The Journal of Animal & Plant Sciences, 25(3): 2015, Page: 669-678
ISSN: 1018-7081

EFFECT OF IRRIGATION INTERVALS ON THE QUALITY AND STORAGE PERFORMANCE OF STRAWBERRY FRUIT

I. Akhtar[1] and A. Rab[2]

[1]Directorate of Agriculture Research, Peshawar, Khyber Pakhtunkhwa, Pakistan
[2]Department of Horticulture, The University of Agriculture, Peshawar, Pakistan
Corresponding author: ijazakh@hotmail.com

ABSTRACT

The effect of irrigation intervals on the quality and storage performance of strawberry fruit was investigated at district Charsadda during the vegetation period 2010/2011.The strawberry (cv. 'Chandler') fruits, harvested from plots irrigated at 4, 6, 8, 10, 12 and 14 days interval were analyzed for physico-chemical characteristics immediately at harvest and after 8 days storage at 5±2°C and 90% relative humidity (RH) in perforated plastic packages. Irrigation intervals significantly affected the fruit quality and storage performance. The maximum fresh fruit weight (11.84 g), moisture content (86.35%) and ascorbic acid content (58.67 mg/100g), recorded with 4 days irrigation interval. Such features declined with increasing irrigation intervals to 14 days to the minimum fruit weight (7.91 g), moisture content (80.04%) and ascorbic acid (38.15 mg/100 g). By contrast, reducing sugars (6.31%), non-reducing sugar (2.01%), total sugars (8.32%), and titratable acidity (1.51%) were highest with 8 days irrigation interval and the highest total soluble solids (9.04%) and organoleptic quality score (8.00) were recorded with 10 days irrigation interval. The storage performance as determined by disease incidence, marketable fruits and shelf life revealed that disease incidence was not significantly affected by irrigation interval and storage but the maximum marketable fruits (95.25%) and shelf life (9.00 days) were recorded with 10 days irrigation interval. The interaction of irrigation interval and storage also significantly affected the fruit quality. The highest (7.26%) reducing sugars was recorded with the interaction of 12 days irrigation interval and 8 days storage, followed by 7.08% with the difference being non-significant recorded with the interaction of 10 days irrigation interval and 8 days storage, the highest TSS (9.37%) and total sugars (8.79%) were recorded with 10 days irrigation interval and 8 days storage. It can be concluded that while 4 days irrigation interval may be optimum for fresh fruit consumption, irrigation interval of 10 days is appropriate for retaining quality during storage or distant marketing.

Key words: Fruit, Irrigation Intervals, Quality, Strawberry, Storage, Sugars, TSS.

INTRODUCTION

Strawberry (*Fragariax ananassa. Duch*) isa commonly grown berry of the world (Parveen *et al*., 2012). It is a small juicy fruit that is rich in vitamin C and other minerals (Johnson and Peterson, 1974). Strawberry is generally adapted to a wide range of climatic conditions and is grown from the tropics to the artic and on different soils with adequate moisture, good drainage and nutrients (Shoemaker, 1978).The fruits and vegetables being living tissue, undergo physico-chemical changes resulting in quality deterioration during postharvest handling and storage (Kader, 1992). According to National Commission of Pakistan on Agriculture, the postharvest losses in fruits and vegetables range from 20 to 40% (Mahmood and Sheikh, 2006). The postharvest life of horticultural produce is determined by the rate of respiration, ethylene production and tenderness of the produce (Day, 1990; DeEll, 2006).Thus, postharvest handling of fruits and vegetables is a major challenge throughout the world (Kader, 1992). Strawberry is a highly perishable fruit and its postharvest handling is a serious problem throughout the world (Nunes *et al*., 2002). It is characterized by high rate of water loss (Kader, 1991) and high susceptibility to fungal decay during storage (Ceponis *et al.*, 1987). The rate of respiration and ethylene production can be decreased by storage at low temperature (Kader, 2002). Thus, low temperature storage is the most common method used to extend storage life (Kader, 2002).

Pre harvest factors such as fertilizers application and irrigation also influence the quality and storage performance of strawberry fruit (Yuan *et al.*, 2003).Water and nitrogen application is essential during early growth stages for bud differentiation and flowering in strawberry (Albregts and Howard, 1980), thus, increasing the yield (Macarthur and Eaton, 1987). However, excess water and nitrogen application result in excessive foliage, performance and survival after transplant, delayed fruit ripening and enhance softening (Strand, 1994). Thus, excess water application adversely affects the secondary plant metabolites, vitamins content and quality of strawberry fruits (Yuan *et al.*, 2003; Stefanelli *et al.*, 2010). Due to higher demand of strawberry fruits, the growers use excessive irrigation, especially where water is relatively inexpensive input to increase the yield (El-Farhan and Pritts, 1997). Excessive irrigation is especially a serious threat to strawberry fruit quality in warmer region of production, where more frequent irrigation is required, that may decrease the aroma of the fruit (Modise *et al.,* 2006). However, increased yield and size of berries is achieved at the cost of fruit quality and postharvest performance (Yuan *et al.,* 2003). Deficit irrigation has been seen as a potential alternative to improve strawberry fruit quality (Kumar and Dev, 2010). Proper irrigation management may optimize the concentration of aroma compounds (Modise *et al.,* 2006) without influencing the fruit size (Bordonaba and Terry, 2010). Keeping in view the importance of water application in relation to fruit yield and quality, the present experiment was designed to investigate the influence of irrigation intervals on the fruit quality and storage performance of strawberry fruit.

MATERIALS AND METHODS

The effect of irrigation intervals on the quality and storage performance of strawberry fruitwas investigated during the vegetation period 2010/2011.

Plant Materials: The runners of the cultivar 'Chandler' were acquired from Agriculture Research Institute, Mingora, Swat and planted in October, 2010on the experimental site at District Charsadda, Khyber Pakhtunkhwa.Raised beds of 20 cm high and 45 cm wide were made and the strawberry runners were planted on both sides of the beds at 20 cm apart from each other.

Irrigation: The plants were irrigated at 6 days interval as a normal practice in the area. The irrigation intervalstreatments were started when the plants approached the flowering stage. The plots were irrigated at 4, 6, 8, 10, 12 and 14 days intervals after the flowering stage to the harvesting stage. During the period of the experiment (March-April/2011), the experimental field wasprotected from rain fall with plastic sheets mounted at 3 meters high. In case of rainfall incidence, the plastic sheets were spread over the experimental plots to avoid interference by rain. The fruit were harvested at red stage of maturity. Data was recorded on different physical and chemicalquality characteristics of strawberry fruits immediately after harvest (Day 0 of storage) and 8 days storage. For storage studies, strawberry fruits (50 fruits with calyx) from each plot irrigated at different interval harvested and storedfor 8 days at 5±2 °C and 90% R.H. in perforated (18 perforations of 0.5 cm diameter) plastic packages (20x15 cm).

Fruit weight (g): The average fruit weight was approximated by randomly taking 20 fruits.

Moisture (%): The moisture percentage was determined by oven drying method (AOAC, 2005). A known weight of fruit sample was taken in a petri dish and kept at 105 °C in an oven till constant weight obtained. The loss in weight after drying was noted and percent moisture content was calculated by the following formula.

$$\text{Moisture\%} = \frac{W1 - W2}{W1} \times 100$$

W_1 = Weight of sample before drying
W_2 = Weight of sample after drying

Organoleptic Evaluation: Strawberry fruits were evaluated at harvest and after 8 days storage by a panel of judges for fruit quality attributes such as color, taste, aroma, texture and overall acceptability score of 1-9, as described by Larmond (1977).

Total Soluble Solids (%): The total soluble solids (TSS) of strawberry fruit were determined using a hand refractometer (Kernco, Instrument Co, Texas) according to AOAC (2005).

Total Sugars (%): Reducing and non-reducing sugars were determined by Lane Eynon Method as reported by the AOAC (2005).

Titratable Acidity (%): The titratable acidity was determined by Acid Neutralization Method (AOAC, 2005).

Sugar Acid Ratio: The sugar acid ratio was obtained by dividing percent sugar with percent acidity of strawberry fruit.

Ascorbic Acid (mg/100 g): The vitamin C (Ascorbic acid) in strawberry fruit was calculated by Titrimatric method as described by AOAC (2005).

Weight Loss (%): Fruits from different treatments were weighed before and after 8 days storage. The percent weight loss during storage was determined by the following formula.

$$\left[\text{Weight loss \%} = \frac{\text{Loss of sample weight}}{\text{Weight of Sample}} \times 100\right]$$

Disease Incidence (%): Disease incidence was recorded after storage by counting the number of fruits with symptoms of diseases and the data was converted to represented percent disease incidence.

$$\text{Disease incidence\%} = \frac{\text{Number of diseased sample}}{\text{Total number of sample}} \times 100$$

Marketable Fruits (%): Physically sound fruits, free from diseases, injury and damages were counted at 8 days storage and the percentage calculated as under:

$$\text{Marketable fruits (\%)} = \frac{\text{Number of desirable fruits}}{\text{Total number of fruits}}$$

Shelf Life (Days): The shelf life was estimated on a separate group of 50 fruits from each treatment and replication. The maximum shelf life data was recorded when 15% fruits showed the symptoms of physical deterioration.

Statistical Analysis: The experiment was laid out in two factorial Randomized Complete Block Design (RCBD) while three study parameters i.e. disease incidence, marketable fruits and shelf life purely related to storage were analyzed by RCBD one factor. The treatments were replicated four times. The data were analyzed using analysis of variance technique and computer software (Statistix-9) was used. The means were separated by least significant difference (LSD) at 5% level of probability as described by Steel *et al.,* 1997.

RESULTS AND DISCUSSION

Fruit Weight (g): Fruit weight was significantly affected by irrigation intervals, storage and interaction of irrigation interval and storage (Table 1). Fruit weight decreased from the maximum of 11.84 g with 4 days irrigation intervals to the minimum of 7.91 g with 14 days irrigation interval. The decrease in fruit weight from 4 to 14 days irrigation interval was 33.19%. The difference in 6 to 8 days and 12 to 14 days irrigation interval was, however, non significant. The fruit weight also significantly declined during storage from the mean fruit weight (10.48 g) at harvest to 9.22 g after 8 days storage, accounting for 12.02% decrease in fruit weight. The interaction of irrigation interval and storage also significantly affected strawberry fruit weight. The highest fruit weight (13.24 g) was recorded with the interaction of 4 days irrigation interval and 0 days storage, followed by 11.7 g with the interaction of 6 days irrigation interval and 0 days storage while the lowest fruit weight (7.60 g) was recorded by the interaction of 12 days irrigation interval and 8 days storage.

The fruit weight of strawberry increases, due to cells expansion, with increasing irrigation frequency (Yuan *et al.,* 2003). Increasing irrigation interval decreased the fruit weight that can be attributed to less moisture absorption (Liu *et al.,* 2007; Bordonaba and Terry, 2010). Extended irrigation intervals or partial root zone drying have been found to decrease the fresh weight and water content of strawberry fruit (Liu *et al.,* 2007). The fruit weight loss during storage decreases the fruit quality, salable weight that result in economic losses to growers and businessmen (Trevisan *et al.,* 1999). The strawberry fruit loses weight due to its respiration and transpiration (Ayranci and Tune, 2003) but much of the weight loss in strawberry fruit can be attributed to moisture loss (Moing *et al.,* 2001; Zhang, 2001). This may explain the reason for significant decrease in weight loss with irrigation intervals of 4 and 6 days and non significant decline in weight at extended irrigation intervals of 12 and 14 days.

Moisture (%): The moisture content of strawberry fruits was significantly affected by irrigation interval, storage and the interaction of irrigation interval and storage. The highest mean moisture content (86.35%) was recorded in fruits harvested from plots irrigated at 4 days interval which decreased to 80.04% with 14 days irrigation interval. The difference in moisture content was, however, non significant for plots irrigated at 4, 6, and 8 days intervals but declined significantly with extending irrigation interval from 8 to 14 days. The decrease in moisture content from 4 to 14 days irrigation interval was 7.31%. Fruit moisture content was also significantly affected by storage. The mean fruit moisture content decreased from 89.46% to 79.29% during storage (Table 1). The interaction of irrigation interval and storage revealed the highest moisture content (92.28%) for fruit produced with 4 days irrigation interval and 0 days storage, followed by 91.82% by the interaction of 6 days irrigation interval and 0 days storage. The moisture content was the least (72.73%) with the interaction of 14 days irrigation interval and 8 days storage. Strawberry fruit contains approximately 89.9% water (Considine, 1982). Thus, limited water application reduces strawberry fruit moisture content and size (El-Farhan and Pritts, 1997). By contrast increased water application results in higher fruit moisture content because the fruit accumulate more water (Yuan *et al.,* 2003). Moisture loss during storage is a major problem in postharvest life of horticultural commodities (Trevisan *et al.,* 1999). Strawberry fruit loses weight during storage due to moisture loss (Miszczak *et al.,* 1995; Moing *et al.,* 2001; Zhang, 2001), which increase progressively when storage duration is increased beyond day 3 (Youngjae *et al*., 2007).

Organoleptic Evaluation: The organoleptic quality of strawberry fruits immediately after harvest (0 days storage) and 8 days storage revealed that irrigation interval significantly affected the organoleptic quality but storage and the interaction of irrigation interval and storage had no significant effect. The highest mean score (8.00) was recorded for fruits harvested from plot, irrigated at 10 days interval, while the lowest mean score (4.00) was recorded for fruits harvested from plot irrigated at 4 and 14 days intervalas compared to fruits harvested from plot irrigated at 10 days interval (Table 1). Sensory evaluation of fruit quality is a reliable method to estimate consumer acceptance (Peneau *et al.,* 2007). Organoleptic quality score of strawberry fruit increased with increasing irrigation interval from 4 to 10 days but declined with further increase in irrigation interval. Since limited water application increase the concentration of sugars, organic acids (Bordonaba and Terry, 2010), total soluble solids (Leon *et al.,* 2007), aroma compounds (Modise *et al.,* 2006) in strawberry fruits. Thus, it is likely to observe high organoleptic quality score with extended irrigation intervals of 10 days. However, the rapid decline in organoleptic quality score with 12 and 14 days irrigation intervals suggest that greater deficit in water application may stress the strawberry plants (Yuan *et al.*, 2003) that may decrease the fruit quality (Kader, 1991).

Total Soluble Solids (%): Total soluble solids (TSS) content of strawberry fruit was significantly affected by irrigation interval, storage and the interaction of irrigation interval and storage. The least mean TSS (7.27%), recorded with 4 days irrigation interval increased significantly to 9.04% with 10 days irrigation interval but declined to 8.93% and 8.34% with 12 days and 14 days irrigation intervals respectively. A positive correlation was observed in TSS content and irrigation interval up to 10 days. Since, the fruit moisture content decreases from 86.35% to 80.04% with increasing irrigation interval from 4 to 14 days. The TSS content of strawberry fruit increased significantly from 7.90% to 8.76% during 8 days storage (Table 1). The TSS content was also significantly affected by the interaction of irrigation interval and storage with the highest TSS (9.37%), recorded in fruits from 10 days irrigation interval and 8 days storage. By contrast, strawberry fruits from plot irrigated at 4 days interval and 0 days storage had the least total soluble solids.

The TSS is an important quality attribute of strawberry fruit and is directly related to total sugars of fruits (Chang and Chang, 2010). The concentration of TSS in strawberry fruit depends on the moisture content of the fruit (Modise *et al.*, 2006). Thus, it is likely to observe high TSS with an increase in irrigation interval to 10 days. However, the significantly lower TSS with 12 and 14 days indicate that such longer irrigation intervals may develop low moisture stress (Yuan *et al.*, 2003), that decrease the rate of photosynthesis (Leon *et al.*, 2007) or due to conversion of sugars to aroma compounds, a characteristics switch with severe water deficit condition (Bordonaba and Terry, 2010).The TSS content generally increases during fruit development and storage (Pineli *et al.*, 2010) may be due to the conversion of insoluble sugars to soluble sugars (Sturm *et al.*, 2003). However, loss of moisture during storage seems a major factor responsible for the increase in TSS (Nunes *et al.*, 2002; Pineli *et al.*, 2010). Hence, the total soluble solids content is positively and significantly correlated with the total weight loss (Kirad *et al.*, 2003).

Reducing Sugars (%): The reducing sugars contents of strawberry fruit increased significantly from the minimum (5.54%) with 4 days irrigation interval to the maximum of 6.31% in fruits harvested from plot irrigated at 8 days interval but declined to the minimum (5.60%) with 14 days irrigation. The difference in reducing sugars of strawberry fruit irrigated at 8, 10 and 12 days was, however, non significant. The reducing sugars contents (5.84%) of strawberry fruit at harvest increased significantly to 6.47% during 8 days storage (Table 1). The interaction of irrigation interval and storage showed that 4 days irrigation interval and 0 days storage resulted in the minimum (5.35%) reducing sugars that increased to the maximum (7.26%) in strawberry harvested from plots irrigated at 12 days interval and stored for 8 days.

The glucose and fructose are the predominant sugars of strawberry fruit (Kafkas *et al*, 2007; Basson *et al.*, 2010). The reducing sugars of strawberry fruit are generally higher, when plant experience water deficiency during fruit development (Modise *et al.*, 2006). Bordonaba and Terry (2010) reported significant increase in dry matter content in fruit harvested from plots that received deficit irrigation and this increase in dry matter content was attributed to increased concentrations of sugars and some acids. However, the significant decline in reducing sugars at 14 days irrigation interval may be either due to decreased photosynthesis (Leon *et al.*, 2007) or due to conversion of sugars to aroma compounds (Bordonaba and Terry, 2010). The reducing sugars content of strawberry fruit also increases during storage (Ruiz *et al.*, 1997) due to conversion of sucrose to glucose and fructose (Sturm *et al.*, 2003) and loss of moisture from the fruit which increases the concentration of reducing sugars (Artes *et al.*, 2006).

Non Reducing Sugar (%): The non reducing sugar content of strawberry fruit was significantly affected by irrigation interval and storage but the interaction of irrigation interval and storage was not significant. The highest non reducing sugar (2.03%) was recorded in fruits that were irrigated at 6 days interval, followed by 2.01% and 1.95% with 8 and 10 days irrigation intervals with difference being non significant. However, 4 days irrigation interval resulted in significantly lower (1.80%) reducing sugars but the least (1.42%) was recorded in fruits that were produced with 14 days irrigation interval that was at par with fruits collected from plots irrigated at 12 days interval (Table 2). The non reducing sugar content of strawberry fruit decreases from 2.04% at harvest to 1.54% during 8 days cold storage, the decrease was 25.01%.

The decrease in non reducing sugar content at irrigation interval beyond 6 days indicates greater consumption of carbohydrates in respiration (Day, 1990; Park *et al.*, 2005) because water stress enhance the changes associated with fruit maturity (Modise *et al.*, 2006) including the conversion of non reducing sugars to reducing sugars (Sturm *et al.*, 2003). Since, the non reducing sugars contribute to the structural and storage carbohydrates, it is also likely that these are less sensitive to modest changes in irrigation interval (Stefanelli *et al.*, 2010). The decline in non reducing sugars during 8 days storage may be due to conversion of sucrose to glucose and fructose (Ruiz *et al.*, 1997). Similarly the hydrolysis of the cell wall may also contribute to the decrease in non reducing sugars in strawberry fruit during storage (Asif *et al.,* 2004).

Total Sugars (%): The total sugars of strawberry fruit was significantly affected by irrigation interval, storage and the interaction of irrigation interval and storage. The total sugar content (7.34%) recorded in fruits harvested from plots irrigated at 4 days interval increased to 8.05% and 8.32 with 6 and 8 days irrigation interval but declined to 8.23 and 7.62% with further extension in irrigation intervals to 10 and 12 days respectively. The least total sugars (7.03%) were recorded in fruits harvested from plot irrigated at 14 days interval. The mean total sugars of strawberry fruit was significantly higher (7.52%) at days 0 of storage (Fresh fruits) as compared to 8.01% after 8 days storage (Table 2). The interaction of irrigation interval and storage also revealed comparable trend with the least total sugars (6.42%) were recorded by the interaction of 14 days irrigation interval and 0 days storage which increased to the maximum (8.79%) recorded in fruits produced with 10 days irrigation interval and stored for 8 days.The total sugars increases in strawberry fruit as it advances in maturity (Cordenunsi *et al.,* 2005; Mahmood *et al.,* 2012). Since, deficit irrigation significantly enhances the maturation process of the fruit it also increases the dry matter content of strawberry fruit due to increase in TSS comprising sugars and organic acids (Leon *et al.,* 2007; Bordonaba and Terry, 2010).The increase in total sugars in strawberry fruit is associated with fruit development and, hence, commonly observed during storage (Moing *et al.,* 2001; Kirad *et al.,* 2003). The increase in total sugars of strawberry fruit during storage could be due to moisture loss, hence increasing the total sugars concentration of strawberry fruit after storage (Kirad *et al.,* 2003).

Titratable Acidity (%): The titratable acidity of strawberry fruit varied significantly with irrigation intervals but storage duration and the interaction of irrigation interval and storage duration did not significantly affect the titratable acidity of strawberry fruit. The mean titratable acidity (1.51%) in fruits harvested from plot which were irrigated at 8 days interval was significantly higher than both shorter and longer irrigation intervals. However, the least titratable acidity (1.19%) was recorded in fruits harvested from plot irrigated at 12 days interval (Table 2). The storage and the interaction of irrigation intervals and storage had no significant effect on titratable acidity of strawberry fruits. The titratable acidity of strawberry fruits depends on the concentration of different organic acids that contribute to the taste and consumer acceptance (Usenik *et al.,* 2008). The amount of organic acids in strawberry fruit are very minute (Bordonaba and Terry, 2010). The increase in titratable acidity with increasing irrigation intervals of 8 days could be due to increased concentration due to less moisture content of the fruit (Kirad *et al.,* 2003). However, the decline beyond 8 days irrigation interval clearly demonstrates that extended irrigation interval may cause water deficit stress that may result in greater consumption of organic acid in respiration (Liu *et al.,* 2007). Titratable acidity at low temperature during storage was retained at certain level and observed no marked changes in organic acids (Green, 1971) and hence titratable acidity was not significantly affected by storage duration.

Sugar Acid Ratio: The sugar acid ratio of strawberry fruit was significantly affected by different irrigation interval, storage and the interaction of irrigation interval and storage. The highest sugar acid ratio (6.41) was recorded in fruits harvested from plot irrigated at 12 days interval, followed by 6.22 with 10 days irrigation interval, however, the difference was non significant. The minimum sugar acid ratio (5.61) was noted in fruits harvested from plot irrigated at 4 days interval. Since the sugar acid ratio is a function of dissolved sugar and acidity of the fruit and there was an increase in reducing sugars with increasing irrigation intervals to 12 days, it is likely to observe higher sugar/acid ratio up to 12 days irrigation interval (Wozniak *et al*., 1997). In similar line of reasoning the decline in sugar acid ratio with irrigation interval of 14 days can be explained by the decrease in sugar content at the same irrigation interval (Leon *et al.,* 2007). The storage duration significantly affected the sugar acid ratio of strawberry fruits. The sugar acid ratio decreased from 6.22 at 0 days storage to 5.58 during 8 days cold storage, the decrease in sugar acid ratio was 10.30% (Table 2). The interaction of irrigation interval and storage also significantly affected the sugar acid ratio. The highest sugar acid ratio (7.31) was recorded with the interaction of 12 days irrigation interval and 8 days storage, followed by 6.76 with 10 days irrigation interval and 8 days storage, while the minimum (5.01) sugar acid ratio was recorded with the interaction of 14 days irrigation interval and 0 days storage. A specific sugar/acid ratio is essential for characteristic flavor of a fruit and is used as a sign of edible maturity (Mahmood *et al.,* 2012). At the beginning of the development process the sugar/acid ratio is low, because of low sugar and high acid content, resulting in sour taste of fruits (Wozniak *et al.,* 1997). During the ripening process, generally expedite by water stress, the fruit acids are used in metabolism, while the sugar content increases (Kafkas *et al.,* 2007), thus the sugar/acid ratio, generally increases with advance in maturity influenced by deficit irrigation (David *et al.,* 2008; Muhammad *et al.,* 2011). Thus, the overripe fruits have very low levels of fruit acid and therefore lack its characteristic flavor (Pineli *et al.,* 2010).

Ascorbic Acid (mg/100 g): The ascorbic acid content of strawberry decreased significantly from the maximum (58.67 mg/100 g) in fruits harvested from plot irrigated at

4 days interval to the least (38.15 mg/100 g) with 14 days irrigation interval (Table 2). The storage also significantly affected the ascorbic acid content of strawberry fruit, which declined from 47.43 mg/100 g to 44.03 mg/100 g during 8 days storage. The interaction of irrigation interval and storage also significantly affected the ascorbic acid content of strawberry fruit. The maximum ascorbic acid (61.21 mg/100 g) recorded with the interaction of 4 days irrigation interval and 0 days storage declined to the minimum of 37.21 mg/100g in fruits irrigated at 14 days interval and stored for 8 days. The ascorbic acid content in strawberry is generally higher at early stages of maturity but decline with advance in maturity (Pineli *et al.,* 2010). Since extending irrigation interval generally enhance the maturation (Modise *et al.*, 2008), it is likely to have initiated the decline in ascorbic acid (Moing *et al.*, 2001). However, water deficit may hinder the synthesis (Cordenunsi *et al*., 2003) or enhance the degradation of ascorbic acid (Lee and Kader, 2000). Thus the ascorbic acid content declined with increasing irrigation intervals. The ascorbic acid is an unstable vitamin and may decline up to 50% (Cordenunsi *et al.,* 2003). High temperature and low relative humidity during storage may also trigger the degradation of ascorbic acid (Seung and Kader, 2000) as is evident for enhanced ascorbate oxidase enzyme (Saari *et al.,* 1995).

Disease Incidence (%): Disease incidence of the fruits during 8 days storage was not significantly affected by irrigation interval. However, the least disease incidence (2%) was observed in fruits harvested from plot irrigated at 10 days interval while the highest disease incidence (5%) was recorded in fruits irrigated at 4 days interval (Table 3). Strawberries are sensitive to fungal decay, grey mold caused by *Botrytis cinerea* is the most common disease (Atress *et al.,* 2010). The relatively higher disease incidence in fruits with 4 days irrigation interval could be due to high moisture content of such fruits (Schouten *et al.,* 2002; Parikka, 2003). High moisture content and water condensation on the surface of strawberry fruits increases the development of fungal and bacterial infection (Nunes and Emond, 1999). Strawberry fruits produced with deficit irrigation are normally relatively more resistant to diseases (Modise *et al*., 2006).

Marketable Fruits (%): The irrigation intervals significantly affected the marketable fruits at 8 days storage. The maximum marketable fruits (95.25%) were recorded in plot irrigated at 10 days interval while minimum marketable fruits (86.25%) were noted in plots irrigated at 4 and 6 days interval (Table 3). Fruits with attractive color, proper shape, good look, firmness and free from diseases are considered as marketable fruits (Parveen *et al.*, 2012). It is suggested by Bordonaba and Terry (2010) that good quality fruits can be produced under deficit irrigation between flower initiation and fruit harvesting by increasing the concentration of taste related compounds in strawberry fruit. Since water loss leads to dull appearance, unattractive color and shriveling of the fruits, when it exceeds 6% for strawberries fruit (Robinson *et al.,* 1975).

Table 1: Effect of Irrigation interval and storage duration on the physicochemical quality characteristics of strawberry fruit

Irrigation Intervals (days)	Fruit Weight (g)	Moisture (%)	Organoleptic Evaluation	Total Soluble Solids (%)	Reducing Sugars (%)
4	11.84 a	86.35 a	4.00 d	7.27 e	5.54 c
6	10.93 b	86.27 a	5.00 c	8.17 d	6.02 b
8	10.63 b	85.70 a	6.00 b	8.24 d	6.31 a
10	9.33 c	84.74 b	8.00 a	9.04 a	6.28 a
12	8.47 d	83.15 c	6.00 b	8.93 b	6.10 ab
14	7.91 d	80.04 d	4.00 d	8.34 c	5.60 c
LSD (0.05)	0.68	0.94	1.00	0.07	0.21
Storage (days)					
0	10.48 a	89.46 a	6.00	7.90 b	5.48 b
8	9.22 b	79.29 b	5.00	8.76 a	6.47 a
LSD (0.05)	0.39	0.54	-----	0.04	0.12
Irrigation Interval x Storage Duration					
I x S	**	**	NS	**	**

Means followed by similar letter(s) in column do not differ significantly from one another at P = 0.05.
** = Highly significant, NS = Non significant and I x S = Interaction of Irrigation interval and Storage duration

Shelf Life (days): Shelf life of strawberry fruits was significantly affected by different irrigation intervals. The maximum storage life (9 days) was observed in fruits harvested from plot irrigated at 10 days interval, followed by 8 days with 8 days irrigation interval, while the minimum storage life (6 days) was recorded in fruits irrigated at 4 and 6 days intervals (Table 3). Strawberry is a non climacteric fruit, highly perishable and characterized by a short shelf life (Han *et al.*, 2005). The loss of quality is mostly due to high metabolic activity (Atress *et al.,* 2010). Postharvest life of strawberries can be extended by several techniques combined with refrigeration (Debeaufort *et al.,* 1998). The maximum storage life of strawberry fruits with longer irrigation could be due to their more resistance to diseases, thus, longer storage life (Modise *et al.*, 2006).

Table 2: Effect of Irrigation interval and storage duration on the chemical quality characteristics of strawberry fruit.

Irrigation Intervals (days)	Non Reducing Sugar (%)	Total Sugars (%)	Titratable Acidity (%)	Sugar Acid Ratio	Ascorbic Acid (mg/100 g)
4	1.80 b	7.34 bc	1.30 bc	5.61 bc	58.67 a
6	2.03 a	8.05 a	1.33 b	6.03 ab	50.41 b
8	2.01 ab	8.32 a	1.51 a	5.50 c	46.21 c
10	1.95 ab	8.23 a	1.32 b	6.22 a	41.65 d
12	1.51 c	7.62 b	1.19 c	6.41 a	39.28 e
14	1.42 c	7.03 c	1.29 bc	5.64 bc	38.15 f
LSD $_{(0.05)}$	0.21	0.32	0.12	0.51	0.14
Storage (days)					
0	2.04 a	7.52 b	1.35	6.22 a	47.43 a
8	1.54 b	8.01 a	1.30	5.58 b	44.03 b
LSD $_{(0.05)}$	0.12	0.19	N.S	0.29	0.08
Irrigation Interval x Storage Duration					
I x S	NS	**	NS	**	**

Means followed by similar letter(s) in column do not differ significantly from one another at P = 0.05.
** = Highly significant, NS = Non significant and I x S = Interaction of Irrigation interval and Storage duration

Table 3: Effect of irrigation intervals on disease incidence and desirable fruits after 8 days storage and shelf life of strawberry fruit.

Irrigation intervals (days)	Disease Incidence (%)	Marketable Fruits (%)	Shelf Life (days)
4	5.00	86.25 c	6.00 c
6	4.75	86.25 c	6.00 c
8	3.00	91.75 ab	8.00 ab
10	2.00	95.25 a	9.00 a
12	4.00	91.00 ab	7.00 bc
14	3.00	89.25 bc	7.00 bc
Significance Level	N.S	**	**
LSD $_{(0.05)}$	-----	4.48	1.15

Means followed by similar letter(s) in column do not differ significantly from one another at P = 0.05.
NS = Non significant, ** = Highly significant

Conclusion: Strawberry fruits grown under deficit irrigation during fruit growth and development had superior quality, marketable fruits and longer shelf life. Increasing irrigation interval to 10 days improves the quality attributes by increasing TSS, reducing sugars, non reducing sugar, total sugars and enhanced the storage life. It can be concluded that strawberry cv. Chandler should be irrigated at the maximum safest irrigation intervals (10 days).

REFERENCES

Albregts, E.E. and C.M. Howard (1980). Accumulation of nutrients by strawberry plants and fruit grown in annual hill culture. J. Amer. Soc. Hort. Sci. 105(4): 386-388.

A.O.A.C. (2005). Association of Official Analytical Chemist. Official Methods of Analysis, 18th Edition, Washington, D.C, USA.

Artes, F., J.A. Tudela, J.G. Marin, R. Villaescusa and F.H. Artes (2006). Modified atmosphere packaging of strawberry under self adhesive films. 5th International Symposium on Protected Cultivation in Mild Winter Climates.

International Society of Horticultural Science (ISHS). Acta Hort. 559.

Asif, M.A., H. Raza., M.A. Khan and M. Hussain (2004). Effect of different periods of ambient storage on chemical composition of apple fruit. Int. J. Agri. and Bio. 6(3): 568-571.

Atress, A.S.H., M.M. El-Mogy, H.E.A. Anean and B.W. Alsannius (2010). Improving strawberry fruit storability by edible coatings as a carrier of Thymol or calcium chloride. J. Hort. Sci. and Ornamental plants 2(3): 88-97.

Ayranci, E. and S. Tune (2003). A method for the measurement of the oxygen permeability and the development of edible films to reduce the rate of oxidative reactions in fresh foods. Food Chem. 80: 423-431.

Basson, C.E, J.H. Groenewald, J. Kossmann, C. Cronje and R. Bauer (2010). Sugar and acid related quality attributes and enzyme activities in strawberry fruits. Food Chem. 121: 1156-1162.

Bordonaba, J.G., and L.A. Terry (2010). Manipulating the taste related composition of strawberry fruits (*Fragaria x ananassa*) from different cultivars using deficit irrigation. J. Food Chem. 122(4): 1020-1026.

Ceponis, M.J., R.A. Cappellini and G.W. Lightner (1987). Disorders in sweet cherry and strawberry shipments to the New York markets, 1972-1984. Plant Disease 71: 472-475.

Chang, J.C. and M.W. Chang (2010). Elongated fruit No. 1, mulberry, an elite cultivar for fresh consumption. J. Am. Pomol. Soc. 64: 101-105.

Considine, M. (1982). Food and Food Products Encyclopedia. Van Nostrad Inc. New York. USA.

Cordenunsi, B.R., J.R.O. Nascimento and F.M. Lajolo (2003). Physicochemical changes related to quality of five strawberry fruit cultivars during cool storage. J. Food Chem. 83(2): 167-173.

David, O., S. Collin, J. Sievert, K. Fjeld, J. Doctor and M. L. Arpaia (2008). Commercial packing and storage of navel oranges alters aroma volatiles and reduces flavor quality. Postharvest Bio. and Tech. 47: 159-167.

Day, B. (1990). Modified atmosphere packaging of selected prepared fruit and vegetables. Chilled Foods, the revolution in freshness. Processing and Quality of Foods 3.

DeEll, J. (2006). Postharvest handling and storage of strawberries. Fresh market quality program lead. Ministry of Agriculture Food and Rural Affairs, Ontario. Canada.

Debeaufort, F.J.A. Quezada-Gallo and A. Voilley (1998). Edible films and coatings tomorrow's packaging: a review. Crit. Rev. Food Sci. 38: 299-313.

El-Farhan, A.H and M.P. Pritts (1997). Water requirements and water stress in strawberry. Adv. in Strawberry Research 16: 5-12.

Green, A. (1971). Soft fruits. In Hulme, A.C. (Ed.), The biochemistry of fruits and their products, New York Academic Press. Pp. 375-410.

Han, C., C. Lederer, M. Mcdaniel, Y. Zhao (2005). Sensory evaluation of fresh strawberries coated with chitosan based edible coatings. J. Food Sci. 70: 172-178.

Johnson, A.H. and M.S. Peterson (1974). Encyclopedia of Food Technology. The AVI. Co. Inc. Westport. Connecticut, USA.

Kader, A.A. (1991). Quality and its maintenance in relation to the postharvest physiology of strawberry. In: A. Dale and J.J. Luby (eds). The strawberry into the 21st, Timber press, Portland, Oregon.

Kader, A.A. (1992). Postharvest technology of horticultural crops, University of California, Davis, Division of Agriculture and National Resources.

Kader, A.A. (2002). Postharvest Technology of Horticultural Crops. 3$^{rd.}$ Eds. Univ. California Oakland. Ext. Publication. USA. Pp. 296.

Kafkas, E., M. Kosar, S. Paydas, S. Kafkas and K.H.C. Baser (2007). Quality characteristics of strawberry genotypes at different maturation stages. Food Chem. 100: 1229-1236.

Kirad K.S., S. Barche, A. Dash and R.K. Sharma (2003). Response of Different Packaging Materials and Chemicals on the Shelf Life of Strawberry (*Fragaria ananassa*) and correlation between different traits. International Conference on Quality Management of fresh cut produce. Acta Hort. 746.

Kumar, S. and P. Dev (2010). Effects of different mulches and irrigation methods on root growth, nutrient uptake, water use efficiency and yield of strawberry. Scientia Hort. 127(3): 318-324.

Larmond, E. (1977). Laboratory methods for sensory evaluation of foods, Research branch Canada, Department of Agriculture, Publication No. 1637.

Lee.S.K and A.A. Kader (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Bio and Tech. 20: 207-220.

Leon, A.T., G.A. Chope and J.G. Bordonaba (2007). Effect of water deficit irrigation and inoculation with *botrytis cinerea* on strawberry (*Fragaria x ananassa*) fruit quality. J. Agric. Food Chem. 55: 10812-10819.

Liu, F., S. Savic, C.R. Jensen, A. Shahnazari, S.E. Jacobsen, R. Stikic and M.N. Andersen (2007). Water relations and yield of lysimeter grown

strawberries under limited irrigation. Scientia Hort. 111(2): 128-132.
Macarthur, D.A.J. and G.W. Eaton (1987). Effect of fertilizer, paclobeutrazol and chlormeguant on strawberry. J. American Society for Horticultural Science 112(2): 241-246.
Mahmood, T., F. Anwar, M. Abbas, M.C. Boyee and N. Saari (2012). Compositional variation in sugars and organic acids at different stages in selected small fruits from Pakistan. Int. J. Mol. Sci. 13: 1380-1392.
Mahmood, M.A. and A.D. Sheikh (2006). Citrus export system in Pakistan. J. Agric. Res. 44(3): 229-238.
Miszczak, A., C.F. Forney and R.K. Prange (1995). Development of aroma volatiles and color during postharvest ripening of 'Kent' strawberries. J. Am. Soc. Hort. Sci. 120(4): 650-655.
Modise, D.M., C.J. Wright and J.G. Atherton (2006). Changes in strawberry aroma in response to water stress. Botswana J. Agri. and Appl. Sci. 2(1): 50-60.
Moing, A., C. Renaud, M. Gaudillere, P. Raymond, P. Roudeillac and B.D. Rothan (2001). Biochemical changes during fruit development of four strawberry cultivars. J. Amer. Soc. Hort. Sci. 124(4): 394-403.
Muhammad A.T., F.M. Tahir, A.A. Asi and M. A. Pervez (2011). Effect of curing and packaging on damaged fruit quality. J. Bio. Sci. 1(1): 13-16.
Nunes, M.C.N and Emond, J.P. (1999). Quality of strawberries after storage in constant or fluctuating temperatures. Paper No. 205. Proceedings of the 20th International Congress of Refrigeration. Sidney, September 19-24, 1999.
Nunes, M.C.N., A.M.M.B. Morais, J.K. Brecht and S.A. Sargent (2002). Fruit maturity and storage temperature influence response of strawberries to controlled atmospheres. J. Amer. Soc. Hort. Sci. 127(5): 836-842.
Parikka, P. (2003). The effect of irrigation method on the quality and shelf life of strawberry fruit in organic production. Published in Plant protection in sustainable strawberry production, page 22. Nordic Association of Agricultural Scientists.
Park, I. S., D.S. Stan, A.M. Daeschel and Y. Zhao (2005). Antifungal coatings on fresh strawberries (*Fragaria* × *ananassa*) to control mold growth during cold storage. J. Food Sci. 70(4): 202-207.
Parveen, S., A. Din, M. Asghar, M. R. Khan and M. Nadeem (2012). Value addition in strawberry, a tool for long term storage- a review. Pak. J. Food Sci. 22(4): 206-208.
Peneau, S., P.B. Brockhoff, F. Escher and J. Nuessli (2007). A comprehensive approach to evaluate the freshness of strawberries and carrots. Post harvest Bio. and Tech. 45: 20-29.
Pineli, L.L.O., C.L. Moretti, M.S. Santos, A.B. campos, A.V. Brasileiro, A.C. Cordova and M.D. Chiarello (2010). Antioxidants and other Chemical and Physical characteristics of two strawberry cultivars at different ripeness stages. J. Food Composition and Analysis.
Ruiz, N. A., A.J.M. Lopez, M.R. Lopez, M.J. Lopez, J.J. Medina, H.A.T. Scheer, F. Lieten and J. Dijkstra (1997). Analysis of sugars from strawberry cultivars of commercial interest contents evaluation. Proceedings of the third international strawberry symposium, Veldhoven, Netherlands. Acta Hort. 29(2): 663-667.
Robinson, J.E., Browne, K.M. and Burton, W.G. (1975). Storage characteristics of some vegetables and soft fruits. Ann. Appl. Biol. 81: 399-408.
Saari, N.B., S. Fujita, R. Miyazoe and M. Okugawa (1995). Distribution of ascorbate oxidase activities in the fruits and some of their properties, J. Food Biochem. 19: 321-327.
Schouten, R.E., D. Kessler, L. Orcaray and O.V. Kooten (2002). Predictability of keeping quality of strawberry batches. Post harvest Bio. and Tech. 26(1): 35-47.
Seung, K. L. and A.A. Kader (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Bio. and Tech. 20: 207-220.
Shoemaker, J.S. (1978). Small fruit culture, 5th edition. McGraw hill book company, Newyork. Pp. 113-230.
Steel, R.G.D., J.H. Torrie and D. Dickey. (1997). Principles and procedures of statistics: a biometrical approach. 3rd Ed McGraw Hill Book Co Inc, New York.
Stefanelli, D., I. Goodwin and R. Jones (2010). Minimal Nitrogen and water use in Horticulture: Effects on quality and content of selected nutrients. Food Res. Int. 43(7): 1833-1843.
Strand, L.L. (1994). Integrated pest management for strawberries. University of California, Division of Agriculture and Natural Resources. Berkeley, California, USA. Publication 3351, Pp. 142.
Sturm, K., D. Koron and F. Stampar (2003). The composition of fruit of different strawberry varieties depending on maturity stage. Food Chem. 83(3): 417-422.
Trevisan, J.N., G.A.K. Martins, S.J. Lopes and D.C. Garcia (1999). Yield and post harvest storability of low land grown onion genotypes. Ciencia Rural. 29(3): 409-413.

Usenik, V., J. Fabcic and F. Stampar (2008). Sugars, organic acids, phenolic composition and antioxidant activity of sweet cherry. Food Chem. 107: 185-192.

Wozniak, W., B. Radajewska, A. Reszelska-Sieciechowicz and I. Dejwor (1997). Sugars and acid content influence organoleptic evaluation of fruits of six strawberry cultivars from controlled cultivation. Acta Hort. 439(1): 333-336.

Youngjae, S., H.L. Rui, F.N. Jacqueline, H. Darryl and Christopher (2007). Temperature and relative humidity effects on quality, total ascorbic acid, phenolics and flavonoid concentrations and antioxidant activity of strawberry. Postharvest Bio and Tech. 45: 349-357.

Yuan, B.Z., J. Sun and S. Nishiyama (2003). Effect of drip irrigation on strawberry growth and yield inside a plastic green house. Bio Systems Eng. 87(2): 237-245.

Zhang M., C.L. Li, Y.J. Huan, Q.,Tao and H.O. Wang (2001). Preservation of fresh grapes at ice temperature high humidity. Int. Agro Physics. 15: 139-143.