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Ethylene and ethephon induced fruit ripening in pear

Dhillon W. S.[1]* and Mahajan B. V. C.[2]

[1]Department of Horticulture, Punjab Agricultural University, Ludhiana, India.
[2]Punjab Horticultural Postharvest Technology Centre, Punjab Agricultural University campus, Ludhiana, India.

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The fruits of 'Patharnakh' pear were harvested at physiological maturity and subjected to different treatments of ethephon for proper ripening, both in the solution form (500, 1000 and 1500 ppm) and as gas application (100 ppm). After treatment, the fruits were kept at 20°C and at ambient temperature for 4, 8, 12 and 16 days. The ripening treatments were better at 20°C as compared to ambient temperature. Among different solution treatments of ethephon, colour development and fruit ripening, which is judged on the basis of fruit firmness and chemical composition of the fruit, was better at 1000 ppm. The ethylene gas application was also equally comparable with this treatment. The optimum ripening in fruits and acceptable quality was achieved after 8 days of ripening period in 'Patharnakh' at 20°C temperature with 1000 ppm ethephon solution, and 100 ppm ethylene gas treatments.

Key words: Cultivar, ethephon, ethylene, fruit firmness, Patharnakh.

INTRODUCTION

The consumption of 'Patharnakh' cv. of pear (*Pyrus pyrifolia* (Burm) Nakai) as table fruit is very low due to more gritty cells in pulp and hard texture of the fruits. The hardness in pear fruit is due to low activity of enzymes responsible for degrading cell wall polysaccharides and hydrochloride soluble pectin into sugars and water soluble pectin, respectively (Ning et al., 1997). This hardy nature of fruits and its organoleptic quality can be improved by following suitable ripening techniques. Pear fruits fail to ripen until they are either exposed to a critical period of chilling temperature (Blankenship and Richardson, 1985) or exposed to exogenous application of ethylene enhancing chemicals, which trigger the ripening process. Proper ripening governs the post-harvest dessert quality of pear fruits.

The changes in cell wall composition which accompany the softening of ripening fruit apparently result from the action of enzymes produced by the fruit (Pressey, 1977). Initiation of ripening activities of climacteric fruit is controlled by the threshold level of internal ethylene concentration (Hansen, 1966). Exogenous ethylene application to immature (Lieberman et al., 1977) or mature (Wang and Mellenthin, 1972) 'd Anjou' pears before completion of the cold requirement can induce ripening and softening without involvement of the respiratory climacteric. Ethylene regulates fruit ripening by coordinating the expression of genes that are responsible for a variety of processes, including a rise in respiration, autocatalytic ethylene production and changes in color, texture, aroma and flavor (Oetiker and Yang, 1995). The temperate pears like Gebhard red strain, harvested at commercial maturity with flesh firmness of 64.5 N, did not ripen normally at 20°C even though the chilling requirement had been met by storage at -1°C (Honma et al., 1997). The fruit did not ripen without the exogenous application of ethylene. Their study showed that 3 day treatment with 100 $\mu l/^{-1}$ ethylene readily induced pulp tissue to convert 1-aminocyclopropane 1- carboxylic acid (ACC) to ethylene. ACC synthase activity was induced only by ethylene treatment, and did not increase until the fruit had been transferred to 20°C for 3 days. This problem of incomplete ripening also exists in hard pear varieties grown in sub- tropics. This offer an opportunity to

*Corresponding author. E-mail: wasakhasingh@yahoo.com.

examine the effect of exogenous ethylene as specific ripening characteristics in a mature fruit of hard pear variety cultivated in sub -tropics. The study was conducted to investigate the effects of ethylene gas, and ethephon - an ethylene releasing chemical; ripening temperature (at ambient, and at 20°C), and duration of time, on softening and ripening of 'Patharnakh' pears.

MATERIALS AND METHODS

The fruits of 'Patharnakh' hard pear were picked at physiological maturity in last week of July during 2006 and 2007. The data presented in this paper is based upon the average values of these two years. The fruit samples were collected at random from all the sides including internal and peripheral areas of the tree. The fruits were subjected to different treatments of ethephon for proper ripening, both in solution form (500, 1000 and 1500 ppm), and ethylene (100 ppm) as gas. The fruits were dipped in required concentration for five minutes and then dried under shade. The fruits were exposed to ethylene gas (100 ppm) for 24 h in fruit ripening chamber. After the treatment, the fruits were kept at 20°C and at ambient temperature for 4, 8, 12 and 16 days. The control fruits were also kept at same environments for comparison. Each treatment was replicated three times. The experiment was laid- out in "completely randomized block design" (Sharma, 1998).

The observations on different parameters were recorded after each interval of ripening period. The color of the fruit was recorded/measured visually, as well as with Hunter Color Lab and the results were expressed as L*, a*, b* (Hunter, 1975). The physiological loss in fruit weight (PLW) was calculated on initial weight basis after every ripening interval. Organoleptic evaluation of the fruits was done by five judges on the basis of Hedonic scale (1 to 9 points), on the basis of general appearance, taste and texture (Amerine et al., 1965). A thin layer of 1 cm^2 from two sides at the shoulder end of the fruit was removed to measure the flesh firmness with the help of IRC-FT 327 penetrometer. 8 mm probe of the penetrometer was pushed gently into the flesh and the puncture resistance measured in lbs force. The total soluble solids(TSS) were determined from fresh strained thoroughly stirred juice of fruits on each sampling date with the help of a hand refractometer (Erma made in Japan). The readings were corrected at 20°C and expressed as percentage soluble solids. The volume was made to 100 ml by adding distilled water. Out of this, 10 ml was taken and titrated against 0.1 N sodium hydroxide solution, using phenolphthalein as an indicator. The results were expressed as percentage Malic Acid (AOAC, 2000). The reducing sugars and titratable acidity were determined by the standard procedure (AOAC, 2000).

RESULTS, DISCUSSION AND CONCLUSION

Certain chemicals, especially ethylene, are known to influence coloring of various fruits. The color of the fruit increased gradually and uniformly in case of ethylene 100 ppm and ethephon 1000 ppm treated fruits. The color values recorded with Hunter Color Lab in terms of L*, a*, b* were 55.78, -4.18, 25.76 for control; 58.58, 3.68, 28.47 for ethylene 100 ppm, and 58.00, 3.10, 28.30 for ethephon 1000 ppm, respectively. In the present studies, b values stands for yellow color of the fruit, which clearly shows that there was dramatic improvement in color with ethephon 1000 ppm and ethylene 100 ppm as gas treatments over control (Table 1). The fruits with these treatments were complete yellow in color after 8 days of ripening at 20°C. However, the color turned out to be deep yellow after 12 days of ripening and dull yellow after 16 days. The color in untreated fruits was light to dull yellow under both ambient and 20°C ripening environments. The change in color during ripening may be due to the synthesis of mainly carotenoids accompanied by the simultaneous loss of chlorophyll (Reyes and Paul, 1995). Exposures of fruits to gas ethylene or ethephon solution have been reported to improve their color and quality during storage and marketing (Kulkarni et al., 2004).

The PLW was significantly higher at ambient temperature as compared to 20°C under all the ripening treatments (Table 2). It also increased significantly after each storage interval from 4 to 16 days under both the ripening environments. After 4 days of ripening period, the lowest PLW was recorded under 1000 ppm ethephon solution treatment at 20°C temperature. However, the high PLW was recorded under 1500 ppm ethephon treatment at ambient temperature. The loss of more than 5% moisture leads to shriveling of fruits and all the treatments showed PLW beyond this limit after 4 days at ambient ripening storage. All the treatments also showed higher PLW more than 5% after 16 days of storage at 20°C temperature, except 500 ppm ethephon treatment which recorded the values very close to it, that is, 4.99%. The PLW was with in permissible limits up to 12 days of ripening storage at 20°C under all the treatments. The loss in weight was less under control treatment as compared to ethephon treatments up to 8 days of storage indicating that the ripening process of the fruits was not started properly. The fruits under ethephon treatments started ripening of fruits immediately after treatment, hence the loss was higher. But, the loss was suddenly on higher side after 12 days of storage in control fruits. Continuous processes of respiration and transpiration have resulted in weight loss during ripening at both the ripening environments. In earlier studies too, the loss in weight of fruit during storage both at ambient and in cold room increased with the enhancement of storage days in pear (Dhillon et al., 2005_b).

The organoleptic rating increased up to 8 days of storage under all the treatments at both the ripening environments (Table 3). Thereafter, it starts declining. The organoleptic rating was 7.96, 8.05 and 7.95 after 4 days under 500, 1000 ppm and fogging treatments (100 ppm), which rose to 8.13, 8.18 and 8.10 after 8 days, respectively. The highest score of 8.18 was recorded after 8 days at 20°C ripening treatment at ethephon 1000 ppm. The next best treatment was recorded to be fogging (100 ppm). The organoleptic rating score was only 6.63 and 6.00 after 4 days in control under 20°C and ambient

Table 1. Effect of ethephon and ethylene gas on color development (fruit color) during ripening in pear.

Treatments	Storage days					
	Temperature	0	4	8	12	16
Ethephon 500 ppm	20℃	Green	Green yellow	Green yellow	Yellow	Dull yellow
	Ambient	Green	Green yellow	Green yellow	Yellow	Dull yellow
Ethephon 1000 ppm	20℃	Green	Yellow green	Yellow	Deep yellow	Dull yellow
	Ambient	Green	Green yellow	Yellow	Deep yellow	Dull yellow
Ethephon 1500 ppm	20℃	Green	Yellow green	Dull yellow	Dull yellow	Dull yellow
	Ambient	Green	Yellow green	Yellow	Deep yellow	Dull yellow
Ethylene gas 100 ppm	20℃	Green	Green yellow	Yellow	Deep yellow	Dull yellow
	Ambient	Green	Green yellow	Yellow	Deep yellow	Dull yellow
Control	20℃	Green	Green	Light green	Dull yellow	Dull yellow
	Ambient	Green	Green	Light green	Dull yellow	Dull yellow

Table 2. Effect of ethephon and ethylene gas on physiological loss in weight (PLW) during ripening in pear.

Treatments	Storage days					
	Temperature	4	8	12	16	Mean
Ethephon 500 ppm	20℃	0.64	1.23	2.45	5.02	2.34
	Ambient	3.40	6.98	13.01	20.43	10.95
Ethephon 1000 ppm	20℃	0.64	1.22	3.54	5.14	2.63
	Ambient	4.15	7.45	14.63	27.32	13.39
Ethephon 1500 ppm	20℃	0.67	1.28	3.92	5.62	2.87
	Ambient	4.48	7.93	15.68	28.76	14.21
Ethylene gas 100 ppm	20℃	0.70	1.34	2.61	5.22	2.47
	Ambient	3.27	6.32	14.00	26.98	12.64
Control	20℃	0.48	0.95	2.85	5.26	2.38
	Ambient	2.81	5.90	12.52	26.23	11.86
Mean		2.12	4.06	8.32	15.60	

C D (0.05) Treatments = 0.03, storage days = 0.05, treatment × storage days = 0.14.

temperature treatments, respectively. Under control, the highest score achieved was 6.93 at 20℃ temperature after 8 days, which were significantly lower than ethephon treatments at 20℃. The score decreased significantly after 16 days under all the treatments at both the ripening environments, thereby indicating that the fruits show over ripening. At this stage, the fruits also lost their optimum firmness. The fruits having score above 7.8 were excellent in texture, flavor and taste. The fruit having score of 7.4 to 7.8 had acceptable eating quality. However, the fruit quality was not to the desired level of those fruits having scored less than 7.4.

The increase in organoleptic rating mainly associated with improvement in fruit color, increase in TSS, decrease in acidity and fruit firmness. The organoleptic score is the balance between sugars and acids. The pear fruits fail to soften until they are exposed to a critical period of chilling temperature which is responsible for biosynthesis of ethylene, thereby triggering the ripening process (Blankenship and Richardson, 1985). Ethylene is

Table 3. Effect of ethephon and ethylene gas on organoleptic rating (1 to 9 point Hedonic scale) during ripening in pear.

Treatments	Storage days					
	Temperature	4	8	12	16	Mean
Ethephon 500 ppm	20°C	7.96	8.13	7.98	7.57	7.91
	Ambient	6.47	6.81	6.58	6.13	6.50
Ethephon 1000 ppm	20°C	8.05	8.18	7.98	7.68	7.97
	Ambient	6.38	6.76	6.65	6.20	6.50
Ethephon 1500 ppm	20°C	7.57	7.71	7.50	7.05	7.46
	Ambient	6.08	6.64	6.08	6.00	6.20
Ethylene gas 100 ppm	20°C	7.95	8.10	7.90	7.25	7.80
	Ambient	6.63	6.95	6.45	6.06	6.52
Control	20°C	6.63	6.93	6.70	6.13	6.59
	Ambient	6.00	6.30	6.10	6.00	6.10
Mean		6.97	7.25	6.99	6.61	

C D (0.05) Treatments = 0.03,storage days = 0.05,treatment × storage days = 0.09.

Table 4. Effect of ethephon and ethylene gas on fruit firmness (lb) during ripening in pear.

Treatments	Storage days					
	Temperature	4	8	12	16	Mean
Ethephon 500 ppm	20°C	15.08	14.29	12.07	10.62	13.01
	Ambient	15.45	15.03	10.90	10.41	12.95
Ethephon 1000 ppm	20°C	14.85	13.15	12.02	10.44	12.61
	Ambient	14.19	14.52	10.88	9.79	12.34
Ethephon 1500 ppm	20°C	14.93	13.08	9.58	7.29	11.22
	Ambient	14.69	12.38	11.77	6.33	11.29
Ethylene gas 100 ppm	20°C	15.10	13.44	12.64	9.79	12.74
	Ambient	15.57	13.93	12.13	9.96	12.89
Control	20°C	16.93	15.74	11.76	10.13	13.64
	Ambient	17.73	13.23	10.41	8.26	12.41
Mean		15.45	13.88	11.41	9.30	

C D (0.05) Treatments = 0.03, storage days = 0.05, treatment × storage days = 0.09.

produced in chilled fruits upon rewarming at a specific temperature (Lilievre et al., 1997). This activity was enhanced by the exogenous application of ethephon in present studies, which is evident from the softening of fruit with ethephon treatments and subsequent ripening at 20°C. The decrease in organoleptic rating after certain period of ripening might be associated with increase in some biochemical changes. The juicy and buttery texture of ripened pear fruits also indicates the involvement of cell substances and then degradation by enzymes (pectinase and polygalacturonase) during ripening process (Chen et al., 1981).

The firmness of the fruit decreased significantly under all the treatments at both the ripening environments with the increase in ripening interval from 4 to 16 days (Table 4). The fruits showed highest firmness after 4 days under

Table 5. Effect of ethephon and ethylene gas on total soluble solids (TSS%) during ripening in pear.

Treatments	Storage days					
	Temperature	4	8	12	16	Mean
Ethephon 500 ppm	20°C	12.83	13.55	12.05	11.14	12.39
	Ambient	12.15	12.33	11.65	11.05	11.79
Ethephon 1000 ppm	20°C	13.12	14.02	12.08	11.73	12.73
	Ambient	12.62	12.77	10.73	11.08	11.80
Ethephon 1500 ppm	20°C	13.05	14.04	11.94	11.55	12.65
	Ambient	12.87	12.70	11.83	11.84	12.31
Ethylene gas 100 ppm	20°C	13.68	14.04	11.93	11.20	12.71
	Ambient	12.13	11.56	10.93	11.00	11.40
Control	20°C	11.08	11.90	10.73	9.05	10.69
	Ambient	11.00	11.10	10.23	8.95	10.32
Mean		12.45	12.80	11.41	10.86	

C D (0.05)Treatments = 0.04, storage days = 0.06,Treatment ×storage days = 0.12.

control treatment at ambient temperature. The fruits recorded above 14.5 lb force were recorded under 1000 ppm ethephon treatment at ambient temperature after 4 days. However, the firmness below 14.5 lb force was recorded under treatment of ethephon 500 ppm at 20°C, ethephon 1500 ppm and exposure to 100 ppm ethylene gas at both the ripening environments and in control at ambient temperature after 8 days of ripening period. All the treatments under both the ripening temperatures showed considerably low fruit firmness after 12 days which was less than ideal fruit firmness of 13.0 lb force. Below 13.0 lb force showed over ripening of the fruits. Considerable reduction in fruit firmness was noted after 16 days. In general, the fruit firmness was lower under all the ethephon treatments as compared to control after 4 days, however, the fruit firmness suddenly decreased under control fruits at ambient temperature after 8 days and thereafter.

Of course, the fruit firmness decreased under control fruits at ambient temperature, but the fruits did not develop the other quality parameters properly. The fully ripened 'Patharnakh' fruit exhibited flesh firmness in range of 13.5 to 15.0 lb/ inch^2 (Dhatt et al., 2005). The 'conference' pear fruits depicted a decrease in flesh firmness when chilled at -1°c and ripened at 20°C (Barkley et al., 1982). The softening of flesh could be due to the degradation of soluble pectin by high activity of endopolyglacturonase in fruits (Martin-Cabrejas et al., 1994). The change in fruit firmness was also attributed to change in the turgor of the cells and changes in the composition of cell wall pectin's and lipo protein membrane bordering the cells (Chenn et al., 1991). The cortical tissues associated with swelling of parenchyma cell walls and dissolution of pectin polysaccharides were responsible for decrease in fruit firmness during ripening (Martin-Cabrejas et al., 1994). The decrease in flesh hardness was also associated with high cellulose activity during fruit ripening in pear (Ning et al., 1997). Similarly, the fruit firmness in 'Patharnakh' pear fruit decreased during ripening at 20°C after chilling the fruit at 0-1°c (Dhillon et al., 2005[b]).

A significant increase in TSS was observed under all the treatments up to 8 days of ripening period and decreased thereafter (Table 5). The highest level of TSS (14.04%) was noted under fogging 100 ppm, and ethephon 1500 ppm at 20°C treatments, closely followed by ethephon 1000 ppm at 20°C. This treatment holds better TSS level even after 12 and 16 days of ripening period. All the ethephon treatments improved the TSS in pear fruits significantly over control at both the ripening environments. The highest level of TSS under control at 20°C was recorded after 8 days which were significantly less than ripening treatment of ethephon even after 4 days. A similar pattern to that of TSS was observed in reducing sugars (Table 6). These sugars increased initially (up to 8 days) and decreased thereafter under both the environments in all the fruit ripening treatments. All the ethephon treatments improved reducing sugars in the fruit over control. The level of reducing sugars was higher in 1000 ppm ethephon and 100 ppm ethylene gas treatments when compared with 500 and 1500 ppm ethephon treatments. The increase in soluble solids and

Table 6. Effect of ethephon and ethylene gas on juice acidity (%) during ripening in pear.

Treatments	Storage days					
	Temperature	4	8	12	16	Mean
Ethephon 500 ppm	20℃	0.431	0.325	0.345	0.348	0.362
	Ambient	0.464	0.353	0.368	0.370	0.389
Ethephon 1000 ppm	20℃	0.423	0.317	0.340	0.353	0.358
	Ambient	0.438	0.334	0.346	0.364	0.370
Ethephon 1500 ppm	20℃	0.424	0.324	0.330	0.353	0.358
	Ambient	0.433	0.329	0.338	0.355	0.364
Ethylene gas 100 ppm	20℃	0.405	0.318	0.310	0.333	0.341
	Ambient	0.443	0.338	0.341	0.351	0.368
Control	20℃	0.480	0.355	0.340	0.378	0.388
	Ambient	0.528	0.378	0.370	0.378	0.413
Mean		0.447	0.337	0.343	0.358	

C D (0.05) Treatments = 0.003, storage days = 0.005, treatment × storage days = 0.010.

Table 7. Effect of ethephon and ethylene gas on reducing sugars (%) during ripening in pear.

Treatments	Storage days					
	Temperature	4	8	12	16	Mean
Ethephon 500 ppm	20℃	5.29	6.03	5.26	4.95	5.38
	Ambient	5.26	5.83	5.22	4.91	5.31
Ethephon 1000 ppm	20℃	5.44	6.03	5.37	5.03	5.47
	Ambient	5.22	5.78	5.21	4.90	5.28
Ethephon 1500 ppm	20℃	5.68	6.00	5.36	5.05	5.52
	Ambient	5.14	5.85	5.21	4.95	5.29
Ethylene gas 100 ppm	20℃	5.55	6.13	5.59	5.22	5.62
	Ambient	5.39	5.89	5.42	5.11	5.45
Control	20℃	5.32	5.83	5.24	4.78	5.29
	Ambient	5.09	5.61	4.98	4.60	5.07
Mean		5.34	5.90	5.29	4.95	

C D (0.05)Treatments = 0.05, storage days = 0.07,treatment × storage days = 0.15.

sugars upon ripening could be due to hydrolysis of starch and organic compounds (Sinha et al., 1983; Lelievre et al., 1997). Also an increase in TSS was observed in fruits chilled at 0℃ and subsequently ripened at 20℃ in Baggugosha (Singh, 1999) and in Punjab Beauty (Dhillon et al., 2005[a]) pear fruits. The decrease in TSS level after 8 days of storage for ripening at ambient and at 20℃ temperatures might be due to the inter conversion of some of the sugars into volatile organic acids. Such findings have been reported in grapes by Peynaud and Ribbereau (1971) during cold storage studies.

The juice acid content decreased significantly under all the ethephon treatments with the prolongation of ripening period from 4 to 8 days and starts increasing thereafter (Table 7). In control fruits, the acid content decreased up to 12 days and slightly increased after 16 days of ripening

interval under both 20°C and ambient ripening temperatures. The acid content under all the treatments was significantly lower at 20°C when compared with ambient temperature. The lowest acidity level was, however, recorded under ethephon 1000 ppm at 20°C after 8 days, while highest (0.528%) under control fruits at ambient temperature after 4 days. The reduction in acid content was pronounced under ethephon treatments over control after 4 days, which narrowed down later on. In general, when the values were compared with those values obtained after 4 days, the acid content in pear juice decreased with the prolongation of ripening period. This decrease might be due to the utilization of available organic acids at a faster rate in the respiration during ripening. This process might have been triggered with the exogenous application of ethephon. The conversion of organic acids into soluble sugars and long chain polysaccharides may also leads to decrease in acids (Lelievre et al., 1997). Similar results were also reported by Mahajan et al. (2008) in guava fruits, who recorded a decrease in acid content during ripening and storage. The increase in acid content in juice after 8 days in ethephon ripening treatments and after 12 days in control under both the environments might be associated with the increase in weight loss. In over all, the fruits treated with ethephon 1000 ppm or fogging with ethephon at 100 ppm and ripened at 20°C temperature for 8 days exhibited best quality.

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