptor binding sites of ethylene production enzymes, thereby responsible for the delay in ethylene production.

Burg and Burg (1967) suggested that high levels of CO₂ in stores could compete with ethylene for binding sites in fruits. Whereas, Yang (1985) showed that CO₂ accumulation in intercellular spaces of the fruits act as an ethylene antagonist. However, Cua and Lizada (1990a, b) reported in Carabao mangoes, that the peak of ethylene production was found at 110 days after flower initiation, which declines as the fruits approach full maturity. Similar results with 1-MCP were reported in mango (Akamine and Goo, 1973) and other fruits such as pears (Wild *et al.*, 1999), banana (Golding *et al.*, 1998), apple (Tatsuki *et al.*, 2007; Watkins and Nock, 2004).

5.4 ORGANOLEPTIC EVALUATION

Flavour is a subtle and complex perception combining taste, smell and texture or mouth feel. Ripening usually brings about an increase in simple sugars to give sweetness, a decrease in organic acids and phenolics to minimize astringency and an increase in volatiles to produce the characteristic flavour (Pantastico, 1975). The characteristic aroma of ripe fruit is due to the production of a complex mixture of individual volatile components. The development of volatiles (low- molecular weight compounds) during ripening is generally responsible for the characteristic aroma and optimal sensory quality of fruits (Kader, 2002).

There are several hundred varieties of mango grown worldwide and they represent a wide range of flavours. More than 285 aroma volatile compounds have been reported from various mango cultivars including monoterpenes, sesquiterpenes, esters, aldehydes, ketones, alcohols, acids, aliphatic hydrocarbons and aromatics (Shibamoto and Tang, 1990; Olle *et al.*, 1997). Aroma of mango fruits has been reported to be influenced by various factors, including mango species and cultivars (Shibamoto and Tang, 1990; Olle *et al.*, 1997) and fruit maturity stage (MacLeod and Synder, 1985; Bartley and Schwede, 1987). Mango being a slightly acidic fruit, basic flavour profile is attributed primarily to the non-volatile constituents, such as sugars and organic acids (sweet sour balance). However, a complex profile of volatile flavour components contribute most of the flavour characteristics of each variety. Decrease in acidity with a corresponding increase in sugar content during ripening yields a pleasant flavour characteristic to fruits. However, because of the complexity of mango flavour volatile profile, there may be no single flavour impact component (Engel and Tressl, 1983). Flavour studies, based on subjective evaluation and on quantitative amounts of flavour components present, have suggested that certain monoterpene hydrocarbons are important in mango flavour (MacLeod and De Troconis, 1982; Engel and Tressl, 1983), as well as lactones and some fatty acids (MacLeod and Pieris, 1984; MacLeod and Synder, 1985).

Indian mangoes have a unique flavour which is attributed to (Z)- ocimene (Engel and Tressl, 1983; Lizada, 1993). Using a high-vacuum distillation techniques, Gholap and his associates studied the aroma profiles of various mango cultivars and correlated lipid content of the flavour characteristics (Bandyopadhyay and Gholap, 1973a; Gholap and Bandyopadhyay, 1975). Alphonso mango fruits are well known as an exotic, flavour rich fruits and the size, taste and storage performance are the main factors of quality attributed by the balance between sugars and organic acids. The nutritive value accompanied by palatability and shelf life in addition to flavour, aroma and taste are the important factors governing the overall fruit quality of Alphonso mango variety. Fruit quality is influenced considerably by number of pre-harvest treatments and post-harvest conditions to which fruits are exposed. Influence of these factors on quality of mango is assessed by determining/estimating various physical and chemical properties of fruits. Among physical properties, fruit size in terms of fruit weight, length and breadth and physiological loss in weight are the important ones; while among chemical properties, fruit pulp acidity, ascorbic acid content, moisture content, TSS, total sugars and reducing sugars hold paramount importance. The overall preferentiality and palatability of fruits in terms of colour, texture and flavour is judged by organoleptic evaluation (Amerine *et al.*, 1965).

In the present investigation, the sensory attributes including spongy tissue was estimated and measured in terms of scoring at the maximum scale of 10. The results indicated that regardless of the 1-MCP treatments or storage conditions, score for sensory evaluation was above the unacceptable level of 5 (Fig. 16). However, results indicated that 1-MCP treatments, irrespective of storage conditions obtained at par score over the control and none of the treatments, had the score below the unacceptable level of 5. All the treatments were as good as control and had similar consumer acceptance as that in control regarding sensory qualities.

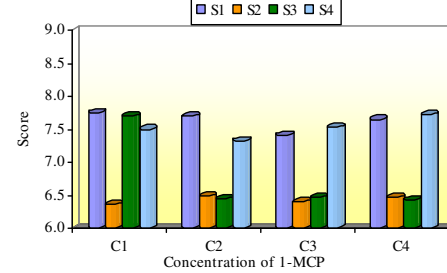
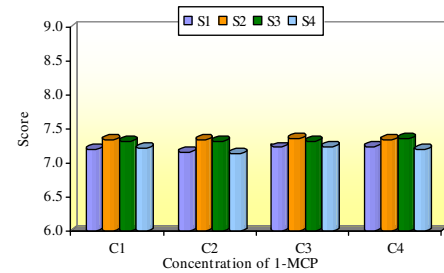
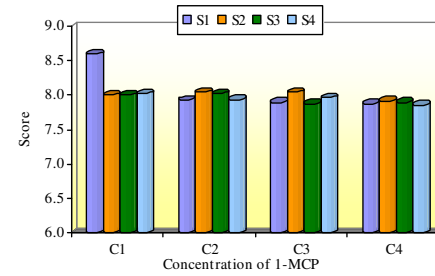
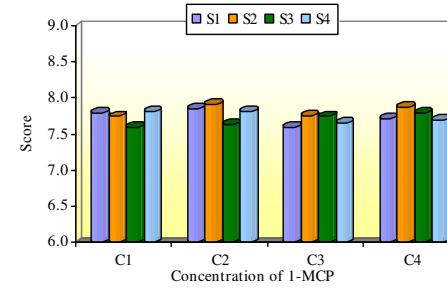
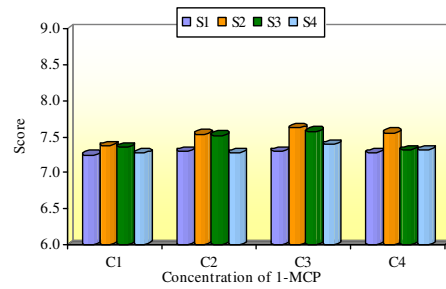


Plate 16 : Influence of different concentrations of 1-MCP and storage conditions on organoleptic evaluation of colour, aroma, taste, flavour and spongy tissue at optimum ripening in alphonso mango (pooled)

Sensory attributes in both control and those treated with 1-MCP are the characteristic of mango at physiological maturity. The 1-MCP and storage conditions did not affect the sensory qualities of mango in spite of fruits kept under cold storage or treated with 1-MCP which shows significant delay in ripening over the ambient conditions. The score obtained for colour and aroma in all the treatment combinations was at par and as good as the score obtained under ambient condition, control (7.25 and 7.80, respectively). However, the ambient control (S₁C₁) had the highest value of taste (8.06) with respect to other treatment combinations. The flavour in all the treatment combinations were at par with each other which was ranging between 7.1 – 7.4 and having a good sensory attributes with the score above the unacceptable level of 5. Sensory qualities indicated no change among the treatment combinations with respect to aroma, colour, taste and flavour. The storage conditions and 1-MCP treatments had no detrimental effect on the sensory qualities, except delaying the process of ripening by 7 days without much affecting the consumer acceptability characters. Similar results with respect to no change in aroma or flavour under low temperatures (10 ± 2°C) were also reported by Bandyopadhyay and Gholap (1973b). However, ripening of Alphonso mangoes at ambient temperature was accompanied by a sharp increase in triglyceride content, together with the development of strong aroma and flavour (Gholap and Bandyopadhyay, 1976). Likewise, delayed aroma development with no effect on sensory qualities was also reported in banana (Golding *et al.*, 1998) and plum (Abdi *et al.*, 1998). Whereas, Cocozza *et al.* (2004) reported no difference in aroma between untreated and 1-MCP treated 'Tommy Atkins' mangoes. However, Lalel *et al.* (2003) observed that 1-MCP treatment of 'Kensington Pride' mangoes suppressed the development of aromatic volatiles during ripening.

Masking the important physiological disorder under good sensory evaluation would be incomplete without discussing the results of the well known disorder i.e. spongy tissue in mango. Commonly, fruits suffer from a wide range of physiological disorders, which are essentially the result of imbalance in metabolism induced by some factors in the pre-harvest or post-harvest environment that lead to a cell collapse or flesh breakdown, viz., known as spongy tissue which was discovered by Cheema and Dani (1934). Knowledge of the metabolic changes causing this physiological disorder in mango is limited, but some researchers have attempted to find out various causes for the occurrence of this disorder (Subramanyam *et al.*, 1971; Joshi, 1975; Gunjate *et al.*, 1979; Katrodia, 1979 and Shivshankar and Mathai, 1999).

Though a significant progress has been made to find out the reasons and remedies of this malady, but still at the darker side, the results are inconclusive. However, the present study revealed that there were no significant differences among the treatment combinations with respect to control. Although the ambient control recorded highest number of spongy affected fruits with a highest average score of (7.75) over rest of the treatments. The data indicated that irrespective of storage treatments, 1-MCP has merely affected the occurrence of spongy tissue by reducing the disorder. The high concentration of 1-MCP at 2000 ppb under cold storage has shown the lowest possible value or score for occurrence of spongy fruits (6.4) among different treatment combinations. These results are in agreement with Burondkar *et al.* (2009) who concluded that 1-MCP treatment had significant effect on the incidence of spongy tissue which significantly reduced the overall incidence, further they have also reported that 1-MCP treated fruits showed significantly higher score on flavour over control. Contradictorily to the above results, the lowest incidence of spongy tissue under cold storage, irrespective of 1-MCP treatments was reported by Burondkar *et al.* (2013), which may be attributed to low temperatures during storage (Joshi and Roy, 1985b), as the low temperatures cause minimum respiratory losses and simultaneously low heat resulting in lower spongy tissue.

Similar results regarding at par organoleptic scores and occurrence of spongy tissue in 1-MCP treatment over ambient control has been reported in mango (Rathore *et al.*, 2007) and other fruits like apple (Kondo *et al.*, 2005; Watkins, 2008), guava (Mahajan and Gagandeep, 2008) and avocado (Woolf *et al.*, 2005).

5.5 FUTURE LINE OF WORK

1. A detailed investigation of the influence of 1-MCP with several other storage conditions and packaging material on post harvest storage, shelf life and quality parameters may be undertaken.
2. Evaluation on the role of 1-MCP application at different time intervals with different concentrations under different storage conditions may be undertaken for extending the shelf life and storage of mango beyond four weeks.

3. Studies leading to inhibitory role of cuticle and cuticle thickness in effective penetration of 1-MCP warrants further study.
4. Estimation of effectiveness of the method to slow expose and continuous release of 1-MCP sachets in fruit boxes during transport or storage.
5. Developing a strategy of post harvest treatments with 1-MCP under different storage conditions to increase shelf life and storage period of different fruits, flowers and vegetables.
6. Evaluation of response of mango to 1-MCP after cold storage as for present commercial storage and after prolonged storage conditions followed by shelf life at ambient temperature to target the commercial needs of the exporters.
7. Study of fruit quality and occurrence of spongy tissue under cold storage with effective concentration of 1-MCP can be undertaken for further research.

SUMMARY AND CONCLUSIONS

'Alphonso', the most popular table purpose variety of mango produced in India specifically grown in the Konkan region of Maharashtra (one of the biggest mango growing belt in the country) has a great demand in the global market owing to its keeping quality, aroma, texture and flavour. Besides export to Middle East countries, 'Alphonso' is increasingly gaining popularity in European market and holds a tremendous potential for future export. However, high shipment cost by air transportation is one of the major bottlenecks in the export of Alphonso mangoes to European destinations. Some commercial attempts made in the recent past to export 'Alphonso' mango by sea transportation were of little success as 20 to 24 days are required to deliver the fruit to Europe from India; as a result, mangoes arrived almost ready for consuming or over ripe stage having hardly few days for marketing resulting in greater losses.

Recently, a compound 1-methylcyclopropene (1-MCP) with strong ability to bind the site of ethylene receptor has been shown to significantly delay the ripening process and substantially extend the storage and shelf life of number of fruits including mango. Keeping this in view, an investigation was undertaken to find out the most optimum dose of 1-MCP for prolonging the ripening and storage of Alphonso mango without much affecting fruit quality till the end of storage period. Laboratory experiments were conducted for two consecutive years (2011 and 2012) at the Department of Agricultural Botany, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The results of the investigation are summarised in this chapter.

6.1 RIPENING BEHAVIOUR OF FRUITS

As expected, mature green Alphonso mango fruits ripened early under ambient condition without 1-MCP treatment (C_1S_1), following early degradation of green colour, loss in physiological weight and texture by 14th day of storage; whereas, fruits stored under cold storage with 2000 ppb of 1-MCP (C_3S_2), exhibited significantly longer retention of green colour (97% fruits green on 12 DAT against 0.0% in C_1S_1), firm texture and slower rate of loss in physiological weight, thereby registering minimum of 7 days delay in normal ripening.

Data also indicated that at 16 DAT, when 98 % of fruits completed ripening under control, none of the fruits ripened under cold storage with 1-MCP (2000 ppb). More than 50% fruits were either diseased or shrivelled by 16 DAT under control; while none of the fruits from cold storage with 2000 ppb 1-MCP developed the disease or showed shrivelling symptoms.

6.2 PHYSICO-CHEMICAL CHANGES

The values obtained for total soluble solids, total sugars and reducing sugar content were found to increase rapidly from the 1st day of treatment till 14 days after treatment in control (S_1C_1) and till 21st days under cold storage with 2000 ppb of 1-MCP (S_2C_3). Although, the peak values of total soluble solids, reducing sugars and total sugar content were obtained on 21st day after treatment in cold storage with 2000 ppb 1-MCP, these values were comparable to those achieved under ambient condition on 14 DAT. Results also indicated that there was a sharp decrease in TSS (32.90%), total sugars (13.89%) and reducing sugars (10.13%) in control at 14 DAT; whereas the decrease in TSS (2.98%), total sugars (10.26%) and reducing sugars (12.02%) was slow in cold storage with 2000 ppb 1-MCP at 21 DAT with relatively high consumer acceptable values of sugars till 26 DAT.

The titratable acidity and ascorbic acid content were found to be reduced considerably from the 1st day till 21st day in ambient conditions (S_1C_1) and till 26th day under cold storage with 2000 ppb of 1-MCP treatment (S_2C_3). The results revealed that throughout the storage period, fruits under ambient condition maintained significantly lower values of titratable acidity and ascorbic acid content as compared to other treatments; whereas, cold storage with 2000 ppb of 1-MCP treatment registered slow decrease in organic acids till the end of storage (26 DAT).

Vitamin A content maintained significantly higher values in control (S_1C_1) throughout the storage period over rest of the treatments. The ambient control also registered higher value of vitamin A content (6679 IU) at 14 DAT following a significant decline by 16 per cent till 21 DAT. However, cold storage with 1-MCP (2000 ppb) showed increase in the vitamin A content upto the end of the study period (4113 IU) without any drop.

6.3 PHYSIOLOGICAL CHANGES

The rate of fruit respiration under ambient condition (S_1C_1) showed significantly higher values as compared to other treatments till 14 DAT (111.5%), However, cold storage with 1-MCP (2000 ppb) showed significantly lower values of fruit respiration (81.8%) as compared to control and other treatment combinations till 21 DAT with a slow decline till the end of the storage period (26 DAT).

Ethylene production under ambient conditions without 1-MCP (S_1C_1) showed gradual rise till 14 DAT (1.39 ppm) followed by decline till 21 DAT (1.05 ppm). Cold storage with 1-MCP (2000 ppb) showed a similar trend of ethylene production rate in the fruits with the peak values occurring at 21 DAT (1.27 ppm) and a further decline till the end of the storage period at 26 DAT (1.08 ppm).

There was a constant loss or degradation of chlorophyll content under ambient condition (S_1C_1) throughout the study period, maintaining significantly lower values from 0 DAT (17.01 mg/100 g of fruit weight) till 21 DAT (0.96 mg/100 g of fruit weight), whereas cold storage with 2000 ppb 1-MCP maintained significantly higher chlorophyll content over rest of the treatments from 0 DAT (16.72 mg/100 g of fruit weight) till 26 DAT (2.28 mg/100 g of fruit weight).

It is revealed the total carotenoids under ambient control (S_1C_1) increased till 14 DAT (11132 $\mu\text{g}/100\text{g}$ fruit weight), declined sharply (16%) at 21 DAT. However, the total carotenoids under ambient conditions, maintained highly significant by higher values over rest of the treatments till 21 DAT. Whereas, cold storage with 1-MCP (2000 ppb) showed constant increase in the total carotenoids till the end of the storage period *i.e.*, 26 DAT (6849 $\mu\text{g}/100\text{g}$ fruit weight). Cold storage with 2000 ppb 1-MCP showed significantly lower values of total carotenoid content as compared to control and other treatments.

6.4 ORGANOLEPTIC EVALUATION

The score obtained for colour and aroma in all the treatment combinations was at par and as good as the score obtained under ambient condition (7.25 and 7.80 respectively). However, ambient control (S_1C_1) maintained highest value for taste (8.06) compared to other treatment combinations. The flavour values ranged between 7.1 – 7.4 and the treatments had almost similar values.

Ambient condition recorded maximum number of spongy affected fruits with a highest average score of (7.75) over rest of the treatments. Whereas, the higher concentration of 1-MCP upto 2000 ppb under cold storage (S_2C_3) had the lower values for the occurrence of spongy fruits (6.4).

Conclusions

The present study on the “Influence of 1- methylcyclopropene (1-MCP) on post harvest physiology and physico-chemical changes in ‘Alphonso’ mango (*Mangifera indica* L.)” conducted for two consecutive years (2011 and 2012), clearly establish that cold storage with 1-MCP @ 2000 ppb holds a great potential in delaying fruit ripening ultimately prolonging the post harvest storage and shelf life. Fruit quality assessed at different time intervals of storage and shelf life also revealed that they were significantly influenced by the 1-MCP treatments and extending the shelf life upto 10- 12 days with the low incidence of spongy tissue.

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Appendix Ia. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 0 and 4 DAT in Alphonso mango (2011)

Treatment combinations	0 DAT						4 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	100	0	0	0	0	0	52	46	0	0	2	0
C ₁ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₁ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₁ S ₄	100	0	0	0	0	0	56	44	0	0	0	0
C ₂ S ₁	100	0	0	0	0	0	62	37	0	0	1	0
C ₂ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₂ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₂ S ₄	100	0	0	0	0	0	64	36	0	0	0	0
C ₃ S ₁	100	0	0	0	0	0	66	33	0	0	1	0
C ₃ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₃ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₃ S ₄	100	0	0	0	0	0	69	31	0	0	0	0
C ₄ S ₁	100	0	0	0	0	0	59	39	0	0	2	0
C ₄ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₄ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₄ S ₄	100	0	0	0	0	0	61	39	0	0	0	0

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Ib. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 8 and 12 DAT in Alphonso mango (2011)

Treatment combinations	8 DAT						12 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	10	12	20	51	5	2	0	2	13	65	13	7
C ₁ S ₂	98	2	0	0	0	0	79	18	1	0	2	0
C ₁ S ₃	96	4	0	0	0	0	76	17	2	3	2	0
C ₁ S ₄	12	14	20	48	4	2	3	5	18	61	9	4
C ₂ S ₁	19	22	26	31	2	0	9	12	27	44	6	2
C ₂ S ₂	100	0	0	0	0	0	93	7	0	0	0	0
C ₂ S ₃	99	1	0	0	0	0	85	13	2	0	0	0
C ₂ S ₄	22	25	28	24	1	0	11	13	28	41	5	2
C ₃ S ₁	28	33	31	7	1	0	13	14	29	39	3	2
C ₃ S ₂	100	0	0	0	0	0	97	3	0	0	0	0
C ₃ S ₃	100	0	0	0	0	0	88	10	2	0	0	0
C ₃ S ₄	31	35	33	0	1	0	16	16	31	33	3	1
C ₄ S ₁	14	16	22	44	3	1	6	8	22	53	8	3
C ₄ S ₂	100	0	0	0	0	0	91	9	0	0	0	0
C ₄ S ₃	98	2	0	0	0	0	82	14	4	0	0	0
C ₄ S ₄	15	21	24	36	3	1	8	11	24	48	6	3

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Ic. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 16 and 20 DAT in Alphonso mango (2011)

Treatment combinations	16 DAT						20 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	0	0	2	39	30	29	0	0	0	22	38	40
C ₁ S ₂	48	28	18	0	4	2	15	21	34	18	8	4
C ₁ S ₃	44	30	19	0	4	3	12	19	35	20	10	4
C ₁ S ₄	0	0	5	45	27	23	0	0	0	30	35	35
C ₂ S ₁	0	0	15	51	18	16	0	0	0	45	24	31
C ₂ S ₂	72	20	8	0	0	0	36	34	19	11	0	0
C ₂ S ₃	61	25	12	0	1	1	21	25	28	15	8	3
C ₂ S ₄	0	0	15	52	17	16	0	0	0	46	24	30
C ₃ S ₁	0	0	17	54	15	14	0	0	0	53	22	25
C ₃ S ₂	76	18	6	0	0	0	49	41	10	0	0	0
C ₃ S ₃	62	23	11	0	4	0	30	31	17	14	6	2
C ₃ S ₄	0	0	20	56	14	10	0	0	0	56	20	24
C ₄ S ₁	0	0	8	48	24	20	0	0	0	39	28	33
C ₄ S ₂	69	21	9	0	1	0	33	33	12	14	6	2
C ₄ S ₃	56	26	15	0	2	1	17	22	35	15	8	3
C ₄ S ₄	0	0	11	49	18	22	0	0	0	43	25	32

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Id. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 24 and 26 DAT in Alphonso mango (2011)

Treatment combinations	24 DAT						26 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	0	0	0	0	43	57	0	0	0	0	0	0
C ₁ S ₂	0	7	15	30	22	26	0	0	0	43	24	33
C ₁ S ₃	0	6	13	31	22	28	0	0	0	44	25	31
C ₁ S ₄	0	0	0	0	38	62	0	0	0	0	0	0
C ₂ S ₁	0	0	0	8	29	63	0	0	0	0	30	70
C ₂ S ₂	26	21	24	21	4	4	6	8	21	29	14	22
C ₂ S ₃	0	9	20	27	20	24	0	0	0	44	23	33
C ₂ S ₄	0	0	0	10	28	62	0	0	0	0	30	70
C ₃ S ₁	0	0	0	12	27	61	0	0	0	0	29	71
C ₃ S ₂	28	25	26	15	4	2	12	13	27	24	11	13
C ₃ S ₃	13	12	21	24	14	16	0	3	15	39	20	23
C ₃ S ₄	0	0	0	15	25	60	0	0	0	0	28	72
C ₄ S ₁	0	0	0	5	32	63	0	0	0	0	35	65
C ₄ S ₂	17	15	22	22	11	13	0	4	18	36	19	23
C ₄ S ₃	0	8	18	28	21	25	0	0	0	43	23	34
C ₄ S ₄	0	0	0	5	30	65	0	0	0	0	33	67

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IIa. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 0 and 4 DAT in Alphonso mango (2012)

Treatment combinations	0 DAT						4 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	100	0	0	0	0	0	50	48	0	0	2	0
C ₁ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₁ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₁ S ₄	100	0	0	0	0	0	54	44	0	0	2	0
C ₂ S ₁	100	0	0	0	0	0	60	39	0	0	1	0
C ₂ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₂ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₂ S ₄	100	0	0	0	0	0	62	37	0	0	1	0
C ₃ S ₁	100	0	0	0	0	0	64	35	0	0	1	0
C ₃ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₃ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₃ S ₄	100	0	0	0	0	0	67	33	0	0	0	0
C ₄ S ₁	100	0	0	0	0	0	57	41	0	0	2	0
C ₄ S ₂	100	0	0	0	0	0	100	0	0	0	0	0
C ₄ S ₃	100	0	0	0	0	0	100	0	0	0	0	0
C ₄ S ₄	100	0	0	0	0	0	59	40	0	0	1	0

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IIb. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 8 and 12 DAT in Alphonso mango (2012)

Treatment combinations	8 DAT						12 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	9	12	20	51	5	3	0	3	13	64	13	7
C ₁ S ₂	97	3	0	0	0	0	79	18	1	0	2	0
C ₁ S ₃	95	5	0	0	0	0	76	18	2	2	2	0
C ₁ S ₄	11	14	20	48	5	2	2	6	16	62	9	5
C ₂ S ₁	19	23	25	31	2	0	9	13	27	43	6	2
C ₂ S ₂	100	0	0	0	0	0	93	7	0	0	0	0
C ₂ S ₃	98	2	0	0	0	0	85	13	2	0	0	0
C ₂ S ₄	21	26	27	25	1	0	11	14	28	40	5	2
C ₃ S ₁	27	33	32	7	1	0	13	15	29	38	3	2
C ₃ S ₂	100	0	0	0	0	0	97	3	0	0	0	0
C ₃ S ₃	99	1	0	0	0	0	88	10	2	0	0	0
C ₃ S ₄	31	35	33	0	1	0	16	17	31	32	3	1
C ₄ S ₁	13	17	21	45	3	1	6	9	22	52	8	3
C ₄ S ₂	99	1	0	0	0	0	91	9	0	0	0	0
C ₄ S ₃	97	3	0	0	0	0	82	14	4	0	0	0
C ₄ S ₄	14	21	25	36	3	1	8	12	24	47	6	3

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IIc. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 16 and 20 DAT in Alphonso mango (2012)

Treatment combinations	16 DAT						20 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	0	0	2	39	30	29	0	0	0	24	36	40
C ₁ S ₂	46	30	19	0	3	2	17	19	32	20	7	5
C ₁ S ₃	42	32	20	0	3	3	14	17	33	22	9	5
C ₁ S ₄	0	0	5	45	27	23	0	0	0	32	33	35
C ₂ S ₁	0	0	15	51	18	16	0	0	0	47	22	31
C ₂ S ₂	70	21	9	0	0	0	38	32	17	13	0	0
C ₂ S ₃	59	26	13	0	1	1	23	23	26	17	7	4
C ₂ S ₄	0	0	15	52	17	16	0	0	0	48	22	30
C ₃ S ₁	0	0	17	54	15	14	0	0	0	55	20	25
C ₃ S ₂	74	19	7	0	0	0	51	40	9	0	0	0
C ₃ S ₃	61	25	12	0	1	1	32	29	15	16	5	3
C ₃ S ₄	0	0	20	56	14	10	0	0	0	58	18	24
C ₄ S ₁	0	0	8	48	24	20	0	0	0	41	26	33
C ₄ S ₂	67	23	10	0	0	0	35	31	10	16	5	3
C ₄ S ₃	54	28	15	0	2	1	19	20	33	17	7	4
C ₄ S ₄	0	0	11	49	18	22	0	0	0	45	23	32

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IId. Influence of different concentrations of 1-MCP and storage conditions on ripening behaviour (%) at 24 and 26 DAT in Alphonso mango (2012)

Treatment combinations	24 DAT						26 DAT					
	G	TY	HR	Ripe	Di	Shrv	G	TY	HR	Ripe	Di	Shrv
C ₁ S ₁	0	0	0	0	43	57	0	0	0	0	0	0
C ₁ S ₂	0	8	16	30	22	24	0	0	0	42	26	32
C ₁ S ₃	0	7	12	32	23	26	0	0	0	42	28	30
C ₁ S ₄	0	0	0	0	38	62	0	0	0	0	0	0
C ₂ S ₁	0	0	0	8	29	63	0	0	0	0	31	69
C ₂ S ₂	28	22	23	21	4	2	5	9	21	29	15	21
C ₂ S ₃	0	12	20	26	20	22	0	0	0	44	24	32
C ₂ S ₄	0	0	0	10	28	62	0	0	0	0	31	69
C ₃ S ₁	0	0	0	12	27	61	0	0	0	0	30	70
C ₃ S ₂	30	26	25	15	4	0	10	15	27	24	12	12
C ₃ S ₃	15	13	20	24	14	14	0	3	15	39	21	22
C ₃ S ₄	0	0	0	15	25	60	0	0	0	0	29	71
C ₄ S ₁	0	0	0	5	32	63	0	0	0	0	36	64
C ₄ S ₂	19	16	21	22	11	11	0	4	18	36	20	22
C ₄ S ₃	0	9	19	28	21	23	0	0	0	43	25	32
C ₄ S ₄	0	0	0	5	30	65	0	0	0	0	34	66

DAT - Days after treatment

G - Green, TY - Turning yellow, HR - Half ripe, Di - Diseased, Shrv - Shrivelled

C₁ : 0 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

C₂ : 1000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

C₃ : 2000 ppb 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₄ : 3000 ppb 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IIIa. Influence of different concentrations of 1-MCP and storage conditions on chroma values at 1, 4, 8, 12, 16, 20, 24 and 26 DAT in Alphonso mango (2011)

Treatment combinations	Chroma value	1 DAT	4 DAT	8 DAT	12 DAT	16 DAT	20 DAT	24 DAT	26 DAT
C ₁ S ₁	a	-6.89	0.57	5.51	9.05	13.14	16.12	—*	—
	b	16.71	16.19	15.54	15.42	14.12	18.49	—	—
	L	42.79	38.28	42.35	41.52	28.93	40.87	—	—
C ₁ S ₂	a	-7.74	-6.09	-4.59	-1.14	0.49	1.68	3.73	7.42
	b	16.74	17.71	16.81	19.45	17.44	15.62	20.51	13.57
	L	38.55	38.85	38.62	45.35	38.52	38.29	44.26	34.72
C ₁ S ₃	a	-7.3	-5.89	-4.26	-0.33	0.93	2.92	4.27	9.02
	b	15.93	23.01	17.67	20.84	17	17.75	17.82	16.28
	L	39.87	45.95	41.49	46.1	41.17	41.64	48.55	40.78
C ₁ S ₄	a	-7.51	0.2	4.66	9.85	13.44	17.28	—	—
	b	15.91	16.57	19.96	26.37	34.9	26.48	—	—
	L	39.74	37.74	18.84	48.02	61.48	52.79	—	—
C ₂ S ₁	a	-7.47	-3.76	0.08	8.35	11.2	15.21	—	—
	b	17.09	17.1	20.73	16.51	19.56	26.22	—	—
	L	42.41	39.69	45.54	40.98	37.21	50.04	—	—
C ₂ S ₂	a	-8.2	-7.37	-6.57	-5.1	-4.28	-3.1	-1.19	0.4
	b	19.28	20.47	20.04	20.79	20.5	23.42	19.19	17.73
	L	41.12	44.12	43.51	42.88	43.58	45.47	46.51	46.79
C ₂ S ₃	a	-7.66	-6.74	-5.43	-3.18	-1.48	-0.11	1	4.23
	b	22.07	22.09	21.15	23.43	16.8	25.64	17.67	19.04
	L	43.69	41.68	42.98	43.45	37.94	47.11	39.73	44.66
C ₂ S ₄	a	-7.43	-4.43	-1.15	7.14	10.55	14.95	16.84	—
	b	16.94	20.88	19.68	13.08	21.17	23.94	30.34	—
	L	40.2	40.29	45.13	33.93	39.02	4160.77	50.12	—

Contd.....

Appendix IIIa. Influence of different concentrations of 1-MCP and storage conditions on chroma values at 1, 4, 8, 12, 16, 20, 24 and 26 DAT in Alphonso mango (2011)

Treatment combinations	Chroma value	1 DAT	4 DAT	8 DAT	12 DAT	16 DAT	20 DAT	24 DAT	26 DAT
C ₃ S ₁	a	-7.38	-4.84	-2.94	6.93	10.26	13.59	16.45	—*
	b	19.43	24.59	19.81	21.93	24.77	29.27	22.56	—
	L	42.48	44.17	43.62	46.53	42.32	48.19	40.12	—
C ₃ S ₂	a	-8.84	-8.19	-7.48	-6.39	-5.86	-4.16	-2.15	-0.25
	b	19.66	19.75	18.56	17.98	21.18	16.04	19.97	20.83
	L	43.89	44.08	45.63	42.2	48.44	37.96	46.74	48.12
C ₃ S ₃	a	-7.87	-6.77	-5.57	-4.52	-2.02	-0.58	0.74	2.55
	b	16.65	21.83	17.84	16.42	16.57	17.15	23.67	16.41
	L	40.09	45.41	43.86	38.36	43.11	45.02	46.48	41.42
C ₃ S ₄	a	-7.42	-5.29	-3.86	6.3	9.18	12.61	16.26	—
	b	16.65	19.16	19.43	18.33	31.17	30.57	29.53	—
	L	40.8	41.12	41.82	42.48	52.36	52.59	52.42	—
C ₄ S ₁	a	-7.21	-1.96	2.77	3.27	11.94	16.54	—	—
	b	16.31	12.27	12.73	29.75	25.37	21.08	—	—
	L	41.86	33.95	35.83	52.34	45.06	40.1	—	—
C ₄ S ₂	a	-8.12	-7.4	-6	-4.82	-3.11	-0.93	-0.93	1.3
	b	18.61	16.77	19.34	20.54	19.8	16.17	16.17	15.24
	L	44.15	40.08	45.5	42.81	45.96	41.45	41.45	40.93
C ₄ S ₃	a	-7.56	-6.41	-5.15	-2.89	-4.63	0.93	2.86	6.48
	b	18.57	18.37	17.17	20.47	14.73	17	16.33	12.51
	L	43.61	49.24	40.98	43.44	37.32	41.17	38.74	37.07
C ₄ S ₄	a	-7.37	-3.16	1.91	8.45	11.83	15.93	—	—
	b	16.94	16.24	22.35	26.92	28.56	24.58	—	—
	L	40.78	39.56	51.01	49.41	52.45	43.46	—	—

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

a : Redness (+ a) to greenness (- a)

b : Yellowness (+ b) to blueness (-b)

L : Lightness and extends from 0 (black) to 100 (white)

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IVa. Influence of different concentrations of 1-MCP and storage conditions on chroma values at 1, 4, 8, 12, 16, 20, 24 and 26 DAT in Alphonso mango (2012)

Treatment combinations	Chroma value	1 DAT	4 DAT	8 DAT	12 DAT	16 DAT	20 DAT	24 DAT	26 DAT
C ₁ S ₁	a	-8.07	-0.61	4.33	7.87	11.96	14.94	—*	—
	b	15.7	15.18	14.53	14.41	13.11	17.48	—	—
	L	42.92	38.41	42.48	41.65	29.06	41	—	—
C ₁ S ₂	a	-8.83	-7.18	-5.68	-2.23	-0.6	0.59	2.64	6.33
	b	15.64	16.61	15.71	18.35	16.34	14.52	19.41	12.47
	L	39.51	39.81	39.58	46.31	39.48	39.25	45.22	35.68
C ₁ S ₃	a	-7.32	-5.91	-4.28	-0.35	0.91	2.9	4.25	9
	b	14.75	21.83	16.49	19.66	15.82	16.57	16.64	15.1
	L	40.83	46.91	42.45	47.06	42.13	42.6	49.51	41.74
C ₁ S ₄	a	-7.53	0.18	4.64	9.83	13.42	17.26	—	—
	b	16.06	16.72	20.11	26.52	35.05	26.63	—	—
	L	42	40	21.1	50.28	63.74	55.05	—	—
C ₂ S ₁	a	-6.51	-2.8	1.04	9.31	12.16	16.17	—	—
	b	17.16	17.17	20.8	16.58	19.63	26.29	—	—
	L	43.69	40.97	46.82	42.26	38.49	51.32	—	—
C ₂ S ₂	a	-8.3	-7.47	-6.67	-5.2	-4.38	-3.2	-1.29	0.3
	b	17.04	18.23	17.8	18.55	18.26	21.18	16.95	15.49
	L	38.99	41.99	41.38	40.75	41.45	43.34	44.38	44.66
C ₂ S ₃	a	-8.76	-7.84	-6.53	-4.28	-2.58	-1.21	-0.1	3.13
	B	19.81	19.83	18.89	21.17	14.54	23.38	15.41	16.78
	L	44.65	42.64	43.94	44.41	38.9	48.07	40.69	45.62
C ₂ S ₄	a	-7.44	-4.44	-1.16	7.13	10.54	14.94	16.83	—
	b	16.59	20.53	19.33	12.73	20.82	23.59	29.99	—
	L	42.44	42.53	47.37	36.17	41.26	4163.01	52.36	—

Contd.....

Appendix IVa. Influence of different concentrations of 1-MCP and storage conditions on chroma values at 1, 4, 8, 12, 16, 20, 24 and 26 DAT in Alphonso mango (2012)

Treatment combinations	Chroma value	1 DAT	4 DAT	8 DAT	12 DAT	16 DAT	20 DAT	24 DAT	26 DAT
C ₃ S ₁	a	-7.39	-4.85	-2.95	6.92	10.25	13.58	16.53	—*
	b	18.19	23.35	18.57	20.69	23.53	28.03	27.19	—
	L	44.96	46.65	46.1	49.01	44.8	50.67	50.51	—
C ₃ S ₂	a	-8.94	-8.29	-7.58	-6.49	-5.96	-4.26	-2.25	-0.35
	b	18.66	18.75	17.56	16.98	20.18	15.04	16.38	16.61
	L	44.13	44.32	45.87	42.44	48.68	38.2	42.45	45.78
C ₃ S ₃	a	-7.97	-6.87	-5.67	-4.62	-2.12	-0.68	0.64	2.45
	b	15.65	20.83	16.84	15.42	15.57	16.15	13.79	25.31
	L	40.33	45.65	44.1	38.6	43.35	45.26	37.56	48.56
C ₃ S ₄	a	-7.43	-5.3	-3.87	6.29	9.17	12.6	16.34	—
	b	15.41	17.92	18.19	17.09	29.93	29.33	31.50	—
	L	43.28	43.6	44.3	44.96	54.84	55.07	57.42	—
C ₄ S ₁	a	-7.31	-2.06	2.67	3.17	11.84	16.44	—	—
	b	16.55	12.51	12.97	29.99	25.61	21.32	—	—
	L	44.36	36.45	38.33	54.84	47.56	42.6	—	—
C ₄ S ₂	a	-8.13	-7.41	-6.01	-4.83	-3.12	-0.94	-0.94	1.2
	b	16.13	14.29	16.86	18.06	17.32	13.69	13.69	14.12
	L	44.37	40.3	45.72	43.03	46.18	41.67	41.67	39.92
C ₄ S ₃	a	-7.49	-6.34	-5.08	-2.82	-4.56	1	2.93	6.54
	b	16.08	15.88	14.68	17.98	12.24	14.51	13.84	16.38
	L	45.85	51.48	43.22	45.68	39.56	43.41	40.98	42.23
C ₄ S ₄	a	-7.38	-3.17	1.9	8.44	11.82	15.92	—	—
	b	15.7	15	21.11	25.68	27.32	23.34	—	—
	L	43.26	42.04	53.49	51.89	54.93	45.94	—	—

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

a : Redness (+ a) to greenness (- a)

b : Yellowness (+ b) to blueness (-b)

L : Lightness and extends from 0 (black) to 100 (white)

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Va. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 0, 2, 4, 6, 8 and 10 DAT in Alphonso mango (2011)

0 DAT						2 DAT					4 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	9.005	8.905	8.901	8.903	8.929	7.103	7.105	7.706	7.103	7.254	6.303	6.603	6.906	6.306	6.530	
S ₂	8.906	8.903	8.904	8.905	8.905	8.199	8.202	8.205	8.202	8.202	7.399	7.702	7.705	7.702	7.627	
S ₃	8.903	8.906	8.904	8.905	8.905	8.198	8.201	8.202	8.200	8.200	7.398	7.402	7.700	7.401	7.476	
S ₄	8.903	8.906	8.903	8.902	8.904	7.103	7.106	7.706	7.105	7.255	6.305	6.605	7.206	6.603	6.680	
Mean	8.929	8.905	8.903	8.904		7.651	7.654	7.955	7.653		6.852	7.078	7.380	7.003		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.013	NS				C	0.007	0.028			C	0.007	0.027			
S	0.013	NS				S	0.007	0.028			S	0.007	0.027			
S X C	0.025	NS				S X C	0.014	0.056			S X C	0.014	0.054			

6 DAT						8 DAT					10 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	3.904	5.304	6.004	3.907	4.780	2.416	3.508	4.131	2.535	3.147	1.804	2.703	3.326	2.010	2.460	
S ₂	6.502	7.103	7.106	7.103	6.954	6.327	6.604	6.896	6.551	6.594	5.170	5.447	5.739	5.394	5.437	
S ₃	6.499	6.803	7.101	6.800	6.801	6.227	6.418	6.516	6.402	6.391	5.070	5.261	5.359	5.245	5.233	
S ₄	3.906	5.907	6.307	4.406	5.132	2.515	3.602	4.371	2.609	3.274	1.911	2.797	3.566	2.030	2.576	
Mean	5.203	6.279	6.630	5.554		4.371	5.033	5.478	4.524		3.488	4.052	4.497	3.669		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.004	0.016				C	0.003	0.012			C	0.004	0.015			
S	0.004	0.016				S	0.003	0.012			S	0.004	0.015			
S X C	0.008	0.032				S X C	0.006	0.023			S X C	0.008	0.029			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Vb. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 12, 14, 16 and 18 DAT in Alphonso mango (2011)

12 DAT						14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	1.567	2.109	2.732	1.686	2.024	1.412	1.572	1.759	1.472	1.554	
S ₂	3.876	4.153	4.445	4.100	4.144	2.520	2.708	3.019	2.705	2.738	
S ₃	3.776	3.967	4.065	3.951	3.940	2.516	2.652	2.662	2.574	2.601	
S ₄	1.666	2.203	2.972	1.690	2.133	1.439	1.630	1.869	1.510	1.612	
Mean	2.722	3.108	3.554	2.857		1.972	2.140	2.327	2.065		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.004	0.014				C	0.004	0.014			
S	0.004	0.014				S	0.004	0.014			
S X C	0.008	0.028				S X C	0.007	0.028			

16 DAT						18 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	1.358	1.465	1.621	1.418	1.466	1.290	1.390	1.449	1.350	1.370	
S ₂	2.107	2.295	2.771	2.292	2.366	1.919	2.107	2.583	2.104	2.178	
S ₃	2.103	2.239	2.249	2.161	2.188	1.915	2.051	2.061	1.973	2.000	
S ₄	1.385	1.522	1.731	1.465	1.526	1.317	1.401	1.559	1.389	1.417	
Mean	1.738	1.880	2.093	1.834		1.610	1.737	1.913	1.704		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.005	0.017				C	0.008	0.029			
S	0.005	0.017				S	0.008	0.029			
S X C	0.009	0.035				S X C	0.015	0.059			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Vc. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 20, 22, 24 and 26 DAT in Alphonso mango (2011)

20 DAT						22 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	1.192	1.315	1.335	1.269	1.278	1.021	1.156	1.235	1.107	1.130	
S ₂	1.701	1.889	2.365	1.886	1.960	1.360	1.586	1.727	1.502	1.544	
S ₃	1.697	1.833	1.843	1.755	1.782	1.349	1.403	1.469	1.382	1.401	
S ₄	1.224	1.326	1.414	1.301	1.316	1.056	1.233	1.299	1.133	1.180	
Mean	1.453	1.591	1.739	1.553		1.197	1.345	1.433	1.281		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.013	0.05				C	0.004	0.014			
S	0.013	0.05				S	0.004	0.014			
S X C	0.026	0.10				S X C	0.007	0.028			

24 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	0.935	1.052	1.201	0.998	1.046	—*	—	—	—	—
S ₂	1.302	1.434	1.542	1.403	1.420	1.052	1.184	1.292	1.153	1.170
S ₃	1.289	1.369	1.389	1.345	1.348	1.039	1.119	1.139	1.095	1.098
S ₄	0.965	1.124	1.235	1.003	1.081	—	—	—	—	—
Mean	1.122	1.244	1.341	1.187						
	S.Em.±	C.D. (1%)								
C	0.003	0.013								
S	0.003	0.013								
S X C	0.007	0.026								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIa. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 0, 2, 4, 6, 8 and 10 DAT in Alphonso mango (2012)

0 DAT						2 DAT					4 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	9.037	8.905	8.899	8.902	8.936	7.105	7.105	7.699	7.102	7.253	6.306	6.306	6.900	6.303	6.454	
S ₂	8.906	8.903	8.902	8.900	8.903	8.206	8.203	8.202	8.200	8.203	7.707	7.704	7.703	7.701	7.704	
S ₃	8.903	8.906	8.901	8.905	8.904	8.203	8.206	8.201	8.205	8.204	7.704	7.707	7.702	7.706	7.705	
S ₄	8.903	8.906	8.898	8.902	8.902	7.103	7.106	7.698	7.102	7.252	6.304	6.307	6.899	6.303	6.453	
Mean	8.937	8.905	8.900	8.902		7.654	7.655	7.950	7.652		7.005	7.006	7.301	7.003		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.017	NS				C	0.012	0.045			C	0.004	0.015			
S	0.017	NS				S	0.012	0.045			S	0.004	0.015			
S X C	0.033	NS				S X C	0.023	0.091			S X C	0.008	0.030			

6 DAT						8 DAT					10 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	3.910	5.010	6.004	3.907	4.707	2.419	3.511	4.134	2.538	3.150	1.913	2.705	3.328	2.032	2.494	
S ₂	7.111	7.108	7.107	7.105	7.107	6.330	6.607	6.899	6.554	6.597	5.172	5.449	5.741	5.396	5.439	
S ₃	7.108	7.111	7.106	7.110	7.108	6.230	6.421	6.519	6.405	6.393	5.072	5.263	5.361	5.247	5.235	
S ₄	3.908	5.011	6.003	4.107	4.757	2.518	3.605	4.374	2.612	3.277	2.012	2.799	3.568	1.806	2.546	
Mean	5.509	6.060	6.555	5.557		4.374	5.036	5.481	4.527		3.542	4.054	4.499	3.620		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.007	0.020				C	0.004	0.017			C	0.004	0.014			
S	0.007	0.020				S	0.004	0.017			S	0.004	0.014			
S X C	0.014	0.040				S X C	0.009	0.034			S X C	0.007	0.027			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIb. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 12, 14, 16 and 18 DAT in Alphonso mango (2012)

12 DAT						14 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.567	2.109	2.732	1.686	2.023	1.412	1.572	1.759	1.472	1.554
S ₂	3.876	4.153	4.445	4.100	4.143	2.520	2.708	3.019	2.705	2.738
S ₃	3.776	3.967	4.065	3.951	3.939	2.516	2.652	2.662	2.574	2.601
S ₄	1.666	2.203	2.972	1.690	2.132	1.439	1.630	1.869	1.510	1.612
Mean	2.721	3.108	3.553	2.856		1.972	2.141	2.327	2.065	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.003	0.013				C	0.004	0.014		
S	0.003	0.013				S	0.004	0.014		
S X C	0.007	0.026				S X C	0.007	0.028		

16 DAT						18 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.358	1.464	1.621	1.418	1.465	1.313	1.408	1.523	1.373	1.404
S ₂	2.107	2.295	2.771	2.292	2.366	1.918	2.106	2.582	2.103	2.177
S ₃	2.103	2.239	2.249	2.161	2.188	1.914	2.050	2.060	1.972	1.999
S ₄	1.385	1.522	1.731	1.466	1.526	1.340	1.424	1.633	1.410	1.452
Mean	1.738	1.880	2.093	1.834		1.621	1.747	1.950	1.715	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.004	0.017				C	0.005	0.018		
S	0.004	0.017				S	0.005	0.018		
S X C	0.009	0.034				S X C	0.009	0.036		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIc. Influence of different concentrations of 1-MCP and storage conditions on fruit firmness (kg/cm²) at 20, 22, 24 and 26 DAT in Alphonso mango (2012)

20 DAT						22 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.269	1.369	1.402	1.329	1.342	1.195	1.330	1.343	1.281	1.287
S ₂	1.693	1.881	2.357	1.878	1.952	1.547	1.847	2.088	1.750	1.808
S ₃	1.689	1.825	1.835	1.747	1.774	1.509	1.669	1.730	1.597	1.626
S ₄	1.296	1.379	1.512	1.371	1.389	1.230	1.341	1.437	1.307	1.328
Mean	1.487	1.613	1.776	1.581		1.370	1.546	1.649	1.483	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.008	0.029				C	0.008	0.030		
S	0.008	0.030				S	0.008	0.030		
S X C	0.015	0.058				S X C	0.015	0.059		

24 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.143	1.278	1.291	1.229	1.235	—*	—	—	—	—
S ₂	1.419	1.648	1.889	1.551	1.626	1.355	1.581	1.722	1.497	1.539
S ₃	1.406	1.470	1.531	1.426	1.458	1.344	1.398	1.464	1.377	1.396
S ₄	1.178	1.289	1.355	1.255	1.269	—	—	—	—	—
Mean	1.286	1.421	1.516	1.365						
	S.Em.±	C.D. (1%)								
C	0.003	0.010								
S	0.003	0.010								
S X C	0.005	0.020								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIIa. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 2, 4, 6, 8, 10 and 12 DAT in Alphonso mango (2011)

2 DAT						4 DAT					6 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	3.63	2.50	2.16	3.30	2.90	8.09	4.25	3.34	4.77	5.11	10.80	5.41	4.09	5.84	6.54		
S ₂	1.56	1.42	0.79	1.47	1.31	2.67	2.22	1.97	1.99	2.21	3.41	2.50	2.67	2.30	2.72		
S ₃	1.59	1.54	1.48	1.55	1.54	2.19	1.97	1.94	1.91	2.00	2.64	2.32	2.22	2.24	2.36		
S ₄	3.44	2.49	1.68	2.63	2.56	3.93	3.02	2.19	3.30	3.11	5.30	3.77	2.68	4.38	4.03		
Mean	2.56	1.99	1.53	2.24		4.22	2.86	2.36	2.99		5.54	3.50	2.92	3.69			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.046	0.17				C	0.237	0.91				C	0.313	1.21			
S	0.046	0.18				S	0.237	0.92				S	0.313	1.21			
S X C	0.14	0.36				S X C	0.475	1.84				S X C	0.6268	2.43			

8 DAT						10 DAT					12 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	12.38	6.52	4.86	6.89	7.66	13.87	7.34	5.68	7.77	8.66	17.53	10.73	8.25	10.44	11.74		
S ₂	3.84	2.86	3.02	2.59	3.08	4.40	3.25	3.30	3.14	3.52	5.72	4.36	4.44	3.81	4.58		
S ₃	2.96	2.56	2.43	2.59	2.64	3.46	2.96	2.76	2.97	3.04	3.42	3.23	3.04	2.89	3.14		
S ₄	6.59	4.26	3.15	5.29	4.82	7.70	4.69	3.66	6.34	5.59	6.47	4.62	3.87	5.98	5.23		
Mean	6.44	4.05	3.36	4.34		7.36	4.56	3.85	5.05		8.29	5.73	4.90	5.78			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.39	1.52				C	0.46	1.79				C	0.61	2.3			
S	0.39	1.53				S	0.46	1.79				S	0.61	2.35			
S X C	0.78	3.05				S X C	0.92	3.59				S X C	1.21	4.69			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIIb. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 14, 16, 18 and 20 DAT in Alphonso mango (2011)

14 DAT					16 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	19.32	9.41	7.53	11.86	12.03	23.40	10.14	8.33	13.06	13.73	
S ₂	5.31	3.96	3.74	3.73	4.18	5.73	4.28	4.03	4.02	4.51	
S ₃	4.26	3.70	3.44	3.87	3.82	4.76	4.23	3.72	4.19	4.22	
S ₄	10.86	5.50	4.80	9.28	7.61	12.25	5.82	5.45	10.38	8.48	
Mean	9.93	5.64	4.87	7.18		11.54	6.12	5.38	7.91		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.7	2.71				C	0.78	3.05			
S	0.7	2.71				S	0.78	3.06			
S X C	1.4	5.42				S X C	1.57	6.11			

18 DAT					20 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	25.10	10.85	9.31	14.96	15.06	26.43	11.80	10.13	16.41	16.19	
S ₂	6.18	4.57	4.17	4.30	4.81	6.54	4.74	4.43	4.38	5.02	
S ₃	5.26	4.64	3.90	4.65	4.61	5.51	4.70	3.96	4.98	4.79	
S ₄	13.48	6.26	5.83	11.32	9.22	15.04	6.58	6.25	12.22	10.02	
Mean	12.51	6.58	5.80	8.81		13.38	6.96	6.19	9.50		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.87	3.38				C	0.98	3.80			
S	0.87	3.38				S	0.98	3.80			
S X C	1.74	6.76				S X C	1.96	7.60			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIIc. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 22, 24 and 26 DAT in Alphonso mango (2011)

22 DAT						24 DAT					26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	28.32	12.59	10.76	17.55	17.30	30.40	13.47	11.55	19.12	18.64	—*	—	—	—	—
S ₂	6.89	4.84	4.61	4.51	5.21	7.43	5.18	4.99	4.78	5.60	8.06	6.10	6.09	5.03	6.32
S ₃	6.02	4.82	4.16	5.21	5.05	6.38	5.09	4.54	5.80	5.45	5.50	4.69	4.28	4.80	4.82
S ₄	16.25	7.06	6.74	13.17	10.80	17.74	7.57	7.16	14.60	11.77	—	—	—	—	—
Mean	14.37	7.33	6.57	10.11		15.49	7.83	7.06	11.07						
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)							
C	1.07	4.14				C	1.17	4.54							
S	1.07	4.14				S	1.17	4.55							
S X C	2.14	8.28				S X C	2.34	9.09							

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIIIa. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 2, 4, 6, 8, 10 and 12 DAT in Alphonso mango (2012)

2 DAT						4 DAT					6 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	3.12	2.79	1.99	2.93	2.71	7.77	4.95	3.49	4.45	5.17	9.52	5.74	3.90	4.57	5.94		
S ₂	2.12	1.65	1.98	1.17	1.73	3.42	2.79	3.06	1.82	2.77	3.34	2.27	2.96	1.54	2.53		
S ₃	0.97	0.91	1.04	0.96	0.97	1.66	1.65	1.59	1.46	1.59	1.03	1.05	0.77	0.70	0.89		
S ₄	0.28	1.08	1.03	1.05	0.86	1.20	1.99	1.64	1.98	1.70	0.61	1.56	1.09	1.52	1.20		
Mean	1.62	1.61	1.51	1.53		3.51	2.85	2.45	2.43		3.63	2.66	2.18	2.09			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.02	NS				C	0.08	0.335				C	0.08	0.341			
S	0.02	0.106				S	0.08	0.335				S	0.08	0.341			
S X C	0.05	0.213				S X C	0.17	0.671				S X C	0.17	0.682			

8 DAT						10 DAT					12 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	10.95	7.27	4.93	5.47	7.16	12.45	8.71	6.27	6.35	8.45	16.337	11.617	8.647	9.247	11.462		
S ₂	4.00	2.68	3.30	1.62	2.90	4.52	3.25	3.69	2.34	3.45	5.367	3.867	4.217	3.007	4.114		
S ₃	1.16	1.09	0.82	0.73	0.95	1.44	1.54	1.12	0.97	1.27	1.837	1.997	1.767	1.297	1.724		
S ₄	0.94	1.89	1.38	1.73	1.49	1.42	2.43	1.84	2.21	1.98	2.107	3.027	2.507	2.857	2.624		
Mean	4.26	3.23	2.61	2.39		4.96	3.98	3.23	2.97		6.412	5.127	4.284	4.102			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.11	0.44				C	0.02	0.08				C	0.07	0.30			
S	0.11	0.45				S	0.02	0.09				S	0.07	0.31			
S X C	0.23	0.89				S X C	0.04	0.18				S X C	0.15	0.61			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIIIb. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 14, 16, 18 and 20 DAT in Alphonso mango (2012)

14 DAT						16 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	17.837	12.917	10.097	10.377	12.807	22.260	15.030	12.080	11.600	15.243
S ₂	5.437	4.027	4.297	2.967	4.182	5.990	4.750	4.940	3.650	4.833
S ₃	1.887	2.087	1.697	1.237	1.727	2.490	2.700	2.330	1.860	2.345
S ₄	2.297	3.467	3.017	3.217	2.999	3.280	4.180	3.890	4.530	3.970
Mean	6.864	5.624	4.777	4.449		8.505	6.665	5.810	5.410	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.06	0.26				C	0.15	0.59		
S	0.06	0.27				S	0.15	0.59		
S X C	0.13	0.53				S X C	0.30	1.18		

18 DAT						20 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	24.090	16.510	14.410	13.010	17.005	25.280	18.480	15.920	13.940	18.405
S ₂	6.510	5.380	5.240	3.940	5.268	6.730	5.610	5.500	3.870	5.428
S ₃	2.960	3.000	2.640	2.120	2.680	2.920	2.910	2.580	2.170	2.645
S ₄	4.390	4.980	4.500	4.900	4.693	4.710	5.070	4.660	5.310	4.938
Mean	9.488	7.468	6.698	5.993		9.910	8.018	7.165	6.323	
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.13	0.51				C	0.08	0.31		
S	0.13	0.51				S	0.08	0.31		
S X C	0.26	1.03				S X C	0.16	0.62		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix VIIIc. Influence of different concentrations of 1-MCP and storage conditions on physiological loss in weight (%) at 22, 24 and 26 DAT in Alphonso mango (2012)

22 DAT						24 DAT					26 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	27.087	20.087	16.987	14.987	19.787	29.253	22.043	18.483	16.943	21.681	—*	—	—	—	—	
S ₂	6.997	5.637	5.757	3.907	5.574	7.463	6.063	6.193	4.253	5.993	7.607	6.167	6.337	4.417	6.132	
S ₃	3.097	2.967	2.607	2.187	2.714	3.563	3.313	3.023	2.663	3.141	3.757	3.417	3.127	2.757	3.264	
S ₄	4.877	5.807	4.997	5.847	5.382	5.693	6.353	5.643	6.453	6.036	—	—	—	—	—	
Mean	10.514	8.624	7.587	6.732		11.493	9.443	8.336	7.578							
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)								
C	0.09	0.37				C	0.16	0.64								
S	0.09	0.37				S	0.16	0.63								
S X C	0.19	0.74				S X C	0.32	1.27								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IXa. Influence of different concentrations of 1-MCP and storage conditions on total soluble solids (⁰Brix) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	8.75	8.56	8.43	8.70	8.61	15.94	14.88	14.84	14.96	15.16	19.29	17.35	16.27	18.13	17.76		
S ₂	8.36	8.56	8.26	8.32	8.37	12.98	11.00	10.80	11.20	11.50	14.23	13.24	12.99	13.29	13.44		
S ₃	8.55	8.67	8.45	8.35	8.50	12.48	11.20	11.20	11.52	11.60	14.27	13.51	13.45	13.75	13.74		
S ₄	8.63	8.79	8.42	8.60	8.61	15.84	14.86	13.55	14.89	14.79	18.43	17.25	14.49	17.95	17.03		
Mean	8.57	8.64	8.39	8.49		14.31	12.99	12.60	13.14		16.56	15.34	14.30	15.78			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.09	NS				C	0.015	0.045				C	0.02	0.086			
S	0.09	NS				S	0.015	0.044				S	0.02	0.086			
S X C	0.18	NS				S X C	0.023	0.089				S X C	0.04	0.173			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix IXb. Influence of different concentrations of 1-MCP and storage conditions on total soluble solids (⁰Brix) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	13.19	15.65	15.50	15.43	14.95	—*	—	—	—	—
S ₂	17.47	18.06	19.02	18.17	18.18	14.32	17.15	18.49	16.08	16.51
S ₃	17.18	19.28	18.61	19.39	18.61	14.22	14.49	15.86	14.09	14.67
S ₄	15.29	16.19	15.48	15.57	15.63	—	—	—	—	—
Mean	15.78	17.30	17.16	17.14						
	S.Em.±	C.D. (1%)								
C	0.025	0.097								
S	0.025	0.098								
S X C	0.05	0.196								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Xa. Influence of different concentrations of 1-MCP and storage conditions on total soluble solids (⁰Brix) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	8.74	8.55	8.44	8.67	8.60	15.96	14.90	14.86	14.98	15.18	18.32	16.38	15.28	17.14	16.78		
S ₂	8.33	8.57	8.35	8.42	8.42	13.00	11.02	10.82	11.22	11.52	13.24	12.24	12.00	12.30	12.45		
S ₃	8.63	8.66	8.47	8.44	8.55	12.50	11.22	11.22	11.54	11.62	13.30	12.54	12.45	12.75	12.76		
S ₄	8.70	8.82	8.41	8.60	8.63	15.86	14.88	13.57	14.91	14.81	17.44	16.26	13.52	16.96	16.05		
Mean	8.60	8.65	8.42	8.53		14.33	13.01	12.62	13.17		15.58	14.36	13.31	14.79			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.09	NS				C	0.11	0.42				C	0.02	0.07			
S	0.09	NS				S	0.11	0.43				S	0.02	0.08			
S X C	0.19	NS				S X C	0.22	0.85				S X C	0.04	0.16			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Xb. Influence of different concentrations of 1-MCP and storage conditions on total soluble solids (⁰Brix) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	12.05	14.54	14.39	14.31	13.82	—*	—	—	—	—
S ₂	16.33	16.92	17.88	17.03	17.04	13.16	15.99	17.32	14.92	15.34
S ₃	16.03	18.15	17.47	18.23	17.47	13.06	13.32	14.72	12.93	13.50
S ₄	14.15	15.05	14.34	14.43	14.49	—	—	—	—	—
Mean	14.64	16.16	16.02	16.00						
	S.Em.±	C.D. (1%)								
C	0.021	0.08								
S	0.021	0.08								
S X C	0.042	0.16								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIa. Influence of different concentrations of 1-MCP and storage conditions on pulp acidity (%) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	3.12	3.11	3.24	3.28	3.19	0.98	1.22	1.27	1.13	1.15	0.41	0.47	0.53	0.43	0.46		
S ₂	3.19	3.20	3.15	3.15	3.17	2.58	2.72	3.03	2.67	2.75	1.33	1.61	1.78	1.52	1.56		
S ₃	3.13	3.23	3.10	3.13	3.15	2.51	2.66	2.61	2.63	2.60	1.31	1.43	1.48	1.42	1.41		
S ₄	3.26	3.09	3.12	3.12	3.15	1.13	1.27	1.27	1.15	1.20	0.42	0.53	0.57	0.47	0.50		
Mean	3.17	3.16	3.15	3.17		1.80	1.97	2.05	1.90		0.87	1.01	1.09	0.96			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.05	NS				C	0.017	0.067				C	0.03	0.123			
S	0.05	NS				S	0.017	0.067				S	0.03	0.123			
S X C	0.01	NS				S X C	0.034	0.134				S X C	0.06	NS			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix Xlb. Influence of different concentrations of 1-MCP and storage conditions on pulp acidity (%) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT					26 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	0.21	0.28	0.31	0.23	0.2575	—*	—	—	—	—
S ₂	0.31	0.53	0.57	0.53	0.485	0.28	0.35	0.36	0.35	0.33
S ₃	0.31	0.34	0.47	0.34	0.365	0.22	0.31	0.34	0.31	0.30
S ₄	0.23	0.31	0.33	0.26	0.2825	—	—	—	—	—
Mean	0.265	0.365	0.42	0.34						
	S.Em.±	C.D. (1%)								
C	0.035	0.056								
S	0.035	0.056								
S X C	0.07	0.113								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix X1la. Influence of different concentrations of 1-MCP and storage conditions on pulp acidity (%) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	3.09	3.11	3.05	3.14	3.10	0.92	1.16	1.21	1.07	1.09	0.39	0.45	0.51	0.41	0.44		
S ₂	3.06	2.97	3.07	3.09	3.05	2.52	2.66	2.97	2.61	2.69	1.31	1.59	1.78	1.50	1.55		
S ₃	3.30	2.97	3.17	3.30	3.18	2.45	2.60	2.55	2.57	2.54	1.29	1.41	1.40	1.40	1.38		
S ₄	3.10	3.00	3.20	2.96	3.07	1.07	1.21	1.21	1.09	1.14	0.40	0.51	0.55	0.45	0.48		
Mean	3.14	3.01	3.12	3.12		1.74	1.91	1.99	1.84		0.85	0.99	1.06	0.94			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.05	NS				C	0.02	0.089				C	0.014	0.056			
S	0.05	NS				S	0.02	0.089				S	0.014	0.055			
S X C	0.11	NS				S X C	0.04	0.179				S X C	0.028	0.112			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIIb. Influence of different concentrations of 1-MCP and storage conditions on pulp acidity (%) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	0.23	0.30	0.33	0.25	0.28	—*	—	—	—	—
S ₂	0.33	0.55	0.59	0.55	0.51	0.28	0.35	0.41	0.35	0.35
S ₃	0.33	0.36	0.49	0.36	0.39	0.22	0.31	0.28	0.31	0.28
S ₄	0.25	0.33	0.35	0.28	0.30	—	—	—	—	—
Mean	0.29	0.39	0.44	0.36						
	S.Em.±	C.D. (1%)								
C	0.02	0.050								
S	0.02	0.050								
S X C	0.04	0.108								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIIIa. Influence of different concentrations of 1-MCP and storage conditions on total sugars (%) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	2.69	2.61	2.50	2.69	2.62	10.95	10.16	10.13	10.22	10.36	14.53	13.07	12.25	13.64	13.37		
S ₂	2.50	2.46	2.46	2.48	2.48	9.28	8.25	8.10	8.40	8.50	10.72	9.97	9.79	10.01	10.12		
S ₃	2.50	2.48	2.48	2.48	2.49	9.36	8.40	8.40	8.64	8.70	10.76	10.19	10.12	10.35	10.36		
S ₄	2.69	2.50	2.50	2.67	2.59	10.88	10.14	10.16	10.16	10.34	13.87	12.98	10.93	13.51	12.82		
Mean	2.60	2.51	2.49	2.58		10.12	9.24	9.19	9.35		12.47	11.55	10.77	11.88			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.24	NS				C	0.03	0.117				C	0.035	0.135			
S	0.24	NS				S	0.03	0.117				S	0.035	0.136			
S X C	0.48	NS				S X C	0.06	0.235				S X C	0.07	0.271			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIIIb. Influence of different concentrations of 1-MCP and storage conditions on total sugars (%) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	13.00	11.78	11.67	11.61	12.02	—*	—	—	—	—
S ₂	13.80	13.57	13.98	13.65	13.75	11.75	12.41	12.53	12.10	12.20
S ₃	13.74	14.00	12.25	13.68	13.42	11.41	11.84	11.95	11.79	11.74
S ₄	11.49	12.17	11.63	11.70	11.75	—	—	—	—	—
Mean	13.01	12.88	12.38	12.66						
	S.Em.±	C.D. (1%)								
C	0.04	0.171								
S	0.04	0.170								
S X C	0.08	0.341								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIVa. Influence of different concentrations of 1-MCP and storage conditions on total sugars (%) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	2.26	2.67	2.43	2.43	2.45	9.47	8.67	8.64	8.73	8.88	15.56	14.10	13.28	14.67	14.40		
S ₂	2.66	2.63	2.59	2.20	2.52	7.79	6.76	6.61	6.91	7.02	11.75	11.00	10.82	11.04	11.15		
S ₃	2.53	2.77	2.73	2.79	2.71	7.87	6.91	6.91	7.15	7.21	11.79	11.22	11.15	11.38	11.39		
S ₄	2.93	2.90	2.65	2.77	2.81	9.39	8.66	8.67	8.68	8.85	14.90	14.01	11.96	14.54	13.85		
Mean	2.59	2.74	2.60	2.55		8.63	7.75	7.71	7.87		13.50	12.58	11.80	12.91			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.13	NS				C	0.02	0.084				C	0.014	0.055			
S	0.13	NS				S	0.02	0.084				S	0.014	0.056			
S X C	0.26	NS				S X C	0.04	0.169				S X C	0.028	0.112			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIVb. Influence of different concentrations of 1-MCP and storage conditions on total sugars (%) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	12.90	11.68	11.57	11.51	11.92	—*	—	—	—	—
S ₂	13.70	13.47	13.88	13.55	13.65	11.77	12.44	12.48	12.14	12.21
S ₃	13.64	13.57	12.15	13.58	13.24	11.43	11.81	11.98	11.82	11.76
S ₄	11.39	12.07	11.53	11.60	11.65	—	—	—	—	—
Mean	12.91	12.70	12.28	12.56						
	S.Em.±	C.D. (1%)								
C	0.02	0.111								
S	0.02	0.112								
S X C	0.05	0.224								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVa. Influence of different concentrations of 1-MCP and storage conditions on reducing sugars (%) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	1.24	1.23	1.32	1.33	1.28	3.29	3.05	3.04	3.07	3.11	4.35	3.92	3.67	4.09	4.01		
S ₂	1.24	1.46	1.16	1.23	1.27	2.78	2.48	2.13	2.52	2.48	3.21	2.98	2.93	3.00	3.03		
S ₃	1.26	1.32	1.22	1.25	1.26	2.81	2.52	2.52	2.59	2.61	3.22	3.05	3.03	3.10	3.10		
S ₄	1.25	1.42	1.26	1.31	1.31	3.26	3.04	3.05	3.05	3.10	4.15	3.89	3.27	4.05	3.84		
Mean	1.25	1.36	1.24	1.28		3.04	2.77	2.68	2.81		3.73	3.46	3.22	3.56			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.037	NS				C	0.02	0.089				C	0.02	0.078			
S	0.037	NS				S	0.02	0.089				S	0.02	0.078			
S X C	0.074	NS				S X C	0.04	0.179				S X C	0.04	0.156			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1°C) + 1-MCP

S₃ : Cold storage (13±1°C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVb. Influence of different concentrations of 1-MCP and storage conditions on reducing sugars (%) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	3.90	3.53	3.50	3.48	3.60	—*	—	—	—	—
S ₂	4.14	4.07	4.25	4.10	4.14	3.52	3.71	3.75	3.62	3.65
S ₃	4.12	4.10	3.46	4.10	3.95	3.41	3.54	3.58	3.53	3.52
S ₄	3.45	3.65	3.49	3.51	3.52	—	—	—	—	—
Mean	3.90	3.84	3.68	3.80						
	S.Em.±	C.D. (1%)								
C	0.01	0.044								
S	0.01	0.045								
S X C	0.02	0.089								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVIa. Influence of different concentrations of 1-MCP and storage conditions on reducing sugars (%) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	1.326	1.255	1.272	1.326	1.295	3.237	2.998	2.989	3.016	3.060	4.272	3.835	3.588	4.006	3.925		
S ₂	1.260	1.242	1.276	1.255	1.258	2.734	2.425	2.080	2.470	2.427	3.129	2.904	2.850	2.917	2.950		
S ₃	1.248	1.246	1.218	1.237	1.237	2.758	2.470	2.470	2.542	2.560	3.142	2.971	2.951	3.018	3.021		
S ₄	1.334	1.265	1.288	1.262	1.287	3.214	2.994	2.999	3.000	3.052	4.074	3.808	3.192	3.966	3.760		
Mean	1.292	1.252	1.264	1.270		2.986	2.722	2.634	2.757		3.654	3.379	3.145	3.477			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.034	NS				C	0.008	0.034				C	0.011	0.044			
S	0.035	NS				S	0.009	0.033				S	0.012	0.045			
S X C	0.069	NS				S X C	0.017	0.067				S X C	0.023	0.089			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVIb. Influence of different concentrations of 1-MCP and storage conditions on reducing sugars (%) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	3.850	3.485	3.350	3.433	3.529	—*	—	—	—	—
S ₂	4.090	4.020	4.200	4.045	4.089	3.449	3.647	3.683	3.556	3.584
S ₃	4.072	4.051	3.410	3.997	3.882	3.347	3.476	3.509	3.461	3.449
S ₄	3.397	3.600	3.440	3.460	3.474	—	—	—	—	—
Mean	3.852	3.789	3.600	3.734						
	S.Em.±	C.D. (1%)								
C	0.034	0.134								
S	0.035	0.134								
S X C	0.069	0.269								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVlla. Influence of different concentrations of 1-MCP and storage conditions on vitamin A (IU) content at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	449	453	452	452	451	5189	4516	4361	5184	4812	6673	4897	4796	6121	5622		
S ₂	453	456	451	452	453	999	896	851	899	911	1588	1300	1258	1325	1368		
S ₃	449	453	454	452	452	1004	964	953	982	976	1590	1376	1339	1449	1439		
S ₄	451	452	455	453	452	5189	4362	4323	5192	4766	6396	4864	4792	5914	5491		
Mean	450	453	453	452		3096	2685	2622	3064		4062	3109	3046	3702			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.9	NS				C	5.72	22.17				C	4.7	18.21			
S	0.9	NS				S	5.72	22.17				S	4.7	18.21			
S X C	1.8	NS				S X C	11.45	44.35				S X C	9.4	36.42			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVIIb. Influence of different concentrations of 1-MCP and storage conditions on vitamin A (IU) content at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	5675	4834	4810	5254	5143	—*	—	—	—	—
S ₂	3751	3310	3309	3313	3421	4291	4113	4112	4116	4158
S ₃	3875	3434	3334	3454	3525	4324	4237	4137	4257	4239
S ₄	5551	4813	4809	4934	5027	—	—	—	—	—
Mean	4713	4098	4066	4239						
	S.Em.±	C.D. (1%)								
C	5.26	20.40								
S	5.26	20.40								
S X C	10.53	20.80								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVIIIa. Influence of different concentrations of 1-MCP and storage conditions on vitamin A (IU) content at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	418	420	420	420	419	5204	4531	4375	5198	4827	6685	4909	4808	6133	5634		
S ₂	420	419	420	420	420	1014	910	865	913	926	1600	1312	1270	1337	1380		
S ₃	419	420	420	419	420	1019	979	967	997	990	1602	1388	1351	1461	1451		
S ₄	420	420	420	419	420	5204	4377	4337	5190	4777	6408	4876	4804	5926	5503		
Mean	419	420	420	419		3110	2699	2636	3075		4074	3121	3058	3714			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.48	NS				C	5.09	19.71				C	4.37	16.93			
S	0.48	NS				S	5.09	19.71				S	4.37	16.93			
S X C	0.97	NS				S X C	10.18	39.43				S X C	8.74	33.86			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XVIIIb. Influence of different concentrations of 1-MCP and storage conditions on vitamin A (IU) content at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	5661	4820	4795	5240	5129	—*	—	—	—	—
S ₂	3736	3295	3294	3298	3406	4294	4115	4114	4118	4160
S ₃	3861	3419	3320	3440	3510	4326	4239	4140	4260	4241
S ₄	5536	4798	4794	4919	5012	—	—	—	—	—
Mean	4698	4083	4051	4224						
	S.Em.±	C.D. (1%)								
C	2.94	8.93								
S	2.94	8.95								
S X C	5.89	22.08								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIXa. Influence of different concentrations of 1-MCP and storage conditions on ascorbic acid content (mg / 100 g fr. wt.) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	75.95	73.74	74.35	75.04	74.77	69.97	70.24	70.87	70.15	70.31	65.97	66.24	66.87	66.15	66.31		
S ₂	74.98	75.30	75.76	73.85	74.97	73.79	74.20	74.23	74.18	74.10	68.80	71.23	71.36	70.12	70.38		
S ₃	75.49	76.88	75.99	76.19	76.14	73.72	73.88	74.00	73.83	73.86	68.24	69.99	70.03	69.68	69.49		
S ₄	75.91	75.12	74.24	76.64	75.48	70.06	70.81	71.79	70.16	70.71	66.06	66.81	67.79	66.16	66.71		
Mean	75.58	75.26	75.08	75.43		71.89	72.28	72.72	72.08		67.27	68.57	69.01	68.03			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.538	NS				C	0.086	0.335				C	0.144	0.559			
S	0.538	NS				S	0.086	0.335				S	0.144	0.559			
S X C	1.077	NS				S X C	0.173	0.671				S X C	0.288	1.118			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XIXb. Influence of different concentrations of 1-MCP and storage conditions on ascorbic acid content (mg / 100 g fr. wt.) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	56.97	57.24	57.87	57.15	57.31	—*	—	—	—	—
S ₂	64.80	67.23	67.36	66.12	66.38	56.80	59.23	59.36	58.12	58.38
S ₃	64.24	65.99	66.03	65.68	65.49	56.24	57.99	58.03	57.68	57.49
S ₄	57.06	57.81	58.79	57.16	57.71	—	—	—	—	—
Mean	60.77	62.07	62.51	61.53						
	S.Em.±	C.D. (1%)								
C	0.101	0.391								
S	0.101	0.391								
S X C	0.202	0.783								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXa. Influence of different concentrations of 1-MCP and storage conditions on ascorbic acid content (mg / 100 g fr. wt.) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	76.10	75.54	76.59	76.19	76.10	69.24	70.51	71.14	70.42	70.33	64.82	65.09	65.72	64.99	65.15	
S ₂	75.93	75.40	74.34	76.70	75.59	74.06	74.47	74.50	74.45	74.37	67.64	70.07	70.21	68.96	69.22	
S ₃	75.01	75.67	76.01	76.81	75.88	73.99	74.15	74.27	74.10	74.13	67.09	68.84	68.87	68.53	68.33	
S ₄	75.18	74.77	76.52	75.96	75.61	70.33	71.08	72.06	70.43	70.98	64.91	65.66	66.64	65.00	65.55	
Mean	75.56	75.35	75.87	76.42		71.91	72.55	72.99	72.35		66.11	67.41	67.86	66.87		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.77	NS				C	0.11	0.44				C	0.06	0.25		
S	0.77	NS				S	0.11	0.45				S	0.06	0.26		
S X C	1.54	NS				S X C	0.23	0.89				S X C	0.13	0.52		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXb. Influence of different concentrations of 1-MCP and storage conditions on ascorbic acid content (mg / 100 g fr. wt.) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	55.95	56.22	56.85	56.13	56.29	—*	—	—	—	—
S ₂	63.78	66.21	66.34	65.10	65.36	55.76	58.19	58.32	57.08	57.34
S ₃	63.22	64.97	65.01	64.66	64.47	55.20	56.95	56.99	56.64	56.45
S ₄	56.04	56.79	57.77	56.14	56.69	—	—	—	—	—
Mean	59.75	61.05	61.49	60.51						
	S.Em.±	C.D. (1%)								
C	0.12	0.48								
S	0.12	0.48								
S X C	0.24	0.96								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIa. Influence of different concentrations of 1-MCP and storage conditions on total chlorophyll content of peel (mg 100⁻¹ g) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	17.05	17.11	16.77	16.61	16.89	10.27	10.57	10.77	10.34	10.49	5.35	6.02	6.21	5.75	5.84	
S ₂	16.61	16.69	16.85	16.75	16.72	11.29	13.20	13.64	12.73	12.72	7.04	8.42	9.89	8.09	8.36	
S ₃	16.69	16.81	16.90	17.11	16.88	11.06	12.03	12.10	11.54	11.69	6.61	7.42	7.70	7.27	7.25	
S ₄	16.69	16.71	16.75	16.61	16.69	10.29	10.61	10.85	10.43	10.55	5.51	6.08	6.29	5.90	5.95	
Mean	16.76	16.83	16.82	16.77		10.73	11.61	11.84	11.26		6.13	6.99	7.53	6.76		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)		
C	0.09	NS				C	0.049	0.191				C	0.03	0.152		
S	0.09	NS				S	0.049	0.191				S	0.03	0.153		
S X C	0.18	NS				S X C	0.098	0.382				S X C	0.07	0.305		

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIb. Influence of different concentrations of 1-MCP and storage conditions on total chlorophyll content of peel (mg 100⁻¹ g) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.02	1.62	1.78	1.10	1.38	—*	—	—	—	—
S ₂	3.29	5.06	6.27	4.60	4.81	0.91	2.03	2.33	1.67	1.74
S ₃	3.10	3.60	4.07	3.47	3.56	0.80	1.04	1.34	0.97	1.04
S ₄	1.06	1.73	1.86	1.29	1.49	—	—	—	—	—
Mean	2.12	3.00	3.50	2.62						
	S.Em.±	C.D. (1%)								
C	0.027	0.107								
S	0.027	0.107								
S X C	0.055	0.215								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIIa. Influence of different concentrations of 1-MCP and storage conditions on total chlorophyll content of peel (mg 100⁻¹ g) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	
S ₁	16.97	17.03	16.76	16.53	16.82	10.07	10.37	10.57	10.14	10.28	5.18	5.85	6.04	5.58	5.67	
S ₂	16.53	16.77	16.60	16.67	16.64	11.09	13.00	13.44	12.53	12.51	6.87	8.25	9.72	7.92	8.19	
S ₃	16.61	16.73	16.82	17.03	16.80	10.86	11.83	11.90	11.34	11.48	6.44	7.25	7.53	7.10	7.08	
S ₄	16.61	16.62	16.68	16.53	16.61	10.09	10.41	10.65	10.23	10.34	5.34	5.91	6.12	5.73	5.78	
Mean	16.68	16.79	16.71	16.69		10.52	11.40	11.64	11.06		5.96	6.82	7.36	6.59		
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)				S.Em.±	C.D. (1%)			
C	0.089	NS				C	0.02	0.095			C	0.02	0.114			
S	0.089	NS				S	0.02	0.095			S	0.02	0.114			
S X C	0.17	NS				S X C	0.04	0.190			S X C	0.05	0.228			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIIb. Influence of different concentrations of 1-MCP and storage conditions on total chlorophyll content of peel (mg 100⁻¹ g) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	0.900	1.500	1.660	0.980	1.260	—*	—	—	—	—
S ₂	3.170	4.940	6.150	4.480	4.685	0.81	1.93	2.23	1.57	1.64
S ₃	2.980	3.480	3.950	3.350	3.440	0.70	0.94	1.24	0.87	0.94
S ₄	0.940	1.610	1.740	1.170	1.365	—	—	—	—	—
Mean	1.998	2.883	3.375	2.495						
	S.Em.±	C.D. (1%)								
C	0.022	0.089								
S	0.022	0.088								
S X C	0.045	0.177								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIIIa. Influence of different concentrations of 1-MCP and storage conditions on total carotenoids ($\mu\text{g} / 100 \text{ g fr.wt.}$) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	749	755	753	754	752	8656	7534	7275	8648	8028	11134	8174	8005	10213	9382		
S ₂	755	760	751	753	755	1673	1501	1426	1506	1526	2659	2179	2109	2220	2292		
S ₃	749	755	757	753	753	1682	1614	1595	1645	1634	2663	2305	2244	2428	2410		
S ₄	751	753	758	755	754	8656	7278	7212	8646	7948	10672	8118	7999	9868	9164		
Mean	751	756	755	754		5167	4482	4377	5111		6782	5194	5089	6183			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	1.51	NS				C	3.79	14.70				C	7.5	29.06			
S	1.51	NS				S	3.79	14.70				S	7.5	29.06			
S X C	0.03	NS				S X C	7.59	29.41				S X C	15	58.13			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage ($13\pm 1^{\circ}\text{C}$) + 1-MCP

S₃ : Cold storage ($13\pm 1^{\circ}\text{C}$) + 1-MCP + Shrink wrapper

S₄ : Ambient storage + 1-MCP + Shrink wrapper

Appendix XXIIIb. Influence of different concentrations of 1-MCP and storage conditions on total carotenoids ($\mu\text{g} / 100 \text{ g fr.wt.}$) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	9435	8033	7992	8733	8548	—*	—	—	—	—
S ₂	6228	5492	5491	5497	5677	7144	6846	6845	6851	6921
S ₃	6435	5699	5533	5733	5850	7198	7053	6887	7087	7056
S ₄	9228	7997	7991	8199	8353	—	—	—	—	—
Mean	7831	6805	6751	7040						
	S.Em.±	C.D. (1%)								
C	5.12	19.86								
S	5.12	19.86								
S X C	10.25	39.73								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIVa. Influence of different concentrations of 1-MCP and storage conditions on total carotenoids ($\mu\text{g} / 100 \text{ g fr. wt.}$) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	755	752	754	758	755	8672	7550	7291	8663	8044	11130	8169	8001	10209	9377		
S ₂	755	759	759	759	758	1689	1517	1441	1522	1542	2654	2175	2105	2216	2288		
S ₃	755	756	759	756	756	1698	1630	1611	1661	1650	2659	2301	2240	2424	2406		
S ₄	756	754	755	754	754	8672	7294	7228	8662	7964	10668	8114	7994	9864	9160		
Mean	755	755	757	756		5183	4498	4393	5127		6778	5190	5085	6178			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.95	NS				C	3.65	14.09				C	3.46	13.41			
S	0.95	NS				S	3.65	14.09				S	3.46	13.41			
S X C	1.9	NS				S X C	7.29	28.19				S X C	6.93	26.83			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage ($13\pm 1^{\circ}\text{C}$) + 1-MCP

S₃ : Cold storage ($13\pm 1^{\circ}\text{C}$) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIVb. Influence of different concentrations of 1-MCP and storage conditions on total carotenoids ($\mu\text{g} / 100 \text{ g fr. wt.}$) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	9455	8053	8012	8753	8568	—*	—	—	—	—
S ₂	6248	5512	5511	5517	5697	7153	6855	6854	6861	6931
S ₃	6455	5719	5553	5753	5870	7207	7062	6897	7097	7066
S ₄	9248	8017	8011	8219	8373	—	—	—	—	—
Mean	7851	6825	6772	7060						
	S.Em.±	C.D. (1%)								
C	4.1	15.89								
S	4.1	15.89								
S X C	8.2	31.78								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVa. Influence of different concentrations of 1-MCP and storage conditions on rate of respiration (%) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	41.05	41.40	41.27	41.27	41.25	75.33	71.36	71.13	73.18	72.75	111.52	89.78	81.55	100.50	95.83		
S ₂	40.37	40.03	40.82	40.42	40.41	55.36	52.97	45.95	53.41	51.93	77.74	63.85	60.84	65.75	67.04		
S ₃	40.37	40.16	40.29	40.25	40.27	55.63	54.72	54.21	55.08	54.91	79.17	76.73	76.50	76.78	77.29		
S ₄	41.36	40.87	40.86	40.96	41.01	74.02	71.28	69.68	71.55	71.64	102.77	81.87	80.63	93.08	89.58		
Mean	40.79	40.62	40.81	40.73		65.09	62.59	60.25	63.31		92.80	78.05	74.88	84.02			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.4	NS				C	0.5	1.94				C	0.26	1.02			
S	0.4	NS				S	0.5	1.95				S	0.26	1.03			
S X C	0.8	NS				S X C	1.0	3.89				S X C	0.53	2.05			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVb. Influence of different concentrations of 1-MCP and storage conditions on rate of respiration (%) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT					26 DAT					
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	109.5	105.1	102.6	105.8	105.8	—*	—	—	—	—
S ₂	101.5	97.8	81.8	99.3	95.1	99.77	95.73	80.22	95.92	92.91
S ₃	101.6	100.2	99.6	100.7	100.5	99.92	99.34	97.92	99.65	99.21
S ₄	106.1	104.7	102.6	105.5	104.7	—	—	—	—	—
Mean	104.7	102.0	96.6	102.8						
	S.Em.±	C.D. (1%)								
C	0.27	1.042								
S	0.27	1.042								
S X C	0.54	2.085								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVla. Influence of different concentrations of 1-MCP and storage conditions on rate of respiration (%) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	40.98	41.31	41.18	41.18	41.16	75.39	71.42	71.19	73.24	72.81	111.44	89.70	81.47	100.42	95.76		
S ₂	40.33	40.05	40.73	40.33	40.36	55.42	53.03	46.01	53.47	51.99	77.66	63.77	60.76	65.67	66.97		
S ₃	40.28	40.28	40.20	40.46	40.30	55.69	54.78	54.27	55.14	54.97	79.09	76.65	76.42	76.70	77.22		
S ₄	41.27	41.33	40.77	40.87	41.06	74.08	71.34	69.74	71.61	71.70	102.69	81.79	80.55	93.00	89.51		
Mean	40.71	40.74	40.72	40.71		65.15	62.65	60.31	63.37		92.72	77.98	74.80	83.95			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.38	NS				C	0.24	0.96				C	0.30	1.17			
S	0.38	NS				S	0.24	0.97				S	0.30	1.17			
S X C	0.77	NS				S X C	0.49	1.93				S X C	0.60	2.34			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVib. Influence of different concentrations of 1-MCP and storage conditions on rate of respiration (%) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	109.56	105.18	102.66	105.79	105.79	—*	—	—	—	—
S ₂	101.54	97.82	81.79	99.35	95.12	99.56	95.52	80.01	95.71	92.70
S ₃	101.67	100.24	99.65	100.78	100.58	99.71	99.13	97.71	99.44	99.00
S ₄	106.11	104.78	102.62	105.58	104.77	—	—	—	—	—
Mean	104.72	102.00	96.68	102.87						
	S.Em.±	C.D. (1%)								
C	0.34	1.32								
S	0.34	1.32								
S X C	0.68	2.64								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVIIa. Influence of different concentrations of 1-MCP and storage conditions on release of ethylene (ppm) at 0, 7 and 14 DAT in Alphonso mango (2011)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	1.11	1.06	1.08	1.09	1.09	1.21	1.06	1.06	1.12	1.11	1.43	1.30	1.28	1.36	1.35		
S ₂	1.06	1.02	1.01	1.03	1.03	1.00	0.90	0.87	0.96	0.93	1.25	1.15	1.01	1.18	1.15		
S ₃	1.08	1.04	1.03	1.04	1.05	1.01	0.98	0.90	0.98	0.97	1.26	1.21	1.19	1.23	1.23		
S ₄	1.10	1.07	1.09	1.07	1.08	1.13	1.03	1.01	1.16	1.08	1.38	1.29	1.27	1.32	1.32		
Mean	1.09	1.05	1.05	1.06		1.09	0.99	0.96	1.05		1.33	1.24	1.19	1.28			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.1	NS				C	0.01	0.028				C	0.007	0.028			
S	0.1	NS				S	0.01	0.029				S	0.007	0.028			
S X C	0.2	NS				S X C	0.02	0.057				S X C	0.014	0.056			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVIIb. Influence of different concentrations of 1-MCP and storage conditions on release of ethylene (ppm) at 21 and 26 DAT in Alphonso mango (2011)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	1.13	1.09	1.13	1.01	1.09	—*	—	—	—	—
S ₂	1.18	1.30	1.32	1.28	1.27	0.92	1.08	1.12	1.01	1.03
S ₃	1.17	1.25	1.27	1.19	1.22	0.91	0.95	0.97	0.94	0.94
S ₄	1.00	1.11	1.15	1.06	1.08	—	—	—	—	—
Mean	1.12	1.19	1.22	1.14						
	S.Em.±	C.D. (1%)								
C	0.009	0.034								
S	0.009	0.035								
S X C	0.018	0.069								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVIII. Influence of different concentrations of 1-MCP and storage conditions on release of ethylene (ppm) at 0, 7 and 14 DAT in Alphonso mango (2012)

0 DAT						7 DAT					14 DAT						
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean		
S ₁	1.03	0.98	1.00	1.01	1.01	1.15	0.97	0.94	1.03	1.02	1.35	1.15	1.13	1.21	1.21		
S ₂	0.98	0.94	0.93	0.95	0.95	0.91	0.86	0.80	0.87	0.86	1.10	1.00	0.99	1.03	1.03		
S ₃	1.00	0.96	0.95	0.96	0.97	0.92	0.89	0.88	0.89	0.90	1.11	1.06	1.04	1.08	1.07		
S ₄	1.02	0.99	1.01	0.99	1.00	1.04	0.94	0.92	1.01	0.98	1.23	1.14	1.12	1.17	1.17		
Mean	1.01	0.97	0.97	0.98		1.01	0.92	0.89	0.95		1.20	1.09	1.07	1.12			
	S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)					S.Em.±	C.D. (1%)			
C	0.1	NS				C	0.008	0.033				C	0.009	0.036			
S	0.1	NS				S	0.008	0.034				S	0.009	0.037			
S X C	0.2	NS				S X C	0.017	0.067				S X C	0.019	0.074			

DAT – Days after treatment

C₁ : 0 ppb 1-MCP

C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXVIIIb. Influence of different concentrations of 1-MCP and storage conditions on release of ethylene (ppm) at 21 and 26 DAT in Alphonso mango (2012)

21 DAT						26 DAT				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	0.96	0.98	1.02	0.90	0.97	—*	—	—	—	—
S ₂	1.07	1.19	1.21	1.17	1.16	0.85	1.01	1.05	0.94	0.96
S ₃	1.06	1.14	1.16	1.08	1.11	0.84	0.88	0.90	0.87	0.87
S ₄	0.89	1.00	1.04	0.95	0.97	—	—	—	—	—
Mean	1.00	1.08	1.11	1.03						
	S.Em.±	C.D. (1%)								
C	0.009	0.036								
S	0.009	0.036								
S X C	0.018	0.072								

DAT – Days after treatment, —* Data were not recorded since all the fruits were spoiled.

C₁ : 0 ppb 1-MCP

C₃ : 2000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper

C₂ : 1000 ppb 1-MCP

C₄ : 3000 ppb 1-MCP

S₂ : Cold storage (13±1⁰C) + 1-MCP

S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIXa. Influence of different concentrations of 1-MCP and storage conditions on organoleptic evaluation of colour and aroma at optimum ripening in Alphonso mango fruits (2011)

Colour						Aroma				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	7.22	7.34	7.34	7.25	7.28	7.77	7.90	7.64	7.69	7.75
S ₂	7.39	7.52	7.60	7.54	7.51	7.76	7.90	7.74	7.86	7.81
S ₃	7.37	7.53	7.56	7.33	7.44	7.61	7.65	7.73	7.81	7.70
S ₄	7.24	7.32	7.44	7.29	7.32	7.79	7.86	7.70	7.67	7.75
Mean	7.30	7.42	7.48	7.35		7.73	7.82	7.70	7.75	

C₁ : 0 ppb 1-MCP
C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP
C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP
S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper
S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXIXb. Influence of different concentrations of 1-MCP and storage conditions on organoleptic evaluation of taste, flavour and spongy tissue at optimum ripening in Alphonso mango fruits (2011)

Taste						Flavour					Spongy tissue				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	8.03	7.97	7.94	7.85	7.94	7.17	7.20	7.27	7.21	7.21	7.72	7.74	7.45	7.62	7.63
S ₂	8.01	8.02	8.02	7.90	7.98	7.35	7.32	7.34	7.32	7.33	6.37	6.46	6.38	6.44	6.41
S ₃	8.01	8.03	7.86	7.91	7.95	7.33	7.33	7.30	7.37	7.33	7.71	6.45	6.44	6.44	6.76
S ₄	7.99	7.98	8.00	7.83	7.95	7.19	7.18	7.28	7.17	7.20	7.47	7.36	7.57	7.69	7.52
Mean	8.01	8.00	7.95	7.87		7.26	7.25	7.29	7.26						

C₁ : 0 ppb 1-MCP
C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP
C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP
S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper
S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXXa. Influence of different concentrations of 1-MCP and storage conditions on organoleptic evaluation of colour and aroma at optimum ripening in Alphonso mango fruits (2012)

Colour						Aroma				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	7.28	7.26	7.26	7.31	7.27	7.83	7.82	7.56	7.75	7.74
S ₂	7.37	7.56	7.64	7.58	7.53	7.74	7.94	7.78	7.90	7.84
S ₃	7.35	7.51	7.60	7.31	7.44	7.59	7.63	7.77	7.79	7.69
S ₄	7.30	7.24	7.36	7.35	7.31	7.85	7.78	7.62	7.73	7.74
Mean	7.32	7.39	7.46	7.38		7.75	7.79	7.68	7.79	

C₁ : 0 ppb 1-MCP
C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP
C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP
S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper
S₄ : Ambient storage + 1- MCP + Shrink wrapper

Appendix XXXb. Influence of different concentrations of 1-MCP and storage conditions on organoleptic evaluation of taste, flavour and spongy tissue at optimum ripening in Alphonso mango fruits (2012)

Taste						Flavour					Spongy tissue				
	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean	C ₁	C ₂	C ₃	C ₄	Mean
S ₁	8.09	7.89	7.86	7.91	7.93	7.23	7.12	7.19	7.27	7.20	7.78	7.66	7.37	7.68	7.62
S ₂	7.99	8.06	8.06	7.94	8.01	7.33	7.36	7.38	7.36	7.35	6.35	6.50	6.42	6.48	6.43
S ₃	7.99	8.01	7.90	7.89	7.94	7.31	7.31	7.34	7.35	7.32	7.69	6.43	6.48	6.42	6.75
S ₄	8.05	7.90	7.92	7.89	7.94	7.25	7.10	7.20	7.23	7.19	7.53	7.28	7.49	7.75	7.51
Mean	8.03	7.96	7.93	7.90		7.28	7.22	7.27	7.30		7.33	6.96	6.94	7.08	

C₁ : 0 ppb 1-MCP
C₂ : 1000 ppb 1-MCP

C₃ : 2000 ppb 1-MCP
C₄ : 3000 ppb 1-MCP

S₁ : Ambient storage without 1-MCP
S₂ : Cold storage (13±1⁰C) + 1-MCP

S₃ : Cold storage (13±1⁰C) + 1- MCP + Shrink wrapper
S₄ : Ambient storage + 1- MCP + Shrink wrapper

INFLUENCE OF 1-METHYLCYCLOPROPENE (1-MCP) ON POST HARVEST PHYSIOLOGY AND PHYSICO-CHEMICAL CHANGES IN ALPHONSO MANGO (*Mangifera indica* L.)

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2013

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ABSTRACT

Investigation were carried out to find out the influence of 1-MCP (1-methylcyclopropene) on physical, physiological and physico-chemical changes and ripening behaviour in Alphonso mango (*Mangifera indica* L.) during 2011 and 2012 at the Department of Agril.Botany, College of Agriculture, Dr.BSKKV, Dapoli. The experiment consisted of 16 treatment combinations comprising 4 concentrations of 1-MCP and 4 storage conditions.

Results revealed that fruits ripened early under ambient condition without 1-MCP treatment. Fruits under cold storage with 2000 ppb of 1-MCP exhibited significantly longer retention of green colour, firm texture and slow rate of loss in physiological weight, thereby delaying ripening compared to ambient condition. Total soluble solids, total sugars, reducing sugars increased and vitamin-A, titratable acidity and ascorbic acid content decreased rapidly until 14 DAT (days after treatment) under control and 21 days under cold storage with 2000 ppb of 1-MCP. There was a gradual rise in ethylene production till 14 DAT followed by decline at 21 DAT under ambient condition. The rate of fruit respiration was significantly higher under ambient condition compared to other treatments and the lowest was recorded in cold storage with 1-MCP (2000 ppb).

Cold storage with 1-MCP showed gradual increase in total carotenoids till the end of storage period as against rapid increase under ambient condition. Ambient condition recorded maximum number of spongy affected fruits and the lowest was noticed with higher concentration of 1-MCP (2000 ppb) in cold storage. There was a constant degradation of chlorophyll under ambient condition throughout the study period; while, cold storage with 2000 ppb 1-MCP maintained significantly higher values till 26 DAT.

The present findings clearly establish that cold storage with 1-MCP @ 2000 ppb holds a great potential in delaying fruit ripening ultimately prolonging the post harvest storage and shelf life by 10 – 12 days.