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EFFECT OF ETHEPHON ON RIPENING AND POSTHARVEST QUALITY OF MANGO

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Abstract

The experiment was conducted at the laboratory of Postharvest Technology Division, BARI to evaluate the effect of postharvest application of 6 concentrations (0, 250, 500, 750, 1000 & 10000 ppm) of ethephon on ripening and postharvest qualityof mango (cv. Langra) fruits harvested at mature green stage on 3rd week of June in 2011 and 2012. The treated fruits were assessed for physiological changes such as ripening %, weight loss (%), biochemical aspects such as TSS (^{0}Brix), titratable acidity (%), reducing sugar (%), total sugar (%), ascorbic acid content (mg/100g), total carotenoids (µg/100g), carbon di oxide production (ml/g fruit) and residual level of the applied ethephon during storage period. The observations were recorded at 2 days interval during 6 days storage at ambient condition (23±2˚C with 80±5% RH). Complete yellow color (full ripe) was developed on the fruits treated with 500-1000 ppm ethephon at 4 days of storage while yellowish green and greenish yellow color was developed on 250 ppm treated and control fruits, respectively, and 10000 ppm ethephon treated fruits overripened at this period. At 6 days of storage, 250 ppm ethephon treated fruits got ripen and 500-1000 ppm ethephon treated fruits overripened whereas 10000 ppm treated fruits got rotten and control one was still unripe. Irrespective of ethephon treatments, weight loss of fruits, TSS, reducing sugar, total sugar, carbon di oxide production and total carotenoid showed increasing trends upto 6 days whereas titratable acidity, ascorbic acid and residue level of ethephon showed decreasing trends in both years. At 4 days of storage, 750-1000 ppm ethephon dipped fruits induced uniform attractive yellow color while untreated control fruits remained yellowish greenish (unripe) even after 6 days of storage. At 6 days of storage TSS, reducing sugar, toatal sugar, ascorbic acid and total carotenoid content were found maximum in 750-1000 ppm treated fruits compared to 250-500 ppm treated fruits. The residue level of ethephon in mango fruits treated with ethephon concentrations (250-1000 ppm) at 6 days of storage was found below 2 ppm (0.1 1ppm-0.54 ppm), which is safe for human consumption. Therefore, mangoes ripened by using ethephon @ 750-1000 ppm can be consumed safely without any health risk.

Keywords: Mango, Ethephon, Ripening, Residue, postharvest quality.

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Introduction

Mango (*Mangiferaindica* L.) belonging to the family *Anacardiaceae* is one of the most important commercially grown fruits in Bangladesh. It is known as 'aam' considered as the king of fruits due to its excellent flavor, taste, nutritive value, processing qualities and its delicacy for the table (Doke *et. al.*, 2018). But, it is highly perishable in nature. Bangladesh occupies 8th position among mango growing countries and produces about 2.74 % of world's total mango production. In Bangladesh, the total production of mango fruits is about 12.88 lakh metric tons from 0.42 lachectors of land in 2016-2017 (BBS, 2018). It is major fruit crop cultivated in tropical and subtropical zones of the world. In Bangladesh it grows well in north-western and south-western region. But recently it is cultivated in all parts of the country. It is an abundant source of carotene, precursor of "vitamin A" after ripening.

Ripening is a process in fruits that causes them to become more palatable. In general, a fruit becomes sweeter, less green and softer as it ripens. The process of fruit ripening is chiefly regulated by a gaseous plant hormone called ethylene. The chemical commonly used to ripen fruits commercially is ethephon (2-chloroethyl phosphonic acid) which penetrates into fruit and decomposes to ethylene(Alexander and Grierson, 2002). Aqueous solution of ethephon is stable below pH 3.5. Above pH 3.5, the hydrolysis of ethephon begins with the release of free ethylene along with chloride and phosphate ions (Sukhjit, 2017).

In natural condition, mango fruits harvested at mature but unripe condition ripen slowly leading to high weight loss, desiccation and ripening is also uneven. Transporting and distributing mango fruits from farmer's field to consumer's basket can take several days. During this time ripen fruits become overripe and inedible. A part of naturally ripened fruits can also be damaged during transportation causing great loss to farmer. For this reason farmers harvest their fruits at mature green stage and apply ethephon to ripen artificially minimizing postharvest loss. Early and uniform ripening and color development can be achieved by dipping of mango fruits (physiologically mature but unripe) in diluted ethephon solution which is recommended for a number of climacteric fruits including mango (Bhandari*et. al.*, 2017; Doke *et. al.*, 2018; Gurjar *et al.*, 2017; Sukhjit, 2017), banana (Mahajan *et. al.*, 2010), tomato (Moniruzzaman *et. al.*, 2015), guava (Mahajan *et. al.*, 2008), and pear (Dhillion and Mahajan, 2011) and their recommended dosage of ethephon is 500-1000 ppm. When the the mature fruits dipped in aqueous solution of ethephon, ethephon enters into the fruit cells, releases ethylene and hastens the ripening process(Zhu *et al.*, 2005).

Farmers use ethylene releasing chemicalsm namely Tomtom, Harvest, Promot, Ripen, Prolong, Ethrel, Goldplus, etc. in high doses (10000 ppm or more) on

mangoes to quicken the ripening process and to increase the shelf life (Anon., 2014). Hakim *et. al.* (2012) opined that ripening chemicals are considered hazardous to human health and they have to be used within safe recommended level. Recently there have been a mixed opinions on the toxicity of ethephon among the consumers all over the country. Ethephon has been registered with EPA (US Environmental Protection Agency) since 1973 as a plant growth regulator used to promote fruit ripening and flower induction. It is a chemical which is irritant to the skin or the eyes but it is not skin sensitizer and carcinogen as classified by IARC(International Agency for Research on Cancer) as group D (not carcinogenic to human) and FAO pointed out maximum allowable daily intake for ethephon at 0.05 ppm (mg/kg) body weight/day (Bui, 2017). Recommended maximum residue level of ethephon is 2 ppm (mg/kg) of treated fruit (Anon., 2001). Optimum dose for ripening of mango fruits has yet not been developed in our country. The present study was therefore, conducted to determine the optimum concentrations of ethephon for ripening of mango without affecting its nutritional and postharvest qualityduring storage at ambient temperature.

Materials and Methods

***Site*:** The present investigation was carried out at the Laboratory of the Postharvest Technology Division in Bangladesh Agricultural Research Institute during 3rd week of June of the year 2011-12 maintaining temperature 23 ± 2^0 C and RH 85±5%. Fruits were carried from the farmer's field to the laboratory in plastic crates covering themselves in newspaper.

***Plant material*:** The mango (cv.Langra) which were physiologically mature and have attained the full size, light green with tinge of yellow at apical end were collected from farmers field nearby Volahat Upazilla, Chapai-nawabganj to use for the study. Fruits were harvested on 18th June, 2011 and 20th June, 2012. The fruits were selected on the basis of uniformity, maturity and size (200-250 gm). The experiment was laid out in Completely Randomized Design (CRD) with 6 treatments with3 replications for each treatments.Selected fruits were divided into two parts. One for investigating chemical parameters at 2 days interval upto 6 days and other one was kept in plastic box at ambient condition to examine physical parameters at same interval upto 6 days of storage.

***Treatment setting*:** The experiment consisted 6 level of ethephon concentrations (T_1=control, T_2= 250 ppm, T_3=500ppm, T_4=750 ppm, T_5=1000 ppm and T_6= 10000 ppm).T_6(10000 ppm) is being used by the farmers as common ripening practice. Prior to use, fruits were washed with clean water, dipped for 2 minutes in 250 ppm "propiconazole" and dried with air flow before setting the experiment. Then the fruits were dipped for 5 minutes in the following

concentrations of ethephon solution as stated above.The temperature was set at 23 ± 2^0 C and RH 85±5%.

After that, the fruits were kept at ambient temperature for 10 minutes in an attempt to reduce possible chemical injury and being dried up. The control fruits were dipped for 5 minutes in tap water without using the ethephon solution. The number of fruits treated under each treatment was 12. The source of ethephon was Ripen-15 as it was available at the market.

***Parameters studied*:** The parameters studied were percentage of ripening, physiological weight loss (%), titratable acidity (%), total soluble solid(TSS), reducing sugar (%), total sugar (%), ascorbic acid content (mg/100g), total carotenoid (µg/100 g) and carbon di oxide production (ml/g fruit). Each data were recorded at 2 days interval upto 6 days.

Percentage of ripening: In order to determine the ripening percentage, mango fruits were daily observed for their color development and when skin color turned to full yellow, they were considered as ripe. Ripening percentage was calculated following the formula;

$$\text{Ripening (\%)} = \frac{\text{Number of ripe fruits}}{\text{Total number of fruits}} \times 100$$

Weight loss: Weight loss was calculated by following formula;

$$\text{Weight loss of fruits (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Ascorbic acid content: For ascorbic acid measurement, 10g pulp was homogenized in 50 mL of 3% cold metaphosphoric acid (HPO_3) using a blender for 2 min and filtered through Whatman filter paper No. 2. The clear supernatant was collected for assaying ascorbic acid by 2, 6-dichlorophenolindophenol titration following the method of Ranganna (1986). Ten milliliters of aliquot were titrated with 0.1% 2, 6-dichlorophenolindophenol solution until the filtrate changed to pink color persisted for at least 15 seconds and the titration volume of 2, 6-dichlorophenolindophenol was recorded. Prior to titration 2, 6-dichlorophenolindophenol solution was calibrated by ascorbic acid standard solution. Ascorbic acid content was calculated according to the titration volume of 2, 6-dichlorophenolindophenol and results were expressed as mg/100g fresh weight.

$$\text{Ascorbic acid content (mg/100g)} \ \frac{\text{T x D x V1 x 100}}{\text{V2 x W}}$$

Where T= Titre, D = Dye factor, V1= Volume made up, V2= Volume of extract taken for estimation, W= Weight of sample taken for estimation.

Titratable acidity of mango pulp: It was determined following the method described by Ranganna (1986).

The titratable acidity (TA) was analyzed using the titration method. Pulp sample (10 g) were homogenised using a kitchen blender with 40 ml of distilled water. The mixture was then filtered through cotton wool. The filtrate (5 ml) with one to two drops of phenolphthalein (0.1%) as indicator was titrated using0.1 N NaOH to an endpoint pink (pH 8.1). The results were expressed as the percentage citric acid per 100 g fresh weight.

$$\text{Total titratable acidity (\%)} \frac{\text{T x N x E x V1 x 100}}{\text{V2 x W}}$$

Where T= Titre, N = Normality of NaOH, V1= Volume made up, E= Equivalent weight of malic acid, V2= Volume of extract taken for estimation, W= Weight of sample taken for estimation.

TSS content of mango pulp:Total soluble solid (TSS) in the extracted juice of fruits was measured by a Digital Hand Refractometer (ATAGO (Brix = 0 to 32) by placing a drop of pulp solution on its prism and direct reading was recorded and the results were expressed as ^{0}Brix.

Total sugar & reducing sugar (%) measurement:Total sugar and reducing sugar content of fruit was estimated by the following procedures described by Lane and Eynon (1923).

Standardization of Fehling's solution

50 milliliter of both Fehling's solution A and Fehling's solution B were mixed together in a beaker. Ten milliliter of mixed solution was pipetted into a 250 ml conical flask and 25 ml distilled water was added to it. Standard sugar solution was taken in a burette. The conical flask containing mixed solution was heated on a hot plate. When the solution began to boil, 3 drops of methylene blue indicator solution were added to it without removing the flask from the hot plate. Mixed solution was titrated by solution. The end point was indicated by de-colorization of the indicator.

Fehling's solution was calculated by using the following formula;

Fehling's Factor (g of invert sugar) = (Titre x 2.5)/1000

Preparation of sample

50 ml of fruit juice was mixed with 100 ml of distilled water and 5 ml of neutral lead acetate solution and then kept for 10 minute and the mixture was homogenized. Then the blended material was transferred to a 250 ml volumetric

flask. The volume was made up to the mark with distilled water. Then solution was filtered.

Titration of reducing sugar

10milliliter of mixed Fehling's solution was taken in a 250 ml conical flask and made 250 ml with distilled water. Purifier juice solution (filtrate) was taken in a burette. Conical flask confining mixed Fehling's solution was heated on a hot plate. 3-5 drops of methylene blue indicator were added to the flask when boiling started and titrated against solution taken in burette. The end point was indicated by de-colorization of indicator. Percent reducing sugar was calculated according to the following formula;

$$\% \text{ reducing sugar} = \frac{F \times D \times 100}{T \times W \times 1000}$$

Where,F= Fehling's factor,D= Dilution, T= Titer andW= Weight of sample.

Non-reducing sugar was estimated by using the following formula;

% Non-reducing sugar = % Total invert sugar - % Reducing sugar

- Estimation of total sugar

  % Total Sugar = % Reducing sugar + % Non- reducing sugar

Measurement of total carotenoids:

Total carotenoid was measured by taking 5 grams of the sample, grounded with acetone and anhydrous sodium sulphate in a pestle and mortar (Ranganna, 1986). Total carotenoids (µg/100g) was measured by spectrophotometer (T-80, PG Instrument Ltd. UK) at 451ηm (Alasalvar*et al*., 2005).

Carbon-di-oxide measurement:

The level of CO_2 volume ml/g fruit weight was measured by Archimedes' principle and expressed as ml/g of fruits.

Residue level of ethephon:The residue level in treated mango was measured by Gas chromatography flame ionized detector in Toxicology laboratory, Entomology Division, BARI, Gazipur and SGS Laboratory, Dhaka and expressed as ppm (mg/kg). The method is stated by Rahman *et. al.* (2012).

***Statistical analysis*:** Data analysis were performed by one-way ANOVA using software SPSS 20.0 (IBM INC: New York). Mean comparison was done by Tuky w test at 5% level of probability. All data were expressed in triplicate as means ± standard deviation.

Results and Discussions

Since there was no significant difference between two year's analytical data, pooled analysis was done and presented.

***Effect on ripening*:** The investigation revealed that ethephon application enhanced the onset of ripening in mango and the response varied according to the concentrations ((Tables 1&2). 100% ripening was found when the fruits were treated with ethephon @10000ppm after 4 days of ambient storage. Almost all the fruits were fully ripened at 6 days of storage except control treatment. The ethephon (2-chloroethyl phosphonic acid) penetrates into fruit and decomposes to ethylene. Ethylene regulates the expression of several genes involved in fruits ripening so as to modulate the activity of various enzymes involved in the process of ripening (Beitz *et al.* 1977). These enzymes act to soften the skin of the fruit and also convert complex polysaccharides into simple sugars. It was explained by Holl (1977) in other way that the ethylene probably brings about the climacteric, since in many fruits the rise in respiration is directly preceded by an elevation in the ethylene concentration. This respiratory climacteric can be induced by ethylene treatment without a simultaneous change in tissue permeability. It has also been reported that ethylene alters the proportion of individual transfer RNA species.In support of the present study, the color development in mango fruits was remarkably affected by post-harvest application of ethephon. Out of all the concentrations, 1000 ppm ethephon gave the most attractive and deep colored fruits. However, the specific mode of action of ethephon in accelerating color development is not clearly understood. Nour and Goukh (2010) observed that peel color score progressively increased during ripening of guava fruits. They observed that fruits treated with ethephon (250-1000 ppm) reached the full yellow stage 3, 4 and 6 days earlier than untreated fruits, respectively. They also reported ethephon treated fruits had reached the soft stage 2-6 days earlier than the control treatment.Color development was better due to rapid degradation of chlorophyll and higher synthesis of carotenoid pigmentation and alteration in pigment due to different applied ethephon treatment. These findings are more or less similar to the findings of Gurjar *et. al* (2017) and Sukhjit (2017) in mango.

***Effect on weight loss*:** Table2 indicates that the physiological loss in weight was significantly increased with the increase of applied ethephon concentrations. This might be due to rapid respiration and transpiration. The maximum weight loss 3.73% was observed at T_6(10000 ppm) where as it was only 1.74% in control treatment (T_1) at 6 days of ambient storage. Similar type of decrease in fruit weight during storage was also observed by Sharma and Singh (1981) in dates when dipped in 250-500 ppm ethephon for 5 minutes and by Gurjar*et. al* (2017) in 'Amrapali' when dipped into 250-1250 ppm ethephon.

***Effect on titratable acidity*:** It was observed from Table 2, that acidity of the mango fruit was not clearly understood by post-harvest application of ethephon and the response varied within the concentrations. Minimum titratable acid (0.704%) was found in mango fruits treated with 1000 ppm ethephon at 6 days of ambient storage. Similar finding was also noted in guava (Singh *et al*.,1979) and in date (Sharma and Singh, 1981). Riberau-Gayaon (1968) suggested that transformation of organic acids into sugars was one of the reasons for deceasing organic acids during fruit ripening. Therefore, another possibility seemed that ethephon might enhance the conversion of organic acids to sugars since present findings revealed that sugar content was increased and acidity was decreased following ethephon application.

***Effect on total soluble solid (TSS)*:** The maximum TSS (20.7^0Brix) was observed in 750 ppm closely followed by 1000 ppm (20.50^0Brix) at 6 days of storage which was significantly different compared to control fruits (12.8%) after 6 days of storage (Table 3). Similarly, increased total soluble solids due to post harvest application of ethephon was also reported by Singh *et al.* (1979) in guava, Sharma and Singh (1981) in date, Meitei *et al.* (1983) in peaches. The initial increased rate of TSS might be due to rapid loss of water from the fruits and the conversion of starch into sugar at a faster rate (Fernandez *et al.*, 2006).

***Effect on reducing sugar and total sugar*:** It revealed that the total sugars and reducing sugar increased with increasing ethephon concentration (Table 3). The maximum total sugar (10.20%) and reducing sugar (7.16%) was observed in treatment T_5 (1000 ppm) treated fruits at 6 days of ambient storage. The extent of sugar content increased up to 6 days of storage. Probably ethephon enhanced the rate of accumulation of reducing sugar in mango fruits. Similarly, high percentage of reducing sugar with ethephon application in dates was observed by Sharma and Singh (1981). The finding is corroborated with the result of Kumar and Singh (1993) who observed that higher percentage of sugar in ethephon (750 ppm and 500 ppm) treated mango fruits over control treatment.

***Effect on ascorbic acid*:** The ascorbic acid decreased significantly up to 6 days after storage for all the treatment (Table 4). At 6 days of storage maximum ascorbic acid content was recorded in 1000 ppm treated fruits (29.12 mg/100 g) followed by 750 ppm treated fruits (28.12 mg/100 g). The fruits during storage, in general showed a declining trend in ascorbic acid content significantly irrespective of the treatments applied. A reduction in ascorbic acid content with the subsequent prolongation of storage might be due to rapid oxidation phenomenon of organic acid in later stage of storage (Orzolek and Argell, 1974).

***Effect on total carotenoid*:** A significant increase in total carotenoids was observed up to 6 days after storage in all the treatment (Table 4). The maximum total carotenoid was observed in 1000 ppm treated mango fruits (13.24 µg/100gm) at 6 days of ambient storage. Ethylene might increase the carotenoid content through its synthesis. This fact was established by Young and Jahn (1972) while working in citrus.

***Effect on Carbon-di-oxide (CO_2) production*:** It was obvious from the experiment that CO_2 level of the air-tight mango sample gradually increased with the increased ethephon application rate as well as with the storage period (Table 4). Maximum CO_2 was found in 1000 ppm treated fruits at 6 days of storage which was 8.60 ml/g fruits and the lowest was observed in control treatment (5.17 ml/g). It might be resulted from the increase in respiration rate of the fruit sample.

Residue analysis: The residue level was observed in all treated mangoes at 2, 4 and 6 days of storage (Table 5). Initially the maximum residue (ethephon) was observed in treatment T_5 (1.86 ppm) followed by treatment T_5 (1.80 ppm) and the minimum was found in treatment T_2 (0.41 ppm) after 2 days of storage. It was observed that residue level decreased below themaximum residue level (MRL) of ethephon (2ppm). The residue level in treated fruits decreased with the increasing storage period and found the value was only 0.50-0.54 ppm at 6 days of storage in case of 750 and 1000 ppm ethephon treated fruits. The reason behind this is that it is very volatile compound and it completely agrees with Beitz *et al.*, (1977).

Table 1. Effect of ethephon on color development during storage ofmango (cv. Langra)

Treatments (ppm)	Storage Days			
	0 DAS	2 DAS	4 DAS	6 DAS
T_1 = Control	Green	Green ,slight yellow	Green > yellow	Yellow >green
T_2 = 250 ppm	Green	More green than yellow	Yellow > green	Ripe
T_3 = 500 ppm	Green	More yellow than green	Full ripe	Over-ripe
T_4 = 750 ppm	Green	More yellow than green	Full ripe	Over-ripe
T_5 = 1000 ppm	Green	Yellowish	Full ripe	Over-ripe
T_6 = 10000 ppm	Green	Yellow	Over-ripe	Rotting

DAS=Days after storage

Table 2. Effect of ethephon on ripening (%), weight loss (%), titratable acidity (%) of mango during storage *(pooled of year 2011 and 2012)*

Treatment (ppm)	Ripening (%)			Weight loss (%)			Titrable acid (%)		
	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS
T_1 = Control	0.00 ± 0.00 e	18.00± 1.00 e	27.54± 0.20 d	1.13± 0.10 c	1.34± 0.10 e	1.74± 0.10 d	0.786± 0.005 b	0.760± 0.01 d	0.745± 0.01 b
T_2 = 250 ppm	26.00± 1.00 d	58.75± 0.20 c	64.37± 1.00 c	1.35± 0.05 c	1.74± 0.10 d	2.12± 0.10 c	0.816± 0.01 a	0.792± 0.002 b	0.780± 0.01 a
T_3 = 500 ppm	25.00± 1.00 d	64.00± 1.00 b	95.00 ± 1.00 b	1.75± 0.10 b	2.35± 0.10 c	2.84± 0.10 b	0.816± 0.01 a	0.774± 0.002 c	0.729± 0.004bc
T_4 = 750 ppm	28.30± 0.50 c	50.00± 1.00 d	100.00± 0.00	1.87± 0.10 b	2.87± 0.10 b	3.43± 0.10 a	0.826± 0.01 a	0.768 ± 0.001 c	0.723 ± 0.004 cd
T_5 = 1000 ppm	38.18± 0.20 b	65.55± 0.10 b	100.00± 0.00 a	2.64± 0.10 a	3.13± 0.10ab	3.64± 0.10 a	0.776± 0.01 b	0.712± 0.002 e	0.704± 0.004 d
T_6 = 10000 ppm	42.34± 0.30 a	100.00± 0.00 a	100.00± 0.00 a	2.75± 0.10 a	3.23± 0.10 a	3.73± 0.20 a	0.828± 0.007 a	0.710± 0.004 a	-

*DAS=Days after storage

**All values are means of triplicate determinations ± SD. Means within columns with different letters are significantly different at 5% level of probability by Tukey w test

Table 3. Effect of ethephon on TSS (^{0}B), reducing sugar (%), total sugar (%) of mango during storage*(pooled of year 2011 and 2012)*

Treatment (ppm)	Total Soluble Solid (^{0}Brix)			Reducing sugar (%)			Total sugar (%)		
	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS
T_1 = Control	10.6± 0.10ab	12.0± 1.00 d	12.8± 0.50 c	3.24± 0.03 c	4.01± 0.05 e	4.25± 0.10 f	5.53± 0.05 b	6.61± 0.03 e	6.82± 0.05 c
T_2 = 250 ppm	10.7± 0.10 a	16.8± 0.50 c	18.3± 0.10 b	3.90± 0.10ab	5.01± 0.05 d	5.48± 0.05 d	6.55± 0.10 a	8.64± 0.10 c	9.61± 0.03 b
T_3 = 500 ppm	10.5± 0.10ab	16.3± 0.50 c	20.4± 0.10 a	3.77± 0.10 b	5.26± 0.02 c	5.06± 0.02 e	6.51± 0.03 a	8.25± 0.04 b	9.68± 0.03 b
T_4 = 750 ppm	10.6± 0.10ab	17.4± 0.20bc	20.7± 0.10 a	3.82± 0.04ab	5.63± 0.10 b	5.81± 0.01 c	6.43± 0.04 a	8.69± 0.06 c	9.62± 0.04 b
T_5 = 1000 ppm	10.5± 0.10ab	21.3± 0.20 a	20.5± 0.10 a	3.95± 0.075ab	5.93± 0.05 a	6.16± 0.02 b	6.45± 0.03 a	9.49± 0.04 a	10.2± 0.04 a
T_6 = 10000 ppm	10.4± 0.10 b	19± 1.00 b	20.9± 0.10 a	4.00± 0.10 a	5.63± 0.05 b	7.88± 0.01 a	6.53± 0.04 a	9.32± 0.01 b	-

DAS=Days after storage

All values are means of triplicate determinations ± SD. Means within columns with different letters are significantly different at 5% level of probability by Tukey w test.

Table 4. Effect of ethephon on ascorbic acid (mg/100g), total carotenoids (µg/100g) and CO_2 production (ml/gm fruit) of mango during storage *(pooled of year 2011 and 2012)*

Treatment(ppm)	Ascorbic acid (mg/100g)			Total carotenoids (µg/100g)			CO_2 production (ml/g fruit)		
	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS
T_1 = Control	36.38± 0.05 a	29.12± 0.04 c	27.15± 0.10 d	4.67± 0.10 b	7.71± 0.03 b	7.90± 0.10 e	3.91± 0.02 e	4.58± 0.04 e	5.17± 0.05 d
T_2 = 250 ppm	35.77± 0.05 c	29.83± 0.05 b	26.40± 0.10 e	5.00± 0.10 a	7.82± 0.03 b	8.80± 0.10 d	5.48± 0.04 c	6.36± 0.02 d	6.87± 0.04 c
T_3 = 500 ppm	36.23± 0.05bc	29.45± 0.10bc	27.95± 0.10 c	5.25± 0.10 a	7.26± 0.02 c	9.07± 0.10 c	5.25± 0.10 d	6.26± 0.01 d	7.47± 0.02 b
T_4 = 750 ppm	36.33± 0.10a	29.74± 0.10 b	28.19± 0.10 b	4.67± 0.10 b	7.74± 0.10 b	13.10± 0.04 b	5.97± 0.05 b	6.90± 0.10 c	7.59± 0.02 b
T_5 = 1000 ppm	35.47± 0.10 d	30.50± 0.50 a	29.12± 0.10 a	5.12± 0.10 a	8.34± 0.10 a	13.24± 0.02 a	5.99± 0.05 b	7.13± 0.10 b	8.60± 0.10 a
T_6 = 10000 ppm	36.03± 0.10 b	27.66± 0.04 d	25.19± 0.05 f	5.15± 0.10 a	8.25± 0.10 a	13.34± 0.02 a	6.53± 0.01 a	9.28± 0.05 a	-

DAS=Days after storage

All values are means of triplicate determinations ± SD. Means within columns with different letters are significantly different at 5% level of probability by Tukey w test

Table 5. Estimated residue level (ppm) of ethephon in treated mango *(pooled of year 2011 and 2012)*

Treatments	Days after storage		
	2 DAS	4 DAS	6 DAS
T_1 = Control	0.00 ± 0.00 f	0.00 ± 0.00 e	0.00 ± 0.00 d
T_2 = 250 ppm	0.41 ± 0.03 e	0.26 ± 0.02 d	0.11 ± 0.02 c
T_3 = 500 ppm	0.64 ± 0.02 d	0.51 ± 0.03 c	0.49 ± 0.02 b
T_4 = 750 ppm	0.85 ± 0.02 c	0.53 ± 0.02 c	0.50 ± 0.01 ab
T_5 = 1000 ppm	1.80±0.01 b	1.28 ± 0.02 b	0.54 ± 0.02 a
T_6 = 10000 ppm	1.86 ± 0.01 a	1.40±0.02 a	-

DAS=Days after storage

All values are means of triplicate determinations ± SD. Means within columns with different letters are significantly different at 5% level of probability by Tukey w test.

Conclusion

It can be concluded from the present investigation that the use of ethephon had a significant impact on the ripening and postharvest quality of mango fruits. Among the treatments ethephon application @ 1000 ppm was best for retaining the various physical and chemical parameters followed by ethephon application @ 750 ppm till the 6 days of storage. Therefore, at matured green stage, ethephon can be applied@750-1000 ppm for uniform ripening of mango at ambient condition (23±2°C) with 85±5% relative humidity. The estimated residue level in 750-1000 ppmethephon treated mango fruits at 4 and 6 days of storage remains lower than maximum residue limit (MRL) of ethephon (2ppm).

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