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Pooja Y
Department of Fruit Science, Ph.D Student, Sri Konda Laxman Telangana State Horticultural University, College of Horticulture - Rajendranagar, Hyderabad, Telangana, India

Kiran Kumar A
Department of Fruit Science, Associate Dean & Comptroller of College of Horticulture – Rajendranagar, Hyderabad, Telangana, India

Dr. Raja Goud CH
Department of Entomology, Associate professor, COH-Rajendranagar, Hyderabad, Telangana, India.

Dr. Bhagwan A
Director of research, Registrar of Sri konda Laxman Telangana state horticultural university, Telangana, India.

Corresponding Author:
Pooja Y
Department of Fruit Science, Ph.D Student, Sri Konda Laxman Telangana State Horticultural University, College of Horticulture - Rajendranagar, Hyderabad, Telangana, India

Effect of post-harvest ethylene treatment on respiration rate of acid lime Cv. Balaji

Pooja Y, Kiran Kumar A, Dr. Raja Goud CH and Dr. Bhagwan A

Abstract
Acid lime Cv. Balaji (*Citrus aurantifolia* S.) is a subtropical in its climacteric requirements and originated from sub- tropical South- east Asia, which belongs to family Rutaceae. The present research was conducted at post-harvest laboratory, college of horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, during the year 2018-2019. Experiment was designated with two factorial completely randomized design with two factors *viz.,* (A) Ethylene concentrations, (B) Number of pulsings were taken for test and executed with the objective: effect of post-harvest ethylene on respiration rate of Acid lime Cv. Balaji. The results concluded that very high doses of ethylene (20ppm) increase the rate of respiration in Acid lime Cv. Balaji. Optimum dose of ethylene (15ppm) induces the uniform degreening and better respiration than control.

Keywords: Acid lime, Cv. Balaji, degreening, rate of respiration, ethylene

Introduction
Acid lime Cv. Balaji (*Citrus aurantifolia* S.) is a subtropical in its climacteric requirements and originated from sub- tropical South- east Asia, which belongs to family Rutaceae. It is an important fruit crop in citrus group. India is the largest producer of Acid lime in the world followed by USA, Spain and Israel. Consumers prefer bright colored citrus fruit and are willing to pay a premium for them. Green colored fruits are considered unripe and fetch lower prices. Hence the color of the rind is important for the aesthetic value and as such it is the most important factor determining marketability. Ethylene causes loss of chlorophyll and produces the minor changes in carotenoids (Grierson and Newhall 1960) [1]. Despite citrus being a non-climacteric fruit, some aspects of its ripening could be still sensitive to external exposure to ethylene. (Sdiri *et al,* 2012) [2]. Treatment with ethylene induces an increase in respiration similar to respiratory climacteric in banana. The rise in CO_2 production is immediate and related to the time duration of ethylene treatment (Dominguez and Vendrell 1994) [3].

Materials and Methods
The present research was conducted at post-harvest laboratory, college of horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, during the year 2018-2019. Experiment was designated with two factorial completely randomized design and executed with the objective: effect of post-harvest ethylene on respiration rate of Acid lime Cv. Balaji. In the experiment, two factors *viz.,* (A) Ethylene concentrations, (B) Number of pulsings were taken for test. Acid lime Cv. Balaji fruits were allowed to degreen in Low Cost Ripening Chamber with ethylene treatment with different levels of ethylene concentrations *i.e.* (A_1) 5ppm (A_2) 10ppm (A_3) 15ppm and (A_4) 20ppm were given four levels of number of pulsings *viz.*, (B_1) 6 pulsings in 24 hrs @ 4 hrs. interval (B_2) 4 pulsings in 24 hrs @ 6 hrs. interval (B_3) 2 pulsings in 24 hrs @ 12 hrs. interval and (B_4) 1 pulsing in 24 hrs @ 24 hrs. interval. The combination of 2 factors gives 16 treatments *viz.*, T_1- 5ppm @ 6pulsings in 24 hrs; T_2- 5ppm @ 4pulsings in 24 hrs; T_3- 5ppm @ 2pulsings in 24 hrs; T_4- 5ppm @ 1pulsing in 24 hrs; T_5- 10ppm @ 6pulsings in 24 hrs; T_6- 10ppm @ 4pulsings in 24 hrs; T_7- 10ppm @ 2pulsings in 24 hrs; T_8- 10ppm @ 1pulsing in 24 hrs; T_9- 15ppm @ 6pulsings in 24 hrs; T_{10}- 15ppm @ 4pulsings in 24 hrs; T_{11}- 15ppm @ 2pulsings in 24 hrs; T_{12}- 15ppm @ 1pulsing in 24 hrs; T_{13}- 20ppm @ 6pulsings in 24 hrs; T_{14}- 20ppm @ 4pulsings in 24 hrs; T_{15}- 20ppm @ 2pulsings in 24 hrs; T_{16}- 20ppm @ 1pulsing in 24 hrs.

Experimental materials

Acid lime Cv. Balaji fruits: Acid lime Cv. Balaji (*Citrus aurantifolia* S.) Cv. Balaji fruits were collected from citrus orchard. Matured fruits are harvested manually and immediately transported to degreeening chamber and subjected to the ethylene treatments.

Ethylene Cylinder: Ethylene release canisters named Ripylene, manufactured by chemtron science laboratories, Mumbai were used in the research. 15 grams of ethylene gas was filled in a cylinder with adjustable gauge. This was approved by NHB, FSSAI and FDA as a gas for ripening.

Low-cost Ripening Chamber: The low-cost ripening chamber consists of 40mm PUF (Polyurethane Foam) insulated panels with PPGI Sheets (Pre painted Galvanised Iron) lamination on either side, with flashings and swing Door - 300 x 600 mm with the capacity of 5 crates (100kg).

Methodology

O_2 and CO_2 Analyser: Head space gas analysis for O_2 & CO_2 was carried out using O_2/CO_2 analyser (PBI Dansensor, checkmate 9900, prg.Ver.1.7. Denmark). Head space gas was recorded at four days interval by placing silicon Teflon septa on the packaging films. The needle of the O_2/CO_2 analyser was passed through the septa to record O_2 and CO_2 (%) for the 4 kg fruits in the poly bags and statistically analysed. The instrument was calibrated for O_2 and CO_2 gases prior to the analysis.

Result and Discussion

O_2 Analyser: The data pertaining to O_2 Analyser of Acid lime Cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in tables (1 to 5) and illustrations (1 and 2). This trend of decreasing % of O_2 with increasing degreening is similar to that reported by Ladaniya (2001) [4] in Sweet Orange. Stimulation of respiration by ethylene was dose-dependent. Fruit colour development and softening were accelerated by ethylene (Tian, 2000; Giuliana, 2012) [5, 6]. Li *et al.* (2018) [7] indicated that, respiration rate of mandarins was significantly higher ($P < 0.001$) as the storage temperature was increased but was significantly lower ($P < 0.001$) as the ethylene concentration decreased. Bhande *et al*, (2008) [8] examined the respiration rate of banana and observed the diminishing concentrations of O_2 and proportional increase in CO_2 concentrations in the respirometer as the storage time progresses.

Effect of ethylene concentrations on % of O_2 in Acid lime Cv. Balaji: On 1st day (Table 1.) among the ethylene concentrations significantly highest % of O_2 was recorded with ethylene @ 5 ppm (20.83%) followed by ethylene @10 ppm (20.38%) while, lowest with 20 ppm (19.24%). On 4th day (Table 2.) among the ethylene concentrations significantly highest % of O_2 was recorded with ethylene @ 5 ppm (20.05%) followed by ethylene @10 ppm (19.23%) while, lowest with 20 ppm (18.27%). On 8th day (Table 3.) among the ethylene concentrations significantly highest % of O_2 was recorded with ethylene @ 5 ppm (20.62%) followed by ethylene @10 ppm (19.88%) while, lowest with 20 ppm (18.99%).

Effect of number of pulsings on % of O_2 in Acid lime Cv. Balaji: On 1st day (Table 1.) among the number of pulsings significantly highest % of O_2 was recorded with 1 pulsing in 24 hrs @ 24 hrs interval (20.33%), followed by 2 pulsings in 24 hrs @ 12 hrs interval (20.16%) while, lowest with 6 pulsings in 24 hrs @ 4 hrs interval (19.88%). On 4th day (Table 2.) among the number of pulsings significantly highest % of O_2 was recorded with 1 pulsing in 24 hrs @ 24 hrs interval (19.24%), followed by 2 pulsings in 24 hrs @ 12 hrs interval (19.13) while, lowest with 6 pulsings in 24 hrs @ 4 hrs interval (18.83%). On 8th day (Table 3.) among the number of pulsings significantly highest % of O_2 was recorded with 1 pulsing in 24 hrs @ 24 hrs interval (20.00%), followed by 2 pulsings in 24 hrs @ 12 hrs interval (19.87%) while, lowest with 6 pulsings in 24 hrs @ 4 hrs interval (19.53%).

Interaction effect of ethylene concentrations and number of pulsings on % of O_2 in Acid lime Cv. Balaji: Among the storage days 1st, 4th and 8th day interaction between ethylene concentration and number of pulsings were significantly differed. On 1st day highest % of O_2 was recorded in 5ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (21.12%) followed by 5ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval (20.83%) while, lowest in 20ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (18.94%). On 4th day highest % of O_2 was recorded in 5ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (20.22%) while, lowest in 20ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (18.14%). On 8th day highest % of O_2 was recorded in 5ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (21.02%) followed by 5ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval (20.66%) while, lowest in 20ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (18.67%).

The mean values recorded in the % of O_2 of Acid lime Cv. Balaji fruits at 12th day and 16th day during storage tabulated at Table 4 and 5 respectively. The results indicated by Su, *et al.* (2017) [9] in peach reported that, Fruit ethylene production (C_2H_4) was significantly positively correlated with respiration rate and production of CO_2. It can be due to utilisation of O_2 and production of CO_2. So, during respiration % of O_2 was decreased, simultaneously % of CO_2 was increased (Jacob *et al*, 1953) [10].

Table 1: O_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 1st day

Ethylene concentrations	Number of pulsings per 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 5ppm	20.63	20.75	20.83	21.12	20.83^{A}
Ethylene @ 10ppm	20.23	20.33	20.45	20.54	20.38^{B}
Ethylene @ 15ppm	19.73	19.83	20.03	20.13	19.93^{C}
Ethylene @ 20ppm	18.94	19.14	19.33	19.53	19.24^{D}
Mean	19.88^{d}	20.01^{c}	20.16^{b}	20.33^{a}	
Factors		CD (5%)	SEm ±		

Ethylene concentrations (A)	0.04	0.01
Number of pulsings (B)	0.04	0.01
Factor A × B	0.07	0.03

Table 2: O_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 4th day

Ethylene concentrations	Number of pulsings per 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 5ppm	20.63	20.75	20.83	21.12	20.83^{A}
Ethylene @ 10ppm	20.23	20.33	20.45	20.54	20.38^{B}
Ethylene @ 15ppm	19.73	19.83	20.03	20.13	19.93^{C}
Ethylene @ 20ppm	18.94	19.14	19.33	19.53	19.24^{D}
Mean	19.88^{d}	20.01^{c}	20.16^{b}	20.33^{a}	

Factors	CD (5%)	SEm ±
Ethylene concentrations (A)	0.04	0.01
Number of pulsings (B)	0.04	0.01
Factor A × B	0.07	0.03

Table 3: O_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 8th day

Ethylene concentrations	Number of pulsings per 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 5ppm	20.34	20.46	20.66	21.02	20.62^{A}
Ethylene @ 10ppm	19.80	19.84	19.93	19.96	19.88^{B}
Ethylene @ 15ppm	19.34	19.53	19.65	19.72	19.56^{C}
Ethylene @ 20ppm	18.67	18.73	19.27	19.32	18.99^{D}
Mean	19.53^{d}	19.64^{c}	19.87^{b}	20.00^{a}	

Factors	CD (5%)	SEm ±
Ethylene concentrations (A)	0.07	0.03
Number of pulsings (B)	0.07	0.03
Factor A × B	0.14	0.05

Table 4: O_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 12th day

Ethylene concentrations	Number of pulsings per 24 hrs.			
	6 pulsings	4 pulsings	2 pulsings	1 pulsing
Ethylene @ 5ppm	-	-	-	-
Ethylene @ 10ppm	-	-	-	-
Ethylene @ 15ppm	-	19.72	19.94	-
Ethylene @ 20ppm	-	-	-	-

Table 5: O_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 16th day

Ethylene concentrations	Number of pulsings per 24 hrs.			
	6 pulsings	4 pulsings	2 pulsings	1 pulsing
Ethylene @ 5ppm	-	-	-	-
Ethylene @ 10ppm	21.14	20.27	-	-
Ethylene @ 15ppm	19.45	19.58	19.71	19.84
Ethylene @ 20ppm	-	-	19.31	19.44

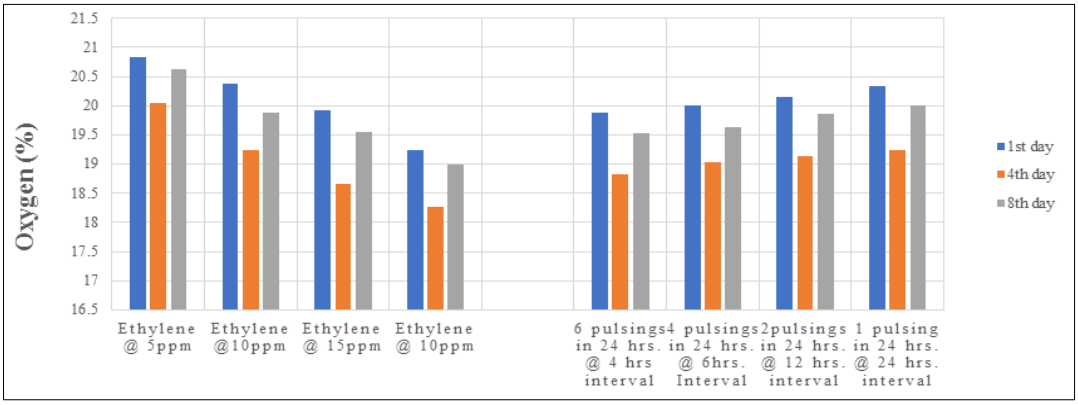

Fig 1: O_2 (%) of Acid lime Cv. Balaji as influenced by different ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature.

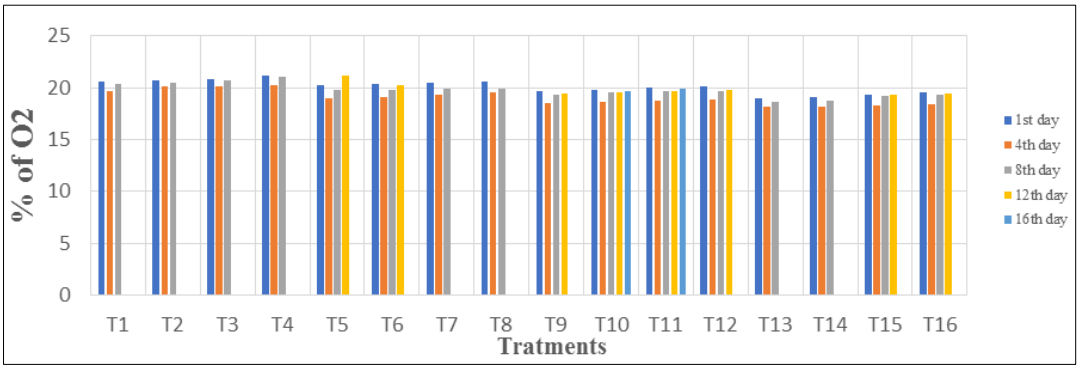

Fig 2: O_2 (%) of Acid lime Cv. Balaji as influenced by interaction between ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 1st, 4th, 8th, 12th and 16th day

CO_2 (%): The data pertaining to CO_2 Analyser of Acid lime Cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in tables (6 to 10) and illustrations (3 and 4). It is evident from this data that the rise in ethylene evolution started about the same time as the rise in CO_2 production. If fruit not exposed to ethylene, respiration rate did not increase and instead gradually declined. The degreening process increases the respiratory rate of citrus fruit. Respiration of fruit increased more than two-fold from 35.4mg CO_2/Kg/h to 80.1mg CO_2/Kg/h after 2 days of degreening (Ladaniya, 2001) [4]. Respiration rate increased from initial 1st day to 4th day in ethylene-exposed fruits and slowly declined after storage at ambient temperature (Ladania and Singh, 2001) [11]. Tian *et al*,. (2000) [5] reported that stimulation of respiration by ethylene in strawberry was dose-dependent.

Effect of ethylene concentrations on % of CO_2 in Acid lime Cv. Balaji: On 1st day (Table 6.) among the ethylene concentrations significantly highest % of CO_2 was recorded with ethylene @ 20 ppm (2.95%) followed by ethylene @15 ppm (1.95%) while, lowest with 5 ppm (1.56%). On 4th day (Table 7.) among the ethylene concentrations significantly highest % of CO_2 was recorded with ethylene @ 20 ppm (3.29%) followed by ethylene @ 15ppm (3.09%) while, lowest with 5 ppm (2.52%). On 8th day (Table 8.) among the ethylene concentrations significantly highest % of CO_2 was recorded with ethylene @ 20ppm (2.99%) followed by ethylene @15ppm (2.11%) while, lowest with 5ppm (1.61%).

Effect of number of pulsings on % of CO_2 in Acid lime Cv. Balaji: On 1st day (Table 6.) among the number of pulsings significantly highest % of CO_2 was recorded with 6 pulsings in 24 hrs @ 4 hrs interval (2.20%), followed by 4 pulsings in 24 hrs @ 6 hrs interval (2.14%) while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval (1.77%). On 4th day (Table 7.) among the number of pulsings significantly highest % of CO_2 was recorded with 6 pulsings in 24 hrs @ 4 hrs interval (3.03%). 4 pulsings in 24 hrs @ 6 hrs interval (2.98%) was at par with 6 pulsings in 24 hrs @ 4 hrs interval (3.03%). while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval (2.87%). On 8th day (Table 8.) among the number of pulsings significantly highest % of CO_2 was recorded with 6 pulsings in 24 hrs @ 4 hrs interval (2.30%) followed by 2 pulsings in 24 hrs @ 12 hrs interval (2.15%). 4 pulsings in 24 hrs @ 6 hrs interval (2.24%) was at par with 6 pulsings in 24 hrs @ 4 hrs interval (2.30%) while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval (1.85%).

Interaction effect of ethylene concentrations and number of pulsings on % of CO_2 in Acid lime Cv. Balaji: Among the storage days 1st, 8th, 12th and 16th day interaction between ethylene concentration and number of pulsings were significantly differed but, 4th day results were non-significant. On 1st day highest % of CO_2 was recorded in 20ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (3.27%) followed by 20ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval (3.17%) while, lowest in 5ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (1.46%). On 8th day highest % of CO_2 was recorded in 20ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (3.28%) while, lowest in 5ppm ethylene with 1 pulsing in 24 hrs (1.52%). The mean values recorded in the % of CO_2 of Acid lime Cv. Balaji fruits at 12th day and 16th day during storage tabulated at Table 9 and 10 respectively. Similar results were acquired by Su, *et al*, (2017) [9] who reported in peach. As the ripening process increased CO_2 production was increased and then decreased.

Table 6: CO_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 1st day

Ethylene concentrations	Number of pulsings per 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 5ppm	1.67	1.57	1.52	1.46	1.56^{D}
Ethylene @ 10ppm	1.82	1.76	1.73	1.64	1.74^{C}
Ethylene @ 15ppm	2.06	1.97	1.92	1.86	1.95^{B}
Ethylene @ 20ppm	3.27	3.24	3.17	2.12	2.95^{A}
Mean	2.20^{a}	2.14^{b}	2.09^{c}	1.77^{d}	

Factors	CD (5%)	SEm ±
Ethylene concentrations (A)	0.04	0.01
Number of pulsings (B)	0.04	0.01
Factor A × B	0.08	0.03

Table 7: CO_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 4^{h} day

Ethylene concentrations	Number of pulsings per 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 5ppm	2.62	2.54	2.51	2.42	2.52^{D}
Ethylene @ 10ppm	2.95	2.92	2.86	2.82	2.89^{C}
Ethylene @ 15ppm	3.17	3.12	3.07	3.01	3.09^{B}
Ethylene @ 20ppm	3.37	3.33	3.24	3.21	3.29^{A}
Mean	3.03^{a}	2.98^{a}	2.92^{b}	2.87^{b}	

Factors	CD (5%)	SEm ±
Ethylene concentrations (A)	0.05	0.02
Number of pulsings (B)	0.05	0.02
Factor A × B	N. S	0.03

Table 8: CO_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 8th day

Ethylene concentrations	Number of pulsings per 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 5ppm	1.71	1.62	1.60	1.52	1.61^{D}
Ethylene @ 10ppm	1.96	1.87	1.76	1.67	1.81^{C}
Ethylene @ 15ppm	2.25	2.22	2.02	1.96	2.11^{B}
Ethylene @ 20ppm	3.28	3.26	3.22	2.23	2.99^{A}
Mean	2.30^{a}	2.24^{a}	2.15^{b}	1.85^{b}	

Factors	CD (5%)	SEm ±
Ethylene concentrations (A)	0.07	0.02
Number of pulsings (B)	0.07	0.02
Factor A × B	0.13	0.05

Table 9: CO_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 12^{h} day

Ethylene concentrations	Number of pulsings per 24 hrs.			
	6 pulsings	4 pulsings	2 pulsings	1 pulsing
Ethylene @ 5ppm	-	-	-	-
Ethylene @ 10ppm	-	-	-	-
Ethylene @ 15ppm	-	1.98	1.93	-
Ethylene @ 20ppm	-	-	-	-

Table 10: CO_2 Analyser of Acid lime Cv. Balaji Cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 16^{h} day

Ethylene concentrations	Number of pulsings per 24 hrs.			
	6 pulsings	4 pulsings	2 pulsings	1 pulsing
Ethylene @ 5ppm	-	-	-	-
Ethylene @ 10ppm	1.93	1.82	-	-
Ethylene @ 15ppm	2.10	1.98	1.94	1.88

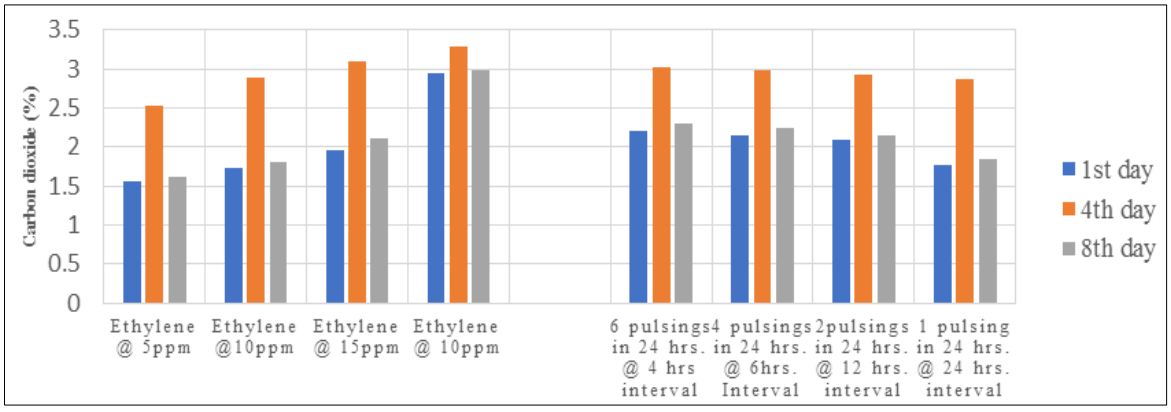

Fig 3: CO_2 (%) of Acid lime Cv. Balaji as influenced by different ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature.

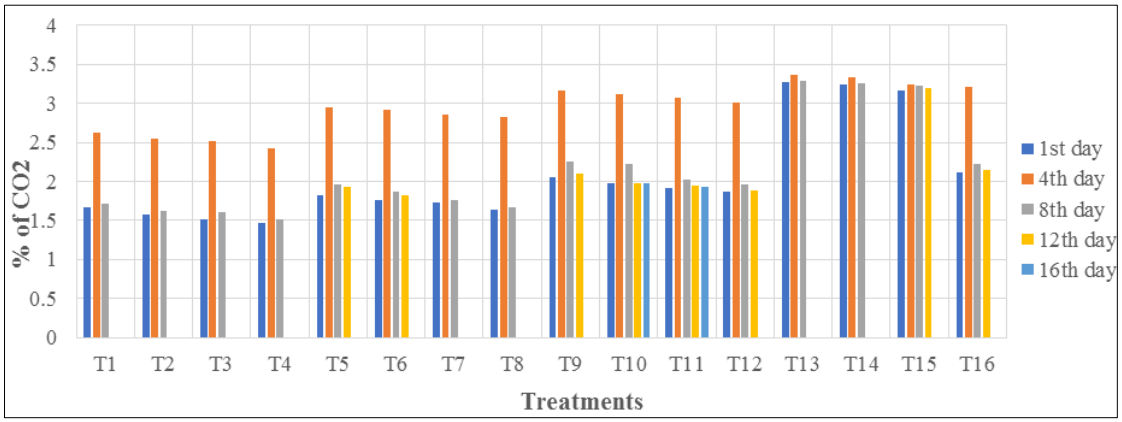

Fig 4: CO_2 (%) of Acid lime Cv. Balaji as influenced by interaction between ethylene concentrations and number of pulsings per 24 hrs. at ambient temperature on 1st, 4th, 8th, 12th and 16th day.

Conclusion: Fruit ethylene production (C_2 H_4) was significantly positively correlated with respiration rate and production of CO_2. It can be due to utilisation of O_2 and production of CO_2. So, during respiration, % of O_2 was decreased, simultaneously % of CO_2 was increased. The results concluded that very high doses of ethylene (20ppm) increase the rate of respiration and adverse effect on shelf life in Acid lime Cv. Balaji. Optimum dose of ethylene (15ppm) induces the uniform degreening and normal rate of respiration than control.

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