

1-Methylcyclopropene (1-MCP) Preharvest Aqueous Spray Delays Ripening of Mango (*Mangifera indica* L.) cv ‘Carabao’

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ABSTRACT--- *A preharvest 1-methylcyclopropene (1-MCP) aqueous spray was applied to mango fruits to determine whether it could effectively block ethylene and subsequent ethylene ripening responses. 1-MCP at 0, 10, 20 and 30 ppm was sprayed to mango fruits at 90, 100 and 110 days after flower induction (DAFI). Fruits were harvested at 117 DAFI and stored at 12.5°C. Ripening parameters were measured during storage. Significant difference in firmness was observed with treatment of 10ppm 1-MCP at 100 DAFI at 14 d storage compared with the rest of the treatments and controls. Delayed peel color development was observed for all the 1-MCP treatments but a significant difference was observed with 10 ppm 1-MCP sprayed at 100 DAFI at 17 d. This treatment also had significantly lowest peel color index (PCI) at the end of the 26 d storage. Slowest decline in visual quality rating (VQR) was also observed in this treatment. No significant differences in ethylene production was observed. A preharvest aqueous spray formulation of 10 ppm 1-MCP applied at 100 DAFI was proven effective to delay the ripening of mango. This is the first study on a preharvest 1-MCP aqueous spray application on ‘Carabao’ mango fruits.*

Keywords: 1-methylcyclopropene, ‘Carabao’ mango, preharvest 1-MCP application, 1-MCP aqueous spray

1. INTRODUCTION

The Philippine ‘Carabao’ mango, *Mangifera indica* L.cv. Carabao, is a major fruit export of the Philippines. Postharvest technologies to lengthen the pre-climacteric stage of ‘Carabao’ mango are important to be able to meet export demands. Studies on its ethylene biosynthesis by Cua [1] revealed that events associated with ripening have been shown to initiate in the mesocarp prior to full maturation, with ethylene production showing a peak at about 10 days before harvest maturity. This means that ripening has been initiated in the inner mesocarp prior to full maturation. This could be the reason why attempts to maintain the mature ‘Carabao’ mango at the pre-climacteric stage to delay ripening has proved futile. Thus, controlling ethylene production before the fruit reaches maturation could give promising results. A preharvest application of 1-MCP on ‘Carabao’ mango before the upsurge in ethylene production could therefore be tested to control ethylene biosynthesis which can result in its delayed ripening.

1-methylcyclopropene (1-MCP) is an ethylene antagonist which acts by binding to ethylene receptors and consequently hampering the ethylene-dependent ripening effects. It has become a tool in the investigation of the role of ethylene in ripening. It has also become a tool in maintaining product quality by delaying ripening and senescence of fruits and vegetables [2]. The affinity of 1-MCP for the receptor is approximately 10 times greater than that of ethylene. Compared with ethylene, 1-MCP is active at much lower concentrations. 1-MCP also influences ethylene biosynthesis in some species through feedback inhibition [3].

A commercial breakthrough in 1-MCP application technology resulted from the formulation of 1-MCP as a stable powder in which it is complexed with γ -cyclodextrin, so that 1-MCP is easily released as a gas when the powder is dissolved in water [2]. Gaseous 1-MCP application has been tried on mango cv. Zihua fruit in combination with polyethylene bags and has shown to extend its postharvest life [4]. However, gaseous 1-MCP application was also found to increase stem-end rot on mango [5].

Other methods of 1-MCP application had been explored. A 1-MCP immersion formulation with 1000 ng kg⁻¹ 1-MCP was found to extend the shelf-life of 'Joana Red' plums at an advanced stage of maturity [6]. Another study determined the efficacy of aqueous 1-MCP formulation applied as a brief, topical dip on the ripening of early ripening-stage tomato (*Solanum lycopersicum* L. 'Florida 47') and avocado (*Persea americana* Mill. 'Hass') fruits [7].

Preharvest application of 1-MCP was found to prevent unwanted defoliation of citrus caused by ethephon [8]. The gaseous nature of 1-MCP however, is an impediment to uniform application and consistent efficacy. Thus, the use of a sprayable 1-MCP formulation was suggested.

A sprayable formulation of 1-MCP applied to 'Scarletspur Delicious' and 'Cameo' apples in the orchard was effective in controlling flesh firmness loss and internal ethylene concentration when applied closer to harvest [9].

There is no sufficient information on the application of 1-MCP as a preharvest spray on 'Carabao' mango to control ripening effects of ethylene. Considering the above facts, present study was undertaken, to determine whether ripening of 'Carabao' mango can be delayed by controlling ethylene responses prior to harvest maturity, the application of a preharvest 1-MCP spray was studied.

2. MATERIALS AND METHODS

1-MCP was applied as a preharvest aqueous spray formulation on 'Carabao' mango fruits in a farm at Brgy. Siranglupa, Calamba, Laguna, Philippines. On-tree mango fruits at 90, 100 and 110 DAFI were sprayed with 0, 10, 20 and 30 ppm 1-MCP aqueous solutions. The 1-MCP used was a gift from Dr. Xiang Chun Meng from Guangdong Academy of Agricultural Sciences, China. The formulation contains 0.43% 1-MCP. Triton-X was added at 0.25mL/L of the spray to facilitate binding of the solution onto the waxy surface of the fruits. The prepared 1-MCP spray was applied to the fruits within 20 min right after its preparation.

On-tree mango fruits were first removed from paper bags, after which, fruits were sprayed with different concentrations of aqueous 1-MCP. After spraying, the fruits were enclosed in plastic bags for 2 h to allow time for binding of 1-MCP. The plastic bags were then removed and the fruits were again bagged with paper.

Mature fruits were harvested at 117 DAFI and stored at normal atmospheric conditions at 12.5°C. The fruits were monitored during storage for ethylene production, firmness, peel color index (PCI), and visual quality rating (VQR).

Ethylene production was measured using a static system. Three replicates were used consisting of 2 fruits per replicate. Samples were weighed and then were placed inside respiration jars. The jars were then sealed for one hour after which, gas samples (1 mL) were collected. The gas samples were injected into a gas chromatograph equipped with flame ionization detector (FID) and activated alumina column (Shimadzu Gas Chromatograph Model 8A). Ethylene production was expressed as nL C₂H₄ kg⁻¹h⁻¹.

Firmness of unpeeled fruits was obtained quantitatively using a hand-held penetrometer. Fruits were punctured at 3 points in the middle portion of the cheeks. Firmness was reported as kg-force.

A separate set of representative fruits were monitored for the non-destructive parameters. PCI was monitored using the following scale: 1 – fully green, 2 – breaker, not more than 10% yellow, 3 – more green than yellow, 4 – more yellow than green, 5 – yellow with traces of green, 6 – fully yellow. VQR was monitored as follows: 9,8 – excellent, field fresh; 7,6 – good, defects minor; 5,4 – fair, defects moderate; 3 – poor, defects serious, limit of saleability; 2 – limit of edibility; 1 – non-edible under usual conditions. For these analyses, 3 replicates were used consisting of 5 fruits per replicate.

Each experiment was carried out under a completely randomized design with three replications repeated at least twice. Data was analyzed using SAS Statistical Software (SAS Institute Inc., Cary, NC, USA) by Duncan's New Multiple Range Test (DNMRT) at 5% level.

3. RESULTS AND DISCUSSION

A rapid decline in firmness was observed in the control and 0 ppm treatments compared with the 1-MCP treatments as shown in Figure 1. The treatment at 90 DAFI, with 10 ppm 1-MCP, at 7 d exhibited the highest firmness. The treatment at 100 DAFI, with 10ppm 1-MCP, on the other hand, showed significantly higher firmness at 7 d compared with the control and 0 ppm treatments. More so, at 14 d, it had significantly highest firmness compared with the rest of the treatments. At this stage, a delayed ripening effect was exhibited by 1-MCP. At 110 DAFI, the 10 ppm treatment also had a significantly higher firmness compared with the control and 0 ppm treatments at 7 d but was not carried over until 14 d.

Control of softening by 1-MCP using lower concentrations was also observed in previous studies. Trends in delaying softening of tomato was maximum at aqueous 1-MCP concentration of 200 µg L⁻¹, with little further inhibition at higher levels. Brief exposures to aqueous formulations of 1-MCP at ≥ 200 µg L⁻¹ deliver biologically active levels of the

ethylene antagonist rapidly and uniformly in intact tomato fruit. Concentrations of 400 and 600 $\mu\text{g L}^{-1}$ would presumably deliver quantities in excess of those necessary to saturate all ethylene receptors [10].

The 1-MCP treated fruits generally had delayed peel color development compared with the control and 0 ppm 1-MCP treatments (Figure 2). The 10 ppm treatments at 90 and 100 DAFI exhibited significantly slowest peel color development starting at 13 d until the end of the monitoring period. 1-MCP was observed to be more effective at a lower concentration in delaying ripening in terms of peel color development. The 1-MCP application at 100 DAFI has shown to be more effective in delaying peel color development than at 90 DAFI. As shown in Figures 2A and 2B, at about 13 d, average PCI is 3.2 for 10 ppm 1-MCP at 90 DAFI while 2.8 for 10 ppm 1-MCP at 100 DAFI. The lower PCI values at 100 DAFI were maintained until 26 d while that of 90 DAFI was not significantly different from the other treatments at 26 d. At 110 DAFI, the 1-MCP treatments did not show significant differences among each other, the values though were lower than the controls, still indicating effectiveness of 1-MCP in delaying peel color development.

Maturity of fruits upon 1-MCP application was found to be a factor in the effect of 1-MCP on peel color development. No differences in hue angle were detected between control and 1-MCP treated with fruit in the immature green and orange stage goldenberries but 1-MCP delayed hue angle change in mature green and yellow fruits [11]. At a very early stage of application, there are still a few ethylene receptors present thus 1-MCP cannot exert obvious inhibitory effects due to the scarcity of receptors. On the other hand, when applied at the later stage of maturity, receptors are already abundant and at the same time, the threshold level of ethylene has already been reached where autocatalytic ethylene is already produced. This upsurge in ethylene production leads to saturation of the existing ethylene receptors. Thus, an application of 1-MCP at this stage would no longer be effective because almost all receptors are already bound to ethylene.

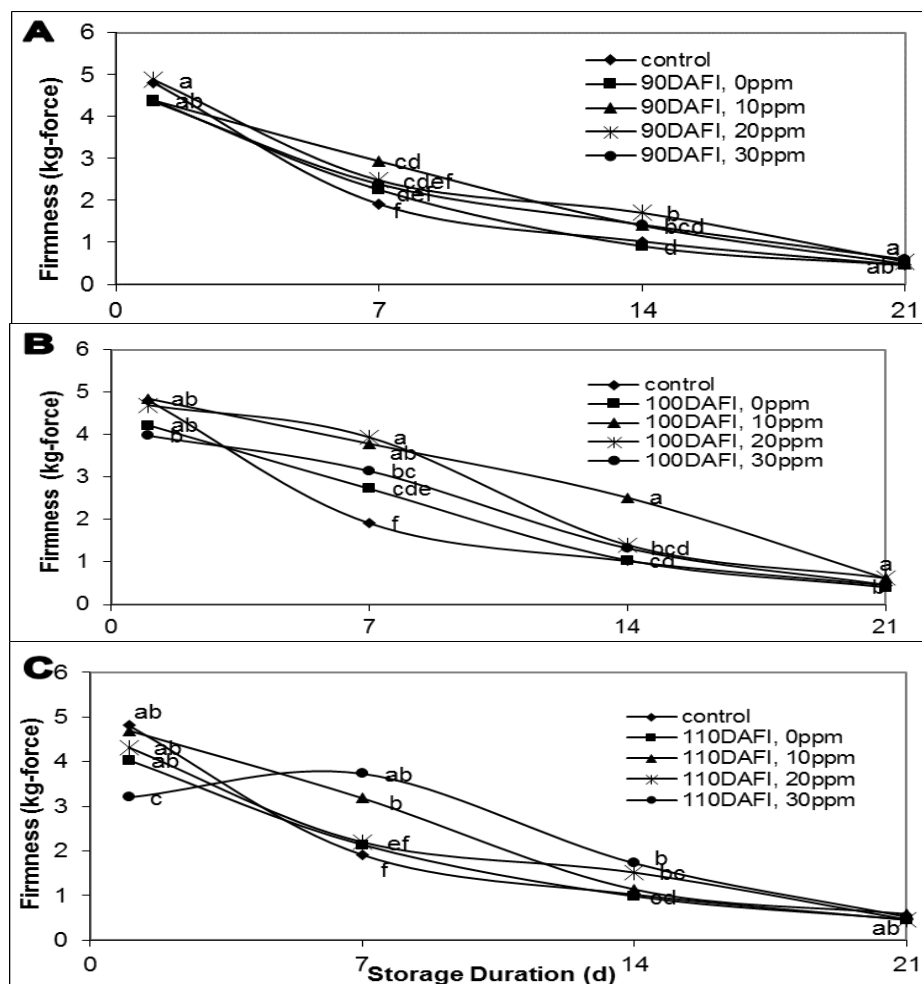


Figure 1. Firmness of mango fruits preharvest-treated with different concentrations of 1-MCP at 90 DAFI (A), 100 DAFI (B) and 110 DAFI (C) during storage at 12.5°C. Each value is a mean of three replicates, each replicate consisting of two fruits. Values with same letter among treatments within each sampling period are not significantly different based on DNMRT, $P < 0.05$.

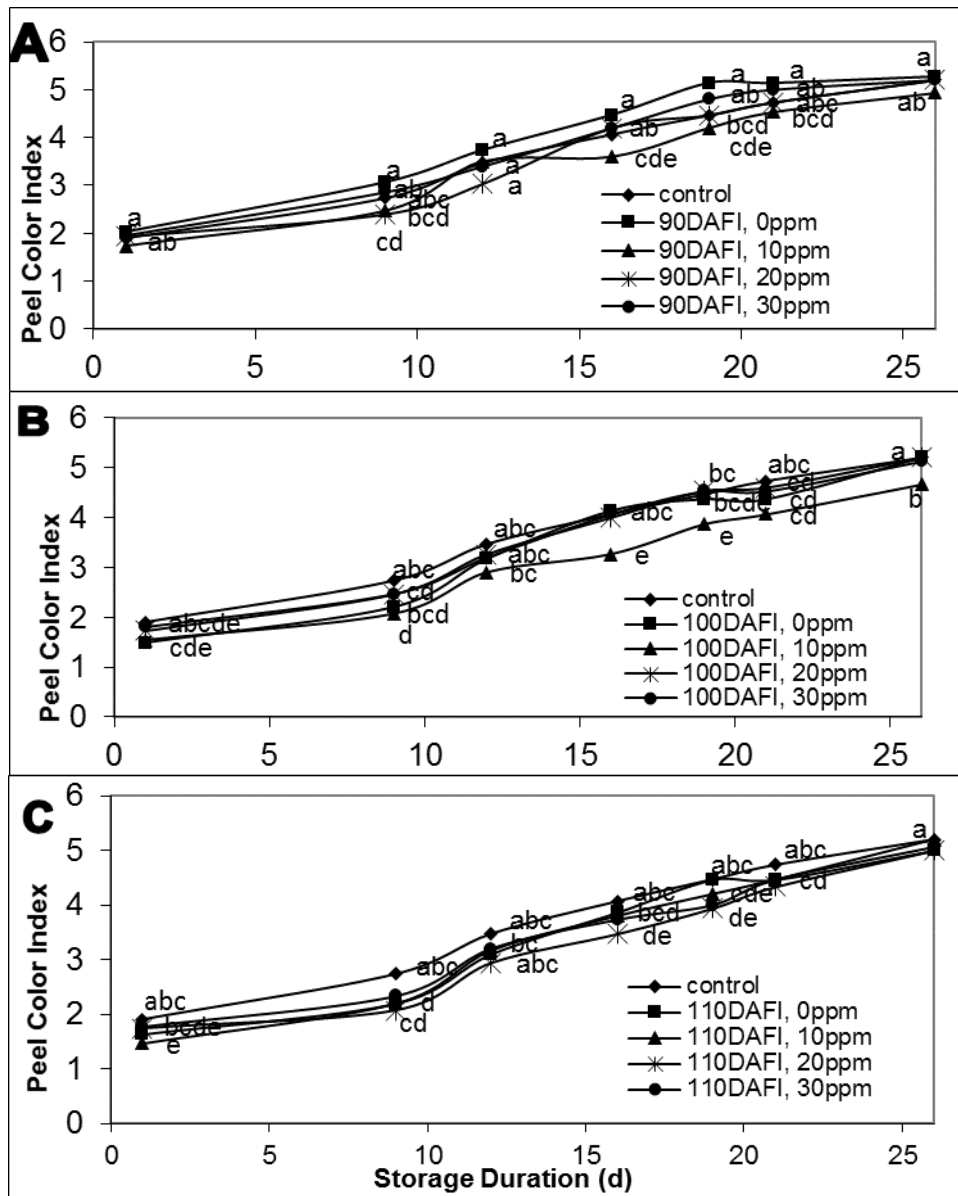
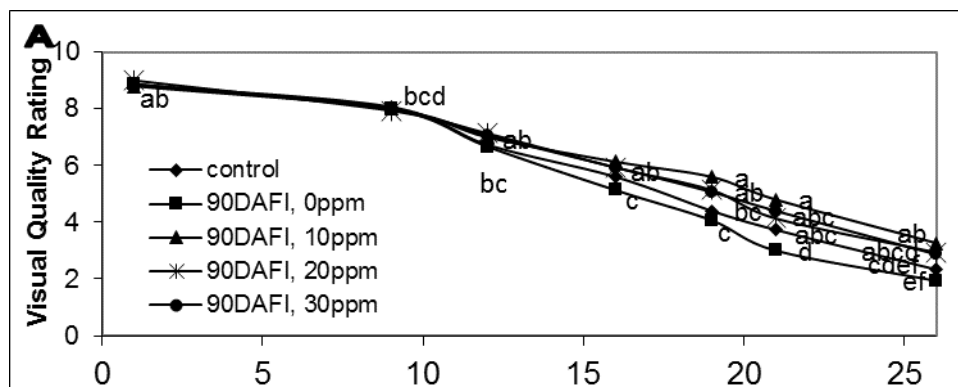


Figure 2. Peel Color Index of mango fruits preharvest-treated with different concentrations of 1-MCP at 90 DAFI (A), 100 DAFI (B) and 110 DAFI (C) during storage at 12.5°C. Each value is a mean of three replicates, each replicate consisting of two fruits. Values with same letter among treatments within each sampling period are not significantly different based on DNMRT, P<0.05



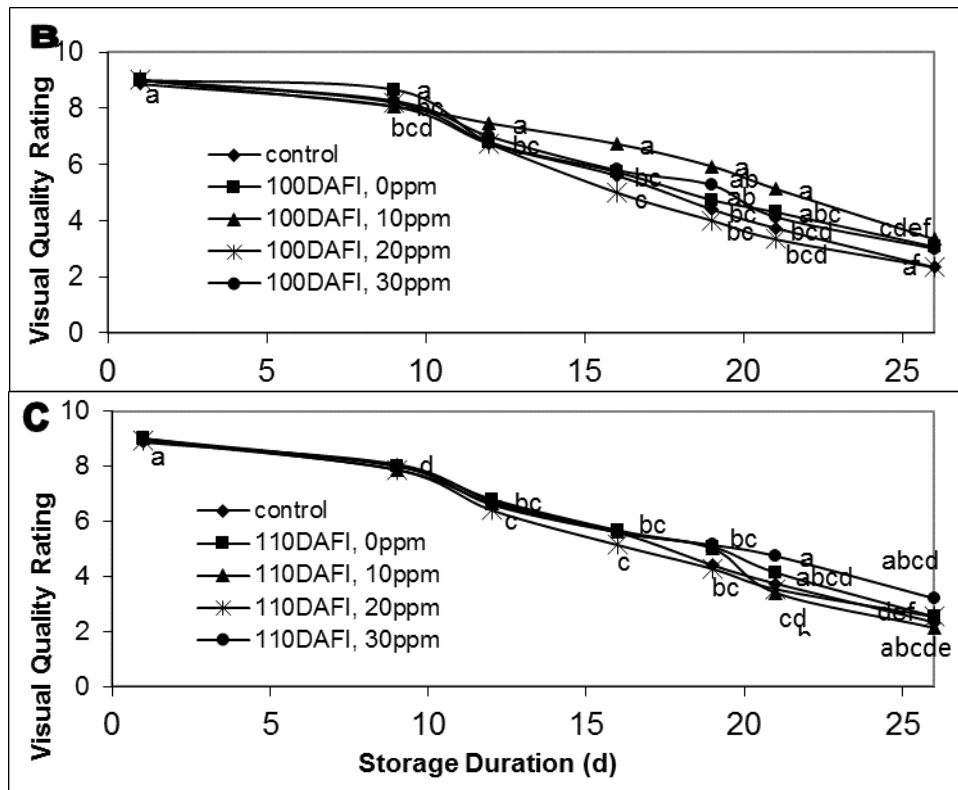
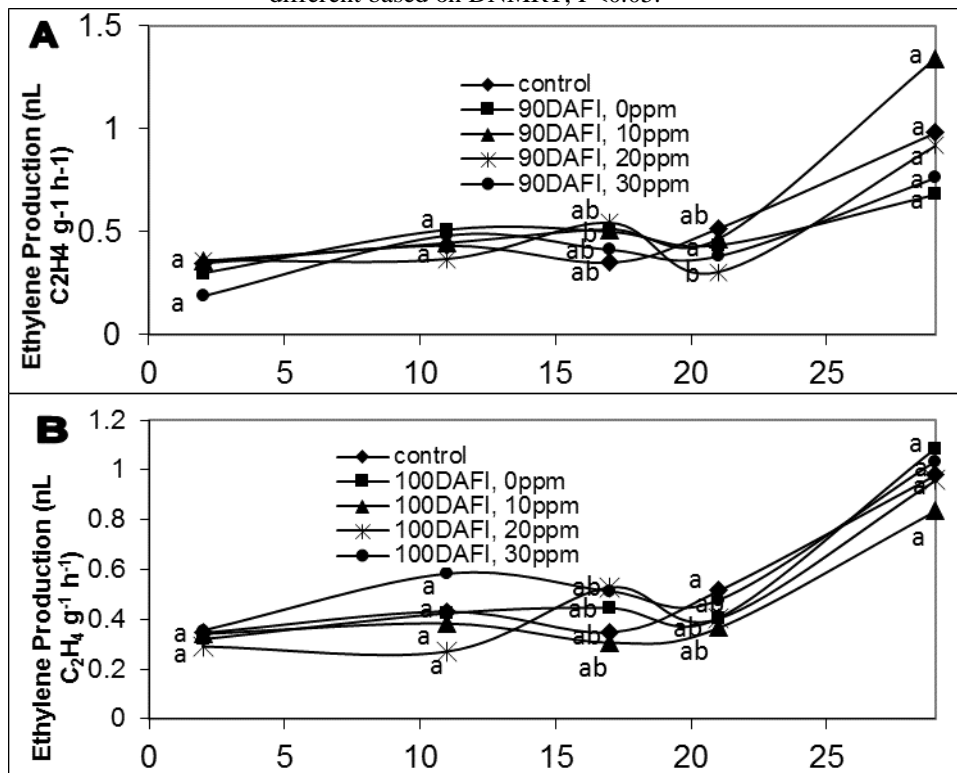


Figure 3. Visual Quality Rating of mango fruits preharvest-treated with different concentrations of 1-MCP at 90 DAFI (A), 100 DAFI (B) and 110 DAFI (C) during storage at 12.5°C. Each value is a mean of three replicates, each replicate consisting of two fruits. Values with same letter among treatments within each sampling period are not significantly different based on DNMRT, $P < 0.05$.



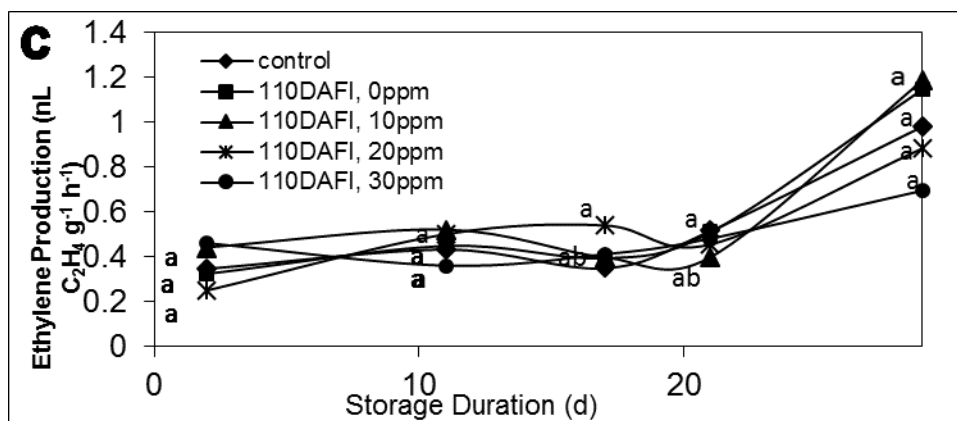


Figure 4. Ethylene production in mango fruits preharvest-treated with different concentrations of 1-MCP at 90 DAFI (A), 100 DAFI (B) and 110 DAFI (C) during storage at 12.5°C. Each value is a mean of three replicates, each replicate consisting of two fruits. Values with same letter among treatments within each sampling period are not significantly different based on DNMR, $P < 0.05$.

Visual quality ratings of the controls at 90 DAFI (Figure 3A) rapidly declined starting at 13 d compared with the 1-MCP treatments. In the 100 DAFI treatments (Figure 3B), it can be noted that the 10 ppm treatment had significantly higher visual quality starting at about 13 d until 17 d compared with the other treatments. No significant differences in VQR of the samples were observed at 110 DAFI (Figure 3C). Overall, the 10 ppm 1-MCP treatment at 100 DAFI, showed the slowest deterioration rate of visual quality.

No significant differences in ethylene production were observed among treatments during storage (Figure 4). However, at 100 DAFI, 20 ppm 1-MCP concentration gave the lowest value of ethylene production of about 0.2 nL kg⁻¹ h⁻¹ at 13d compared with the other treatments. This treatment also showed delayed onset of ethylene peak. It was observed that mango fruits are most sensitive to 1-MCP application at 100 DAFI. An earlier application at 90 DAFI and a later application at 110 DAFI did not exhibit inhibitory effects.

Recent studies have shown that sensitivity to ethylene is affected by the stage of maturity of the fruits. It has been shown in tomatoes that ethylene receptor proteins are high during the immature green stage of fruit development and decreases significantly towards ripening, paving the way for ethylene-mediated ripening processes [12]. In ‘Sanuki Gold’ kiwifruit, fruits at commercial maturity were less sensitive to propylene treatment compared with the younger fruits [13].

At 100 DAFI, 1-MCP has shown to control ethylene ripening effects because at this time, the fruit has not yet reached the upsurge in ethylene production. Thus, many ethylene receptors are not yet occupied by ethylene. The application of 1-MCP prior to the upsurge in ethylene production was effectively able to block the receptors. Compared with fruits at 90 DAFI when the fruits are still young, the levels of ethylene receptors in the tissues are still low. Inhibition of ethylene ripening effects was not evident when applied at this stage of maturity due to the scarce receptors to be blocked. On the other hand, at 110 DAFI, the upsurge in ethylene production had already occurred prior to 1-MCP application. An ethylene peak is observed in ‘Carabao’ mango 10 d before harvest maturity [1]. At this stage, the receptors had already been saturated with ethylene, thus 1-MCP was not able to exert its ethylene-blocking effect.

4. CONCLUSIONS

The preharvest 1-MCP spray application was found to be effective when applied at 100 DAFI at a concentration of 10 ppm. The delayed ripening effects of 1-MCP at this time: concentration combination was evident in almost all parameters observed such as firmness, peel color development and visual quality. Effect on ethylene production was not significant. 1-MCP applied at 100 DAFI has shown significant delay in fruit flesh softening, peel color development and decline of visual quality. At this stage of maturity, sufficient ethylene receptors have already been possibly synthesized and yet ethylene production is still low. The application of 1-MCP is timely since most of the ethylene receptors are still free of ethylene thus, more 1-MCP can bind ahead of ethylene. When an upsurge in ethylene production takes place, most of the receptors are no longer free so ethylene cannot bind, thus ethylene-dependent ripening effects are hampered. The effective 1-MCP concentration of 10 ppm suggests the effectiveness of 1-MCP at very low concentrations. This low concentration is already enough to saturate the receptors present. A further increase in concentration would no longer generate a more favorable response.

5. ACKNOWLEDGMENT

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