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CULTIVAR, HARVEST LOCATION AND COLD STORAGE INFLUENCE FRUIT SOFTENING AND ANTIOXIDATIVE ACTIVITIES OF PEACH FRUIT [*PRUNUS PERSICA* (L.) BATSCH.]

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Abstract

Fruit softening and quality management is very important to reduce postharvest losses in peach. Present study was conducted to observe the effect of cultivars and harvest locations on peach fruit softening and quality during ripening following cold storage. Fruits of two peach cultivars *Prunus persica* (L.) Batsch., harvested from two different locations were evaluated at ripening for their postharvest fruit softening and quality after 28 days of low temperature storage. Fruit harvested from Sillanwali exhibited significantly higher ethylene production, respiration rate, fruit weight loss, ascorbic acid contents, activities of fruit softening enzymes [*endo*-polygalacturonase (*endo*-PG), *exo*-polygalacturonase (*exo*-PG)] and significantly lower fruit firmness, ground colour, soluble solid contents (SSC), SSC:TA, total phenolic contents (TPC), antioxidant scavenging activity (ASA), activities of catalase (CAT), peroxidase (POD), superoxide dismutase (SOD), and pectin esterase (PE) enzymes as compared to fruit harvested from Soan Valley. Peach cv 'Early Grand' showed significantly higher ethylene production, respiration rate, ascorbic acid contents, activities of CAT, *endo*-PG and *exo*-PG enzymes, whereas lower fruit weight loss, fruit firmness, SSC, SSC:TA, TPC, ASA, activities of POD, SOD, PE and enzymes than 'Flordaking'. Harvest location and cultivar significantly influenced various physico-chemical attributes including activities of various fruit softening and antioxidative enzymes in peach fruit during ripening after low temperature storage.

Key words: Antioxidant; Cultivars; Fruit quality; Harvest location; Peach; Softening enzymes.

Introduction

During the last decade, there was a considerable increase in area and production of peaches and nectarines, which is estimated at about 1.5-fold and about 1.3-fold in the world, respectively. Similarly, about 3-fold and 2-fold increase in area and production of peach has also been observed in Pakistan, respectively (Anon., 2013). Peach being a versatile fruit is consumed both as fresh and processed forms. It is rich in vitamin C, vitamin A, and phenolic compounds that are good sources of antioxidants (Byrne, 2002).

Rapid postharvest fruit softening of peach limits its shelf and storage life (Brummell *et al.*, 2001; Brummell, 2006) with redeuced fruit quality (Lurie & Crisosto, 2005). Numerous factors have been reported to effect postharvest fruit quality including genotype (Kays, 1999) and geographic region of cultivation (Dragovic-Uzlac *et al.*, 2007), as different peach cultivars have been reported to show variation in susceptibility to chilling injury during the postharvest storage and ripening (Crisosto *et al.,* 1999). Moreover, fruit softening is associated with the solubilisation and degradation of cell wall contents particularly pectins and accompanied with their depolymerization during ripening. This phenomenon leads to changes in cell wall integrity and vary in fruit from species to species (Brummell, 2006). Different climatic conditions between two geographical sites significantly affect the size, shape and fruit quality as evidenced in banana (Cano *et al.,* 1997) and chayote (Kays, 1999) fruits. Appropriate light and temperature influences the postharvest quality and appearance in banana fruit (Kays, 1999; Hewett, 2006). Low temperature storage had been reported to use for fruit quality conservation and some fruit give a pleasant taste upon eating even stored for long time. However, once taken out of storage and ripened at ambient conditions the stone fruit softened rapidly and became inedible (Stanley *et al.,* 2010). Some apple cultivars, kiwifruit and grapes had been successfully stored for 12, 7 and 5 months, respectively (Gross *et al.,* 2004).

To the best of our knowledge, presently no information is available about effect of harvest locations and cultivars on the changes in fruit softening and antioxidative enzymes in peach during ripening following low temperature storage. We hypothesized that peach cultivars harvested from different growing locations could exhibit differences in their softening and quality at ripening followed by cold storage. Keeping in view the above factors two peach cultivars harvested from two locations were studied for changes in fruit softening and quality at full ripe stage after low temperature storage. The aim of the present study was to investigate the effect of cultivars and harvest locations on fruit quality and changes in fruit softening and antioxidative enzymes in peach during ripening following cold storage.

Materials and Methods

Experimental treatments: Four and five years old healthy peach (*Prunus persica* (L.) Batsch) trees of uniform size, grafted on peach seedling rootstock trained on a central open leader were selected for the study at Horticulture Research Station, Noshehra, Soan Valley Distt. Khushab and a private Farm from Sillanwali, District Sargodha, Punjab, Pakistan, respectively. The

trees were planted in North- South direction having 7 m between row to row and plant to plant distance in both the orchards. Uniform sized fruit, free from diseases and visual blemish symptoms of peach cultivars 'Early Grand' and 'Flordaking' were harvested at physiological mature stage (Table 1) from above mentioned locations. Both orchards were following the recommended standard cultural operations along with plant protection measures. The harvested fruit were transported to Postharvest Research and Training Centre, IHS, UAF, Pakistan in a forced air temperature controlled reefer van at 7 ± 2°C temperature and 85-90% RH. Uniform size fruit, apparently free from any defect were selected. These fruit were stored at low temperature (0 ± 1°C and 85-90% RH.) for 28 days followed by ripening at shelf under ambient conditions at 25±1°C and 60-65% RH. Data regarding different fruit quality parameters (respiration rate, ethylene production, fruit weight loss, firmness, colour, SSC, TA, TPC, ASA) and activities of various enzymes (fruit softening and antioxidative) were recorded at fully fruit ripening stage (eating soft). Ten fruit were used as an experimental unit. The experiment was conducted using CRD under factorial arrangement replicated three times.

Determination of physiological fruit quality: Two peach fruit per experimental unit were put in an air tight plastic jar of known volume (2200 mL) for determination of ethylene production and respiration rate (CO_2). A hand held ethylene analyzer (Model-56, ICA Storage Limited, UK) was used to determine ethylene productions while CO_2 gas analyzer (Model MI-70, Vaisala, Finland), was used to determine respiration rate. Ethylene productions and respiration rate were expressed as μL C_2H_4 kg^{-1} h^{-1} and mL CO_2 kg^{-1} h^{-1} of fruit weight, respectively (Ullah *et al.,* 2013).

Determination of physical fruit quality: Fruit weight loss was calculated as outlined by Ullah *et al.* (2013) and was expressed as percentage of fruit weight. Firmness of peach fruit was measured with a penetrometer (Model DFM50, Ametek Inc., USA) fitted with 8 mm tip. It was expressed in Newton (N). Ground colour of peach was determined subjectively by using a scale based on visual observations from 1 (25% yellow and 75% green) to 4 (100 % yellow and 0% green) as described earlier by Hussain (2010).

Determination of biochemical fruit quality: SSC of peach fruit juice was recorded with a handheld digital refractometer (Model RX 5000 Atago, Japan) and was expressed as Brix. The TA of plum juice was determined by titration with 0.1N NaOH to light pink end point, using phenolphthalein as an indicator as described by Khan *et al.* (2012), and expressed as % malic acid. The level of ascorbic acid was determined as reported earlier by Ullah *et al.* (2012) and was expressed as mg 100 g^{-1}. Protein contents of the peach fruit were determined by the method outlined by Bradford (1976) and were expressed as mg g^{-1} of fruit weight.

Determination of total phenolic contents and antioxidants scavenging activity: Total phenolic contents (TPC) from peach fruit pulp were determined by the method of Ainsworth and Gillespie (2007) using Folin–Ciocalteu (FC) reagent. TPC was express as mg GAE 100 g^{-1} (gallic acid equivalent) by using gallic acid as standard. Antioxidant scavenging activity (ASA) was measured by using method reported by Mimica-Dukic *et al.* (2003) and ASA was determined as percentage inhibition as described earlier by Ullah *et al.* (2012).

Determination of activities of fruit softening and antioxidative enzymes: Activities of fruit softening enzymes including pectin esterase (PE: EC 3.1.1.11), *endo*-1,4-*β*-D-Glucanase (EGase: EC 3.1.1.4), *endo*-polygalacturonase (*endo*-PG: EC 3.2.1.67) and *exo*-polygalacturonase (*exo*-PG: EC 3.2.1.15) from peach fruit pulp were determined by using the method reported by Khan & Singh (2007). The activities of EGase and *endo*-PG enzymes were expressed as Δ viscosity mg $protein^{-1}$ h^{-1}, while of PE and *exo*-PG in m*M* NaOH mg $protein^{-1}$ h^{-1} and μg galacturonic acid mg $protein^{-1}$ h^{-1}, respectively.

The activities of CAT (EC 1.11.1.6) and POD (EC 1.11.1.7) enzymes were determined by using method described by Liu *et al*. (2009) with some modifications. It was expressed as U mg $protein^{-1}$, where one unit was defined as "an absorbance change in 0.01 unit min^{-1}". The activity of SOD (EC 1.15.1.1) was determined by using the method described by Ullah *et al.* (2012). One unit of SOD activity was defined as 'the quantity of enzyme used to inhibit 50% photoreduction of NBT'.

Statistical analysis: The experimental data were analysed with ANOVA using Statistix 9 for windows software. LSD test ($p \leq 0.05$) was employed to test the significance of experimental means (Steel *et al.,* 1997). Pearson's correlations were also performed to estimate relationship between fruit firmness and fruit softening enzymes using Statistix 9 for windows software.

Table 1. Maturity indices for peach cultivars from two locations at commercial harvest.

Location	Geography	Cultivar	Firmness (N)	SSC (Brix)
Sillanwali	72°12′ 27.02″ E	'Early Grand'	57 ± 2.1	7.5 ± 0.2
	32°1′12.62″ N	'Flordaking'	70 ± 1.8	6.5 ± 0.5
Soan Valley	72°40′16″ E	'Early Grand'	65 ± 0.5	8.5 ± 0.4
	32°5′1″ N	'Flordaking'	73 ± 1.1	7.0 ± 0.5

± represents SD, n = 30 (10 fruit × 3 replications)

Results

Respiration rate and ethylene production: Respiration rate and ethylene production decreased as the ripening period progressed in all the storage periods (Figs. 1 & 2). Fruit exhibited their ethylene production and respiratory peaks on day-3 of fruit ripening in both the harvest location and cultivars. However a variation in ethylene peak was observed in both the cultivars and location during ripening after 14 days of storage. However, a significant increased ethylene production and respiration rates in those peach fruit were observed which were harvested from Sillanwali as compared to Soan Valley (Table 2). Peach cultivar 'Early Grand' showed more ethylene production and respiration rate as compared to 'Flordaking' (Table 3).

Fruit weight loss, ground colour and fruit firmness: Fruit weight loss showed a significant decreasing trend with increase in storage period in fully ripe peaches, irrespective of cultivar and harvest location. Both cultivars showed significant variations in fruit ground colour development. However, fruit harvested from Sillanwali developed less colour, as compared to Soan Valley at fruit ripening stage. Fruit firmness showed a significant increasing trend as fruit storage period progressed with most firmer fruit after 28 days of storage in both locations of harvest and cultivars (Fig. 3). However, regarding effect of harvest location, fruit harvested from Sillanwali showed about 1.1-fold more fruit weight loss while about 2.3-fold and 1.02-fold less ground colour development and fruit firmness, respectively compared with Soan Valley (Table 2). Peach cv. 'Early Grand' showed about 1.2-fold more ground colour development while 1.22-fold and 1.17-fold less fruit weight and fruit firmness respectively than 'Flordaking' at ripe stage following cold storage (Table 3).

SSC, TA and SSC:TA ratio: Harvest locations, cultivars and storage period did not show any significant effect on SSC, TA and SSC:TA of fully ripe peach fruit after low temperature storage (Fig. 4). However a significant higher SSC and SSC: TA ratio was observed in peach fruit harvested from Soan Valley (Table 2). Peach cultivar 'Flordaking' showed about 1.03-fold and 1.05-fold more SSC and SSC:TA than 'Early Grand' at ripening stage following low temperature storage (Table 3).

PE, EGase, *endo*-PG and *exo*-PG enzymes: A significant decreasing trend was observed for PE, EGase, *endo*-PG and *exo*-PG enzymes activities in ripe peach fruit followed by low temperature storage (Fig. 5). Activities of all softening enzymes under study showed a significant difference as affected by harvest location except activity of EGase (Table 2). Fruit harvested from Sillanwali exhibited about 1.57-fold less activity of PE, while 1.06-fold and 1.11-fold more activities of PE, *endo*-PG and *exo*-PG enzymes, respectively than fruit harvested from Soan Valley (Table 2). Peach cv 'Early Grand' showed about 1.13-fold and 1.35-fold significantly higher activities of *endo*-PG and *exo*-PG while about 1.3-fold and 1.12-fold significantly lower activities of PE and EGase enzymes, respectively than 'Flordaking' (Table 3).

Table 2. Mean changes in fruit softening and quality of peach fruit as influenced by harvest locations.

Parameters	Harvest locations		LSD
	Sillanwali	Soan Valley	($p \leq 0.05$)
Weight loss (%)	16.89a	15.36b	0.3470
Ground colour (score)	1.16b	2.63a	0.0663
Firmness (N)	10.71b	10.92a	0.0715
SSC (Brix°)	12.30b	13.26a	0.1808
TA (%)	0.60a	0.58a	NS
SSC:TA	21.08b	22.81a	0.7136
Ascorbic acid (mg 100 g^{-1})	20.21a	15.73b	0.3298
TPC (mg GAE 100 g^{-1})	90.76b	205.12a	0.5299
ASA (%)	56.94b	74.58a	0.3568
CAT (U mg $protein^{-1}$)	57.16b	64.96a	0.4804
POD (U mg $protein^{-1}$)	50.72a	50.81a	NS
SOD (U mg $protein^{-1}$)	29.71b	40.70a	0.6763
PE (m*M* NaOH mg $protein^{-1}$ h^{-1})	0.54b	0.85a	0.0227
EGase [Δ viscosity (mg $protein^{-1}$ h^{-1})]	2.94a	2.91a	NS
Endo-PG [Δ viscosity (mg $protein^{-1}$ h^{-1})]	22.73a	21.39b	0.7955
Exo-PG (µg gal acid mg $protein^{-1}$ h^{-1})	219.80a	199.20b	1.9456
Ethylene (µL C_2H_4 kg^{-1} h^{-1})	23.99 ± 1.39	20.23 ± 0.92	-----
Respiration (mL CO_2 kg^{-1} h^{-1})	1.71 ± 0.07	1.32 ± 0.03	------

Means followed by different letters for a given parameter for harvest location significantly different at p≤0.05 (LSD test). NS = non-significant (p≤0.05). SSC = soluble solid concentration, TA = titratable acidity, AA = ascorbic acid, TPC = total phenolics contents, ASA = antioxidant scavenging activity, CAT = catalase, POD = peroxidase, SOD = superoxide dismutase, PE = pectin esterase, Egase = *endo*-1,4-*β*-D-Glucanase, *Endo*-PG = *endo* polygalacturonase, *exo*-PG = E*xo* polygalacturonase

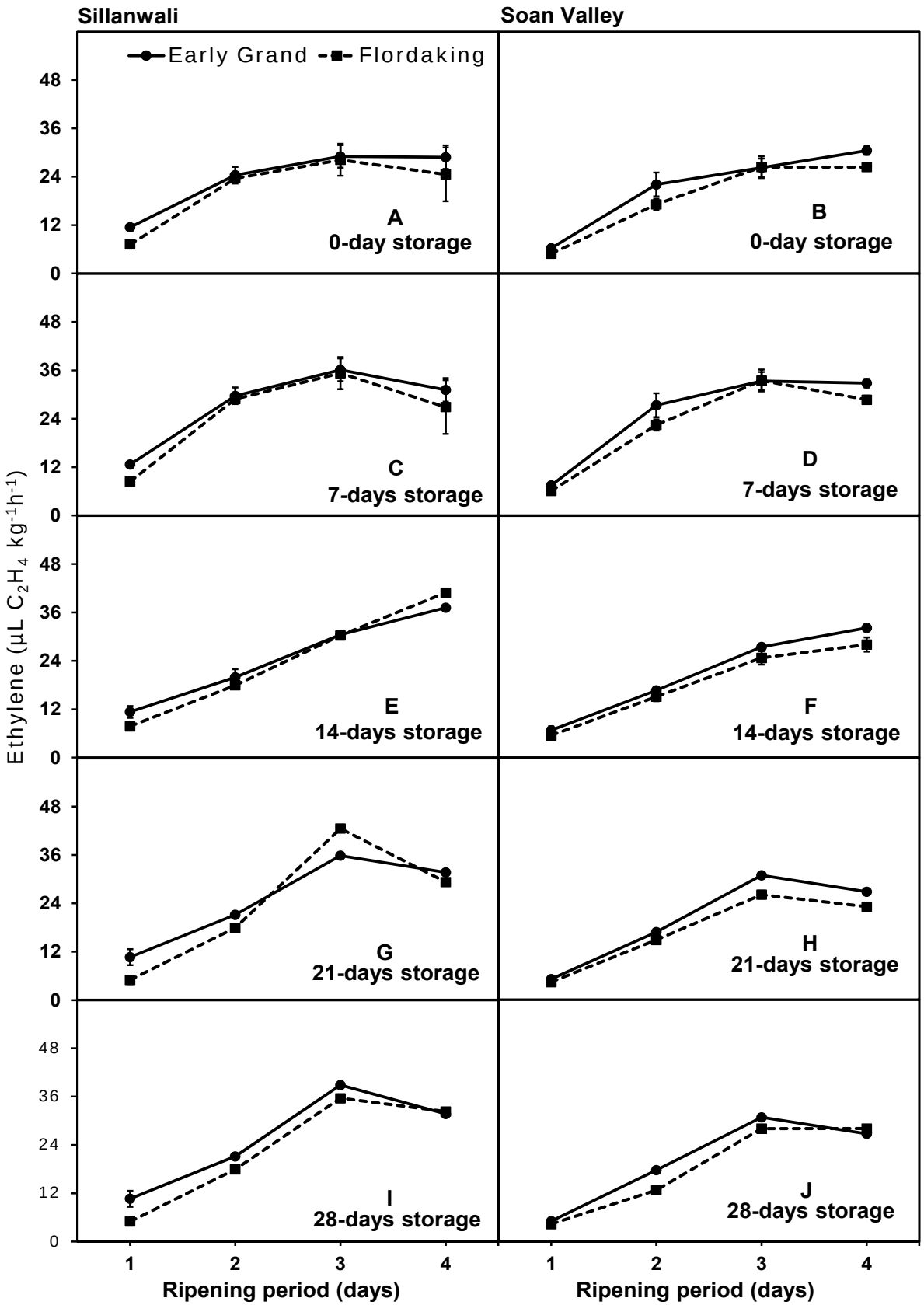

Fig. 1. Effect of cultivars and harvest locations on ethylene production of peach fruit after 0-day (A, B), 7-days (C, D), 14-days (E, F), 21-days (G, H) and 28-days (I, J) of low temperature storage. Vertical bars represent ± SE of means.

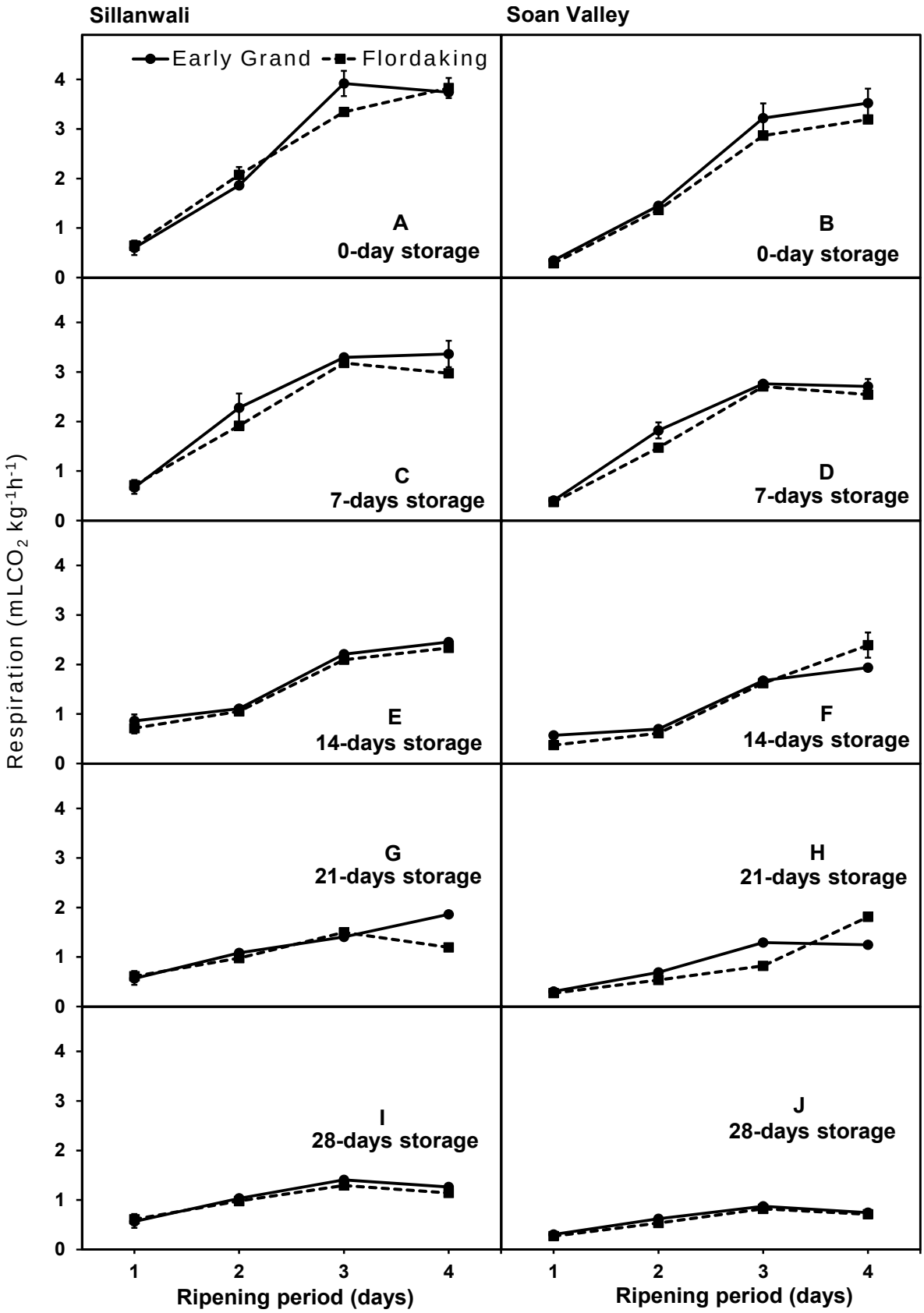

Fig. 2. Effect of cultivars and harvest locations on respiration rate of peach fruit after 0-day (A, B), 7-days (C, D), 14-days (E, F), 21-days (G, H) and 28-days (I, J) of low temperature storage. Vertical bars represent ± SE of means.

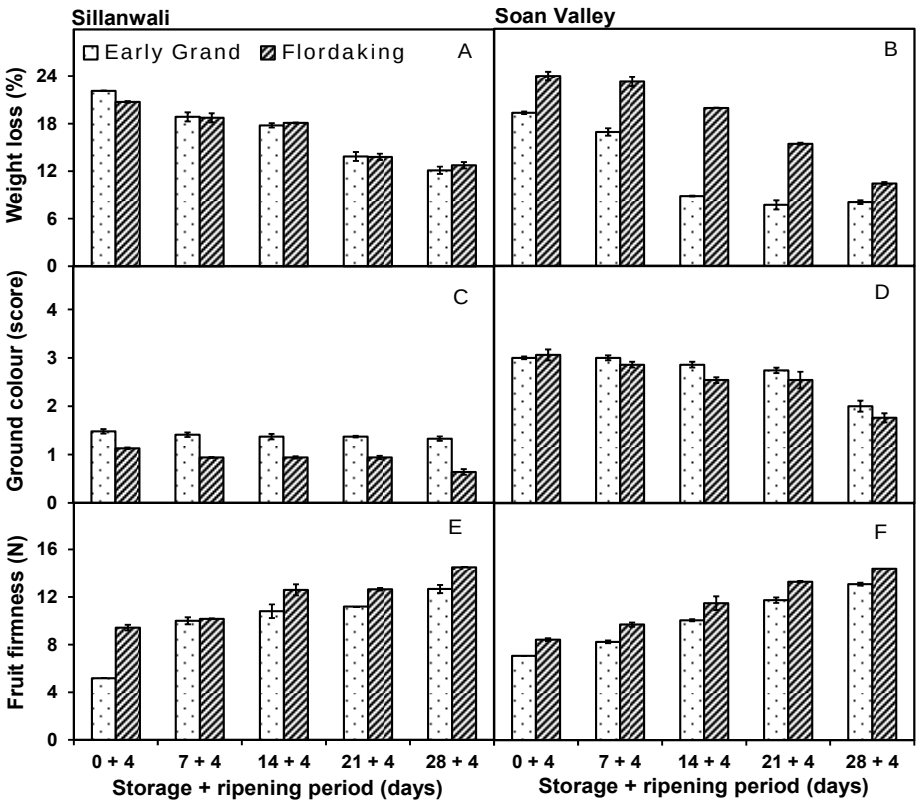

Fig. 3. Effect of cultivar and harvest location on fruit weight loss (A, B), ground colour (C, D) and firmness (E, F) of peach fruit at ripening following cold storage. Vertical bars represent ± SE of means.

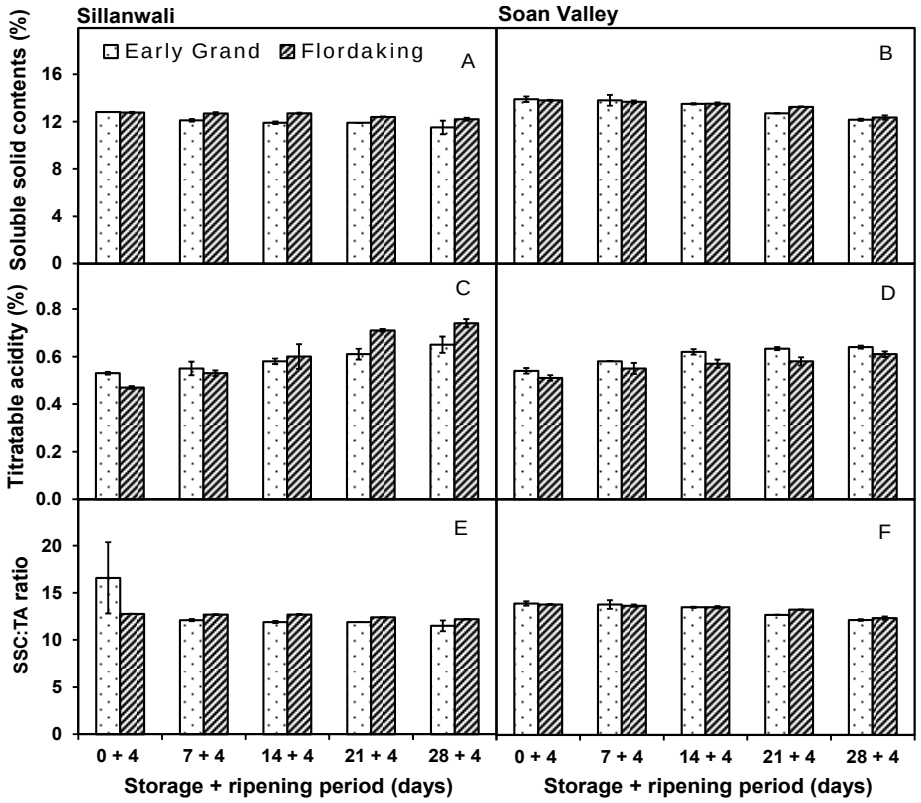

Fig. 4. Effect of cultivar and harvest location on soluble solid contents (A, B), titratable acidity (C, D), and SSC: TA ratio (E, F) of peach fruit at ripening following cold storage. Vertical bars represent ± SE of means.

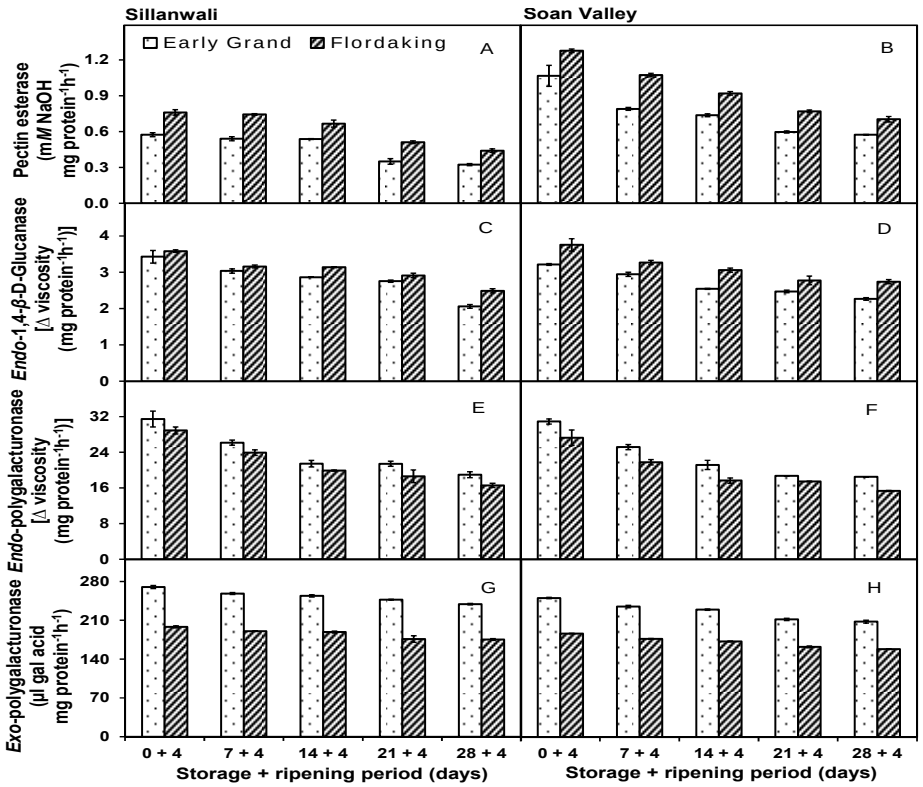

Fig. 5. Effect of cultivar, harvest location and shelf ripening on activities of pectin esterase (A, B), *endo*-1,4-*β*- Glaucanase (C, D), *endo*-polygalacturonase (E, F) and *exo*-polygalacturonase (G, H) enzymes in pulp of peach fruit at ripening following cold storage. Vertical bars represent ± SE of means.

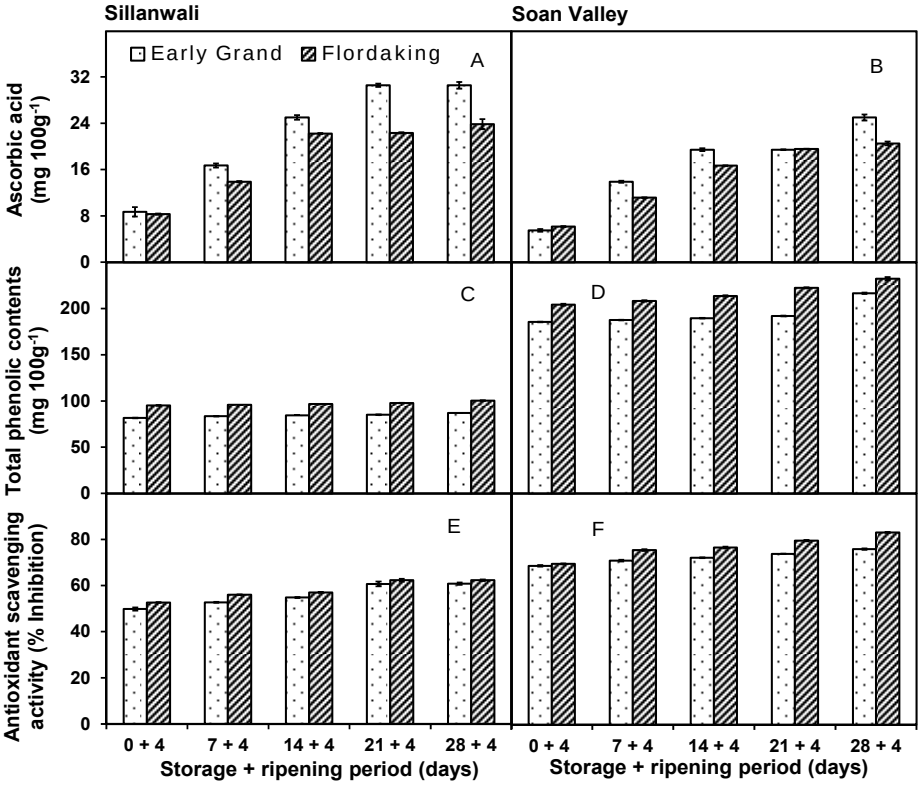

Fig. 6. Effect of cultivar and harvest location on ascorbic acid (A, B), total phenolic contents (C, D) and antioxidant scavenging activity (E, F) of peach fruit at ripening following cold storage. Vertical bars represent ± SE of means.

Table 3. Mean changes in fruit softening and quality of peach fruit influenced by cultivars

Parameters	Peach cultivars		LSD ($p \leq 0.05$)
	'Early Grand'	'Flordaking'	
Weight loss (%)	14.54b	17.70a	0.3470
Ground colour (score)	2.06a	1.73 b	0.0663
Fruit firmness (N)	11.67a	10.00a	0.0715
SSC (Brix°)	12.62b	12.93a	0.1808
TA (%)	0.62a	0.61a	NS
SSC:TA	21.39b	22.50a	0.7136
Ascorbic acid (mg 100 g^{-1})	19.48a	16.46b	0.3298
TPC (mg GAE 100 g^{-1})	139.25b	156.62a	0.5299
ASA (%)	64.05b	67.47a	0.3568
CAT (U mg $protein^{-1}$)	62.36a	59.76b	0.4804
POD (U mg $protein^{-1}$)	45.14b	56.40a	0.4507
SOD (U mg $protein^{-1}$)	32.39b	38.02a	0.6763
PE (m*M* NaOH mg $protein^{-1}$ h^{-1})	0.61b	0.79b	0.0227
EGase [Δ viscosity (mg $protein^{-1}$ h^{-1})]	2.76b	3.09 a	0.0657
Endo-PG [Δ viscosity (mg $protein^{-1}$ h^{-1})]	23.38a	20.73b	0.7955
Exo-PG (µg gal acid mg $protein^{-1}$ h^{-1})	240.36a	178.65b	1.9456
Ethylene production (µL $C_2H_4kg^{-1}$ h^{-1})	23.32 ± 1.26	21.15 ± 1.27	------
Respiration rate (mL CO_2 kg^{-1} h^{-1})	1.57 ± 0.07	1.47 ± 0.04	------

Means followed by different letters for a given parameter for harvest location significantly different at p≤0.05 (LSD test). NS = non-significant (p≤0.05). SSC = soluble solid concentration, TA = titratable acidity, AA = ascorbic acid, TPC = total phenolics contents, ASA = antioxidant scavenging activity, CAT = catalase, POD = peroxidase, SOD = superoxide dismutase, PE = pectin esterase, Egase = *endo*-1,4-*β*-D-Glucanase, *Endo*-PG = *Endo* polygalacturonase, *exo*-PG = *Exo* polygalacturonase

Ascorbic acid, total phenolic contents and antioxidant scavenging activity: Significant increasing trend was observed in TPC and ASA, however a decreasing trend was observed in ascorbic acid contents in fully ripe peach fruit followed by low temperature storage (Fig. 6). Regarding mean effect of harvest location, fruit harvested from Sillanwali showed about 1.3-fold more ascorbic acid, while 2.3-fold and 1.3-fold less TPC and ASA, respectively as compared to fruit harvested from Soan Valley (Table 2). Peach cv 'Early Grand' showed about 1.2-fold more ascorbic acid and about 1.13- and 1.05-fold less mean total phenolic contents and antioxidant scavenging activity, respectively as compared to 'Flordaking' (Table3).

CAT, POD and SOD enzymes: Significant increase in activities of POD and SOD enzymes were observed in both peach cultivars fruit harvested from both locations. However, non-significant changes were observed in activity of CAT at fruit ripening stage after low temperature storage (Fig. 7). Fruit harvested from Sillanwali showed about 1.14-fold and 1.37-fold significantly higher activities of CAT and SOD enzymes as compared to fruit harvested from Soan Valley (Table 2). A significant difference in CAT and SOD activities was observed in both peach cultivars (Table 3). About 1.25-fold and 1.17-fold higher while 1.05-fold lower activities of POD, SOD and CAT, respectively were observed in cv. 'Early Grand' as compared to 'Flordaking'.

Relationship of fruit softening enzymes with firmness and ethylene: Peach fruit firmness showed a highly significant negative (p≤0.01) correlations with activities of PE (r = -0.4286), EGase (r = -0.6307), *endo*-PG (r = -0.8947) and *exo*-PG (r = -0.5912) enzymes in fruit pulp at fruit ripening at shelf after low temperature storage (Fig. 8). The fruit softening enzyme PE showed highly significant (p≤0.01) negative (r = -0.4920) relationship with ethylene, while activities of *endo*-PG and *exo*-PG were positively correlated with ethylene production at ripening stage after low temperature storage.

Discussion

In the present study fruits of both cultivars harvested from both locations showed a reduced respiration rate and ethylene production with increase in the low temperature storage period duration. Following low temperature storage, peach fruit exhibited their climacteric peaks on day-3 of ripening except 14 days of storage for both locations (Figs. 1 & 2). Although both the cultivars and locations showed a difference in respiration rate and ethylene production during ripening, which could be attributed to different prevailing climatic conditions in both the harvest locations as they determine rate of photosynthesis and supply of carbohydrates to fruit which are indispensable for all biochemical reactions in fruit after harvest (Tromp, 2005) with autocatalytic rise in ethylene production. This increase in ethylene production and respiration rate in fruits with no storage or few days storage interval is ascribed to rapid conversion of sugars, organic acid to CO_2 during the at ripening. As respiratory metabolism of climacteric fruit have been found to involve dramatic rise in respiration rate including peach (Saltveit, 1999).

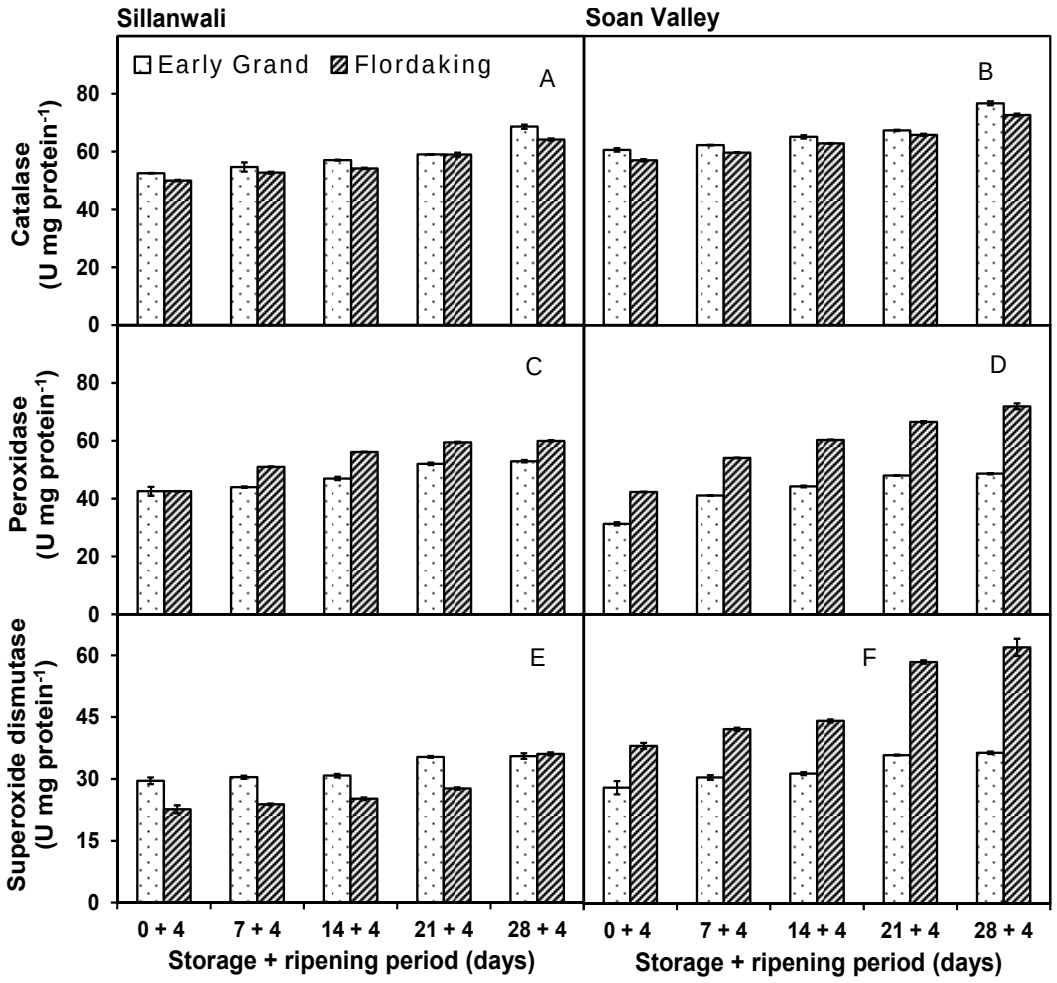

Fig. 7. Effect of cultivar and harvest location on the activities of catalase (A, B), peroxidase (C, D) and superoxide dismutase (E, F) SOD enzymes in pulp of peach fruit at ripening following cold storage. Vertical bars represent ± SE of means.

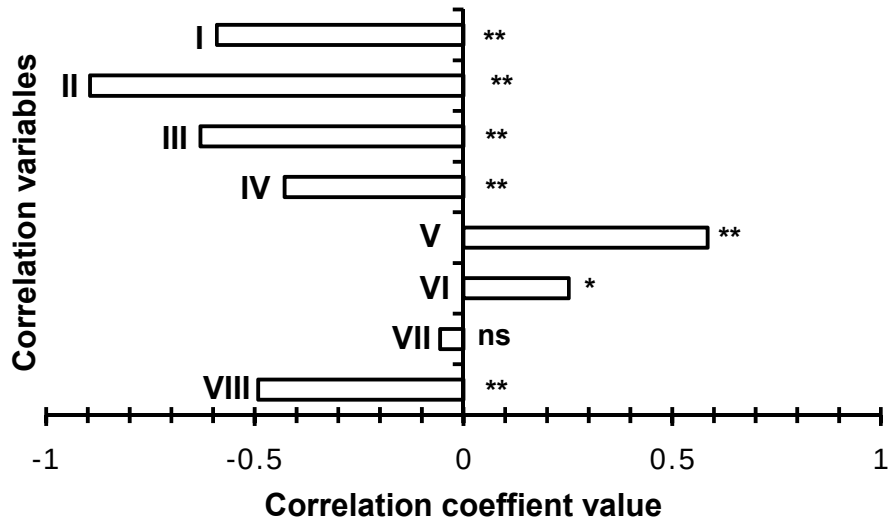

Fig. 8. Relationship of fruit firmness with fruit softening enzymes in pulp tissue of two peach cultivars harvested from two different locations at shelf after low temperature. I= Firmness vs *exo*-polygalacturonase, II = firmness vs *endo*-polygalacturonase, III = firmness vs *endo*-1,4-*β*- Glucanase, IV= firmness vs pectin esterase, V = ethylene vs *exo*-polygalacturonase, VI = ethylene vs *endo*-polygalacturonase, VII = ethylene vs *endo*-1,4-*β*- Glaucanase, VIII = ethylene vs pectin esterase.*,** denotes correlation is significant at $p \leq 0.01$ and $p \leq 0.05$, respectively while 'ns' denotes non-significant at $p \leq 0.05$.

Fruit weight loss decreased with increasing storage period, however significant differences found among the cultivars might be due to different genetic makeup as postharvest fruit quality and physiological characteristics are genetically controlled (Beverly, 1993). Our results have shown that peach fruit softening during ripening is significantly negatively correlated with activities of PE, EGase, *endo*-PG and *exo*-PG enzymes (Fig. 8). Similarly, recently, it has been reported that melting-flesh peach cultivars produce high levels of ethylene resulting in rapid fruit softening at the late-ripening stage (Tatsuki *et al.,* 2013). Although low temperature is used to extend the storage life of fruit but stone fruit are very prune to fruit softening due to enhanced activities of fruit softening enzymes (Khan & Singh, 2007). As evidenced from the results that fruit softening and ethylene is highly correlated to activities of all the softening enzymes including PE, EGase*, endo*-PG and *exo*-PG decreased at ripening stage as storage period increased (Fig. 8). Both the locations and cultivars showed difference in activities of softening enzymes which can be attributed to genetic variation and environmental factors as light and temperature influences the fruit quality (Kays, 1999) and above photosynthetic saturations can increase fruit temperature during fruit growth which may results in fruit damage and loss of fruit texture (Sams, 1999). It occurs owing to the breakdown of cell walls as well as conversion and dissociation of cell wall polymers during ripening (Singh & Singh, 2011). On the other side, loss of neutral sugar like galactose from pectin associated compound is proposed to coincide with the beginning of fruit softening. Subsequent solubilization of pectins is subjected to depolymerise in the later stages of ripening through the action of *endo*- or *exo*-PG enzymes (Dawson *et al.,* 1992). Different fruits had been reported to show a marked difference in their softening rates during ripening like mango (Lazan & Ali, 1993), banana (Kojima *et al.,* 1994) and carambola (Chin *et al.,* 1999). It was reported that pectin solubilisation occurs prior to depolymerisation in peach fruit (Brummell *et al.,* 2004). Breakdown of polyuronides has been found to be started at mid-softening stages in fruits (Brummell, 2006). In both peach cultivars harvested from Sillanwali as well as Soan Valley the SSC and SSC: TA of the fruit progressively decreased, whilst TA increased during at ripening followed by low temperature storage (Fig. 4). Increased SSC in fruits with 0 or 7 days storage than in fruit stored for 14 days or more could be attributed to oxidative breakdown of starch to sugars, and organic acids (Akhtar *et al.,* 2010). A declined TA at ripening stage in fruit with less storage interval might be due to decarboxylation of malate and the consequent decarboxylation of pyruvate (Hawker, 1969).

The increase of phenolic compounds observed in this study for both the cultivars at both harvest locations might be attributed to increased production of ethylene during ripening. Higher ethylene production during ripening at ambient temperature stimulates the biosynthetic pathway of phenol compounds. In fact, ethylene motivates phenylalanine ammonia lyase activity, an important enzyme involved in biosynthesis of phenolic compounds followed by accumulation of phenolics (Ritenour *et al.,* 1995). Fruits contain many different antioxidant components. Most of the antioxidant capacity of a fruit or vegetable may be from compounds other than enzymatic antioxidants. Phenolic compounds also had been demonstrated to exhibit strong antioxidant activities in fruits (Hanasaki *et al.,* 1984). Many factors are involved in alteration of fruit antioxidant activities including cultivars, storage techniques, geographical location and duration between fruit harvesting and consumption. It is evident that postharvest life of peaches has been reported to influence deeply their antioxidants capability (Di-Vaio *et al.,* 2008). Our results revealed significant higher activities of antioxidant enzymes with respect to both the harvest locations and cultivars at fruit ripening stage. It might be attributed to genetic variation as previously reported by Agarwal *et al*. (2001) where 12 different peach cultivars were used to determine the activities of four antioxidative enzymes including peroxidase.

Conclusions

Cultivars and harvest locations significantly influenced the various physico-chemical attributes along with the activities of fruit softening and antioxidative enzymes in peach fruit. 'Flordaking' peach harvested from Soan Valley exhibited superior fruit quality during ripening following cold storage as compared to 'Early Grand' peach harvested from Sillanwali.

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