Biochemical and Anatomical Characters of Snap Bean (*Phaseolus vulgaris* L.) Pods under Furrow and Drip Irrigation System at Harvest and during Postharvest

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Abstract: The biochemical and anatomical analysis of furrow and drip-irrigated pods at harvest and after postharvest were investigated. Results showed that, furrow-irrigated pods were significantly higher in the concentration of vitamin C, free phenolics, protein and proline as well as superoxide dismutase activity than drip-irrigated ones. On the other hand, concentration of free amino acids and activity of catalase were higher in drip-irrigated pods by about 4 and 1.7 times than furrow-irrigated ones, respectively. Both types of pods were similar in chlorophylls, carotenoids, TA (%), TSS and reducing sugars concentrations. The two pod types were similar in the anatomical parameters studied except that furrow-irrigated pods which showed an increase in the thickness of parenchymatous cells in the pericarp. During storage, furrow-irrigated pods stored at 7±1°C and 85% RH for 25d showed lower % of decay, rot, soggy and shriveling, but showed more water loss than drip-irrigated ones at all storage periods. Drip-irrigated pods maintained high concentration of chlorophylls and carotenoid than furrow-irrigated pods until 20 d of storage. Furrow-irrigated pods preserve the vitamin C at high concentration at all storage periods. TA (%) and TSS were increased with storage in both fruit types without any significant differences between them. Both pod types had the same trend in the concentration of organic compounds and the activity of antioxidative enzymes. Furrow-irrigated pods maintained their pericarp and symmetric of cells compared to drip-irrigated ones. It could conclude that furrow irrigation was better to produce visual appearance, high nutritional snap beans with high quality. It can be stored without deleterious effect for 25 d at 7±1°C and 85% RH than drip irrigation.

Keywords: Visual appearance, antioxidative enzymes, quality, biochemical and anatomical characters.

INTRODUCTION

In Egypt, snap bean (*Phaseolus vulgaris* L., Fabaceae) is one of the most valuable vegetable crops cultivated for local consumption, industry and exporting. It originated in Southern Mexico and warm regions of Guatemala (Singh *et al*., 1991). It is an excellent source of protein, ω-3 fatty acids, niacin, vitamins K, C, A, thiamin, riboflavin, folate, manganese, potassium, iron, copper, calcium and phosphorus. It has significant amounts of fibers which help in lowering blood cholesterol and hence reduce the chance of heart attack or stroke (Ouzounidoua *et al*., 2012). It is classified in the top ten among other common vegetables in relation to antioxidant content and activity (Ou *et al*., 2002). World production of green beans annually increased, reached to about 21.4 m ton in 2013, produced from about 1.54 m hectare, and China was the first producers by about 16 m ton. However, Egypt in the 6th rank produced about 263080 ton from 25071 hectare (FAO-STAT, 2013).

Like other plant species, irrigation is an important factor for growth and vigor of both snap bean plant and its pods. The trend in recent years has been towards conversion of furrow to drip irrigation which is considered to be a more efficient water delivery system. The effect of irrigation system on postharvest quality of snap beans hasn't been extensively studied (Sezen *et al*., 2008). Gabelman and Williams (1960) found that fiber development in pod of green beans is determined by genotypes and temperature than by soil moisture content. However, environmental factors such as temperature and irrigation influence the nutritional status such as ascorbic acid, ß-carotene, essential amino acids and other nutrients of vegetable crops (Harris, 1975). Lee *et al*. (1977) reported that interlocular cavitation in the susceptible varieties of green bean pods was associated with heavy irrigation during pod growth. However, Drake and Silbernagel (1982) found differential effect of irrigation systems on ascorbic acid content and color of the fresh green bean. The high amount of water with short intervals improved the yield and quality of beans under drip irrigation (Sezen *et al*., 2008). Although little is known about the effect of irrigation systems on postharvest quality, water shortage during growth has generally deleterious effect on pod weight loss during postharvest (Ferguson *et al*., 1999). The marketable yield of green bean increased with an increase in seasonal water applied approximately up to 410 mm and thereafter yield tended to decline (Kuscu *et al*., 2009).

Postharvest life of snap bean is limited by physiological disorders. Due to its tropical nature, it exhibit physiological disorders known as chilling injuries (CI) when they are exposed to low temperature, depending upon ripeness and variety, which is manifested by grayish scald-like discoloration of the skin, peel shriveling, brown spot incidence, water-soaking, skin pitting, uneven ripening, aroma and flavor reduction during ripening and susceptibility to fungal decay, which seriously reduces the fruit marketability (Watada and Morris, 1966). Poor quality in snap beans is often associated with fibrousness, shriveling due to water loss and chilling injuries and decay due to exposure to inappropriate temperatures (Cantwell, 2004).

It is widely accepted that symptoms of CI are a consequence of oxidative stress in the tissues occurring when reactive oxygen species (ROS) such as hydrogen

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peroxides, superoxides and hydroxyl radicals are in excess of the scavenging capacity of fresh tissue (Hodges *et al*., 2004). ROS destroyed the biomolecules in plant cells as DNA, RNA, proteins, Chlorophylls and Carbohydrates. Oxidative damage can be minimized by antioxidant defenses that scavenge or prevent the generation of ROS. Involvement of antioxidant enzymes in regulation of ROS can be followed by measuring superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) activity during postharvest storage. The first quencher of ROS is SOD, which converts superoxide (O_2^-) to H_2O_2 and then CAT destroyed it to $H_2O + O_2$ as well as POD but through intermediate as ascorbic acid or phenolic compounds (Sherwin, 1990 and El-Malak, 2007). Therefore, the present investigation aimed to compare the biochemical and anatomical characters of furrow and drip-irrigated snap bean pods at harvest and during postharvest period. In addition, the beneficial role of enzymatic and non-enzymatic antioxidant during cold stress was studied.

MATERIALS AND METHODS

Plant material, agricultural practices and irrigation requirements:

Field experiment was conducted in Helwan Export and Import private orchard, Ismailia Governorate, Egypt (30º 58′ N latitude, 32º23′ E longitude and 13 m above sea level) during 2013/14 season. In 15th of December seeds of snap bean, *Phaseolus vulgaris*, L. cv. *Paulista* were sown under furrow and drip irrigation system. The experimental plot area was 6 m^2 (2m x3m). Each plot included 5 rows, 20cm apart with 3m length and 0.4 m width. Four plots for each irrigation system were distributed according to blocks experimental design.

The climate in this region is almost arid with scarce annual rainfall of about 20 mm concentrated over the months of December to February, the temperature average is about 15.2°C during winter, and the relative humidity average is about 58.3%. The predicted monthly climatic data at Ismailia region during the growing seasons of snap beans are presented in Table (1). Soil physical and chemical properties were analyzed according to Grossmann and Reinsch (2002) and presented in Table (2). Both field capacity and wilting point were determined following the method of Cassel and Nielsen (1986). The irrigation amount was calculated with Penman-Monteith equation (Allen *et al*., 1998) depending on the predicted monthly climatic data (Table 1) during the growing periods (67 d from seed sowing until harvest) according to the crop coefficient (Kc) and the daily reference potential evapotranspiration (ETo). The latter was determined by Allen *et al*. (1996). The FAO Kc of snap bean plant was 0.6 for initial stage, 1.15 for mid-season stage and 0.8 for last-season stage. Irrigation amount was estimated by 1840 m^3/ha per season in furrow irrigation and plant consumed about 477.6 ml of water/season as well as 1081 m^3/ha per season with consumption about 895.5 ml of water/season in drip irrigation. All cultural practices for snap bean were applied as recommended.

Table (1): The predicted monthly climatic data at Ismailia Governorate during the growing periods of snap beans in 2013/14 season.

Months	Average temperature °C			Average RH (%)	Average Wind speed (m/sec.)
	Maximum	Minimum	Average		
December	19.7	8.50	14.1	58.2	3.0
January	21.1	9.00	15.1	58.3	3.6
Feb.	22.7	10.3	16.5	58.4	3.5

Data collected from Agriculture Research Center Meteorological Station in Ismailia.

Table (2): Soil physical and chemical properties of the experimental field soil.

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Hydraulic conductivity (cm h^{-1})	Texture class	Bulk density (g cm^{-3})
0-60cm	88.91	6.18	5.31	7.50	Sand	1.65

Soil depth (cm)	Field capacity (%)	Wilting point (%)	pH	Organic matter (%)	EC (dS m^{-1})
0-60cm	7.6	1.50	7.62	0.29	2.05

Postharvest conditions:

Precooling pods at 4ºC for 4h were transported to laboratory of Dept. of Agric. Bot. Fac. of Agric., Suez Canal Univ., Ismailia, Egypt. Samples of pods of uniform size and appearance were washed by chlorine solution (100 ppm for 15 min using Clorox 12%), air dried and held for 1 hour at 18ºC. Each treatment (100g ≈ 25 pods each) was packed in foam plates (22 cm length and 14 cm width) and covered with perforated polyethylene pages (40 pores with 5 mm width), as 10 replicates (5 plates were used in order to determine weight loss and visual properties; the others were used for chemical properties assessments). Pods were stored at 7±1ºC and 85% relative humidity (RH). Measurements were done at 5 days (d) intervals on 10 pods as 5 replicates of each treatment.

Visual appearances:

Description of chilling injury (%) as soggy tissue, brown spots and pericarp shrinking was rated on 125 pods for each treatment at 5d intervals. The (%) of fruit decay symptoms (chilling injuries and rots) were determined for each treatment during storage periods until the end of storage period.

Quantitative analysis:

Weight loss of pods was calculated as a transpire content of water (g) each 5 days intervals. Total soluble solide (TSS, brix^{o}) was measured by LCII-Digital Refractometer (Medline Scientific, United Kingdom, SR-95 digital, 0-90%).Total Acidity (TA, %) was determined by titrating pod sap with 0.05 N of NaOH up to pH 8.1, the results were expressed as (%) of malic acid according to A. O. A. C. (1990). Vitamin C concentration (mg g^{-1} FW) in the pods was determined by the 2,6 dichlorophenolindophenol method according to Pearson (1970).

Determination of organic compounds:

All analysis were done using UV/VIS spectrophotometer, PG instrument Ltd, USA. The photosynthetic pigments (chlorophyll a, b and carotenoids) were spectrophotometrically determined at 662, 644 and 440.5 nm, respectively (Arnon, 1949). Total chlorophylls were calculated as sum of Chl. a and Chl. b. To determine the following organic substances, ethanolic extraction of pods was prepared as described by Abdel-Rahman *et al*. (1975). Free phenolics concentration was determined by a modified Folin-Ciocalteu method at 650 nm according to William *et al*. (1965). Reducing sugars was determined by Nelson's method with alkaline copper and arsenomolybdate reagents as described by Moore (1974) at 540 nm. Total free amino acids concentration was estimated using the method of Rosen (1957) with ninhydrin reagent at 570 nm. Soluble proteins concentration was determined using Bradford method (1976) at 595 nm. Free proline was determined using acid ninhydrine reagent at 520 nm according to Bates *et al*. (1973).

Antioxidative enzymes assay:

According to Urbanek *et al*. (1991), 0.2 g pods was homogenized by using a mortar and pestle with 0.1 M phosphate buffer (pH 6.5) at 4ºC and stirred for 20 min. The suspension obtained was filtered through one layer of muslin cloth and then centrifuged at 18,000×g for 15 min, 4ºC. The supernatant was used to determine activity of enzymes and enzyme protein as follows:-

Superoxide dismutase (SOD, E.C.: 1.15.1.1) was assayed by measuring the oxidation of nitrobluetetrazolium at 560 nm. Peroxidase (POD, E.C.: 1.11.1.7) by measuring the oxidation of o-dianisidine at 430 nm. The SOD activity was expressed as unit per 100 mg of protein whereas one unit of peroxidase activity was taken as the change of 1.0 unit of optical density/100 mg protein minute according to Giannopolitis and Ries (1997). Catalase (CAT, E.C.:1.11.1.6) activity was estimated by measured the oxidation of H_2O_2at 240 nm in 30 s intervals for 5 min. The unit of CAT activity was defined as the amount of enzyme, which decomposes 1 mmol H_2O_2/100 mg protein min. at 25ºC (Urbanek *et al*., 1991).

Anatomical studies:

According to Willey (1971), pod pericarp specimens were killed and fixed in formalin acetic acid (F.A.A), dehydrated in ethyl alcohol series, embedded in Paraffin wax, sectioned to thickness of 15 µ, double stained with Safranin and Light green, cleared in Xylene and mounted in Canada balsam. All measurements were calculated by eyepiece micrometer at 10x (magnification 100x).

Statistical analyses:

All data were statistically analyzed as randomized complete blocks design (Steel *et al.,* 1997); using the MSTAT-C statistical package (M-STAT, 1990) and means were separated by LSD test, $P \leq 0.05$.

RESULTS

Effect of irrigation system on Chemical composition of snap bean pods at harvest:

Data in Table (3) showed that furrow-irrigated pods were significantly higher in the concentration of vitamin C, free phenolics, soluble protein and proline as well as high activity of superoxide dismutase (SOD) than drip-irrigated ones. Double amount of vitamin C was detected in furrow-irrigated pods over drip irrigated ones. Also, free phenolics, protein and proline concentration increased by about 22.5, 33.8 and 50.2% in furrow irrigated pods over drip-irrigated pods, respectively. However, concentration of free amino acids and activity of catalase were higher by 4 and 1.7 times in drip-irrigated pods than furrow-irrigated ones, respectively. Also, drip-irrigated pods had higher activity of peroxidase by 34.8% than furrow-irrigated ones. There weren't any significant differences in the concentration of chlorophyll a, b, carotenoids, total chlorophylls, total acidity (TA, %) total soluble solids (TSS) and reducing sugars between the both types of pods.

Pod weight loss (g):

The loss of water was decreased with the extend of storage period in both types of pods. At all storage periods, drip-irrigated pods lost less water (g) than furrow-irrigated ones (Table 3). The maximum amount of water loss was 13.83 g in furrow-irrigated pods after 5 d of storage. Furrow-irrigated pods lost water over the

Table (3): Chemical characters of furrow and drip-irrigated pods of snap bean at harvest and during different periods of storage at 7±1°C and 85%RH for 25days.

Chemical compounds concentration and enzyme activity	furrow-irrigated pods						Drip-irrigated pods					
	At harvest	Storage periods (day)					At harvest	Storage periods (day)				
		5	10	15	20	25		5	10	15	20	25
Weight loss (g)	0.00	13.83 a	6.66 a	6.03 a	4.46 a	3.73 a	0.00	10.30 b	5.06 b	4.26 b	1.53 b	1.40 b
Chlorophyll a (mg $100g^{-1}$ FW)	5.87 a	2.06 a	3.76 a	3.10 b	2.20 b	2.13 b	5.73 a	1.23 b	2.70 b	4.60 a	5.06 a	2.66 a
Chlorophyll b (mg $100g^{-1}$ FW)	3.83 a	1.46 a	2.66 a	2.73 b	1.86 b	1.80 a	3.77 a	0.86 b	2.60 a	4.16 a	4.70 a	2.16 a
Total chlorophylls (mg $100g^{-1}$ FW)	9.70 a	3.56 a	6.43 a	5.83 b	4.10 b	3.93 a	9.50 a	2.10 b	5.30 b	8.80 a	9.76 a	4.83 a
Carotenoids (mg $100g^{-1}$ FW)	4.63 a	1.56 a	2.70 a	2.26 b	1.90 b	1.83 b	4.57 a	1.06 b	2.03 b	3.26 a	3.83 a	2.46 a
Total acidity (%)	0.03 a	0.040 a	0.043 a	0.060 a	0.070 a	0.110 a	0.03 a	0.040 a	0.050 a	0.070 a	0.076 a	0.090 a
Total soluble solids (brix°)	4.60 a	5.90 a	6.66 a	6.80 a	6.93 a	7.03 b	4.37 a	4.26 b	5.06 b	5.83 b	6.33 b	7.90 a
Vitamin C (mg g^{-1} FW)	6.00 a	10.83 a	7.50 a	6.83 a	4.00 a	5.83 a	2.50 b	5.50 b	8.00 a	5.83 a	3.50 a	3.00 b
Reducing sugars (mg g^{-1} FW)	31.23 a	16.33 a	16.90 b	17.03 b	15.76 a	15.50 a	32.30 a	14.73 a	20.00 a	22.86 a	15.66 a	15.56 a
Free phenolics (mg $100g^{-1}$ FW)	125.70 a	91.43 a	94.30 a	147.50 a	148.90 a	183.20 a	102.60 b	75.73 b	79.66 b	118.90 b	123.00 b	154.76 b
Free amino acids (mg $100g^{-1}$ FW)	4.13 b	12.06 a	52.13 a	75.53 a	31.83 a	30.80 a	16.73 a	5.80 b	13.23 b	21.13 b	11.06 b	11.06 b
Protein (mg g^{-1} FW)	17.17 a	21.40 a	22.90 a	46.26 a	69.96 a	63.76 b	12.83 b	12.13 b	19.76 b	46.43 a	72.00 a	77.10 a
Proline (mg $100g^{-1}$ FW)	13.37 a	8.13 a	8.50 b	15.46 b	19.20 a	16.10 a	8.90 b	6.23 a	13.70 a	21.80 a	17.53 a	8.73 b
Superoxide dismutase (unit $100g^{-1}$ protein min)	1.43 a	1.46 b	0.67 b	0.03 a	0.02 a	0.02 a	0.89 b	2.36 a	1.27 a	0.03 a	0.02 a	0.02 a
Peroxidase (unit $100g^{-1}$ protein min)	4.43 b	5.13 a	5.70 a	2.40 b	1.13 b	0.30 a	5.97 a	2.30 b	3.23 b	3.43 a	1.60 a	0.40 a
Catalase (unit $100g^{-1}$ protein min)	0.07 b	0.073 a	0.103 a	0.030 a	0	0 b	0.12 a	0.070 a	0 b	0 b	0	0.030 a

Values followed by the same letter within a row are not significantly different at L.S.D, $P \leq 0.05$ level of probability

drip-irrigated ones by about 34.3, 31.6 and 41.5 % after 5, 10 and 15 d of storage, respectively. The loss of water increased by about 2.9 and 2.6 times at 20 and 25 d of storage, respectively.

Photosynthetic pigments concentration in pods:

At all storage periods, the drip-irrigated pods maintained more chlorophyll a, b and carotenoids concentration than furrow-irrigated pods (Table 3). The concentration of chlorophyll a and b increased until 15 and 20 d of storage in furrow and drip-irrigated pods, respectively then decreased. Total chlorophylls and carotenoids increased until 10 and 20 d of storage in furrow and drip-irrigated pods, respectively, then decreased. The maximum concentration of chlorophyll a, b, total chlorophylls and carotenoids was 5.06, 4.7, 9.76 and 3.83 mg 100 g^{-1} FW in drip-irrigated pods after 20 d of storage, respectively.

Fruit quality:

TA % and TSS increased in both types of pods during all storage periods (Table 3). The concentration of vitamin C was increased until 5 and 10 d of storage in furrow and drip-irrigated pods, respectively. Furrow-irrigated fruits showed higher concentration of vitamin C than drip-irrigated ones. There weren't any significant differences in TA (%) in both pods types at all storage periods. The maximum value of vitamin C (10.83 mg g^{-1} FW) and TA (0.11%) were detected after 25 and 5 d of storage in furrow-irrigated pods and TSS (7.9) in drip-irrigated ones at the end of storage, respectively. The values of TSS were only significantly differed at the initial and end period of storage between both types of pods.

Organic compounds concentration:

Furrow and drip-irrigated pods were similar in the trend of organic compounds concentration during storage (Table 3). Reducing sugars and free amino acids concentrations were increased until 15 d of storage, and then decreased in both types of pods. Free phenolics and protein were increased at all storage periods in both types of pods. Proline concentration was increased until 20 d of storage then decreased in both types. Furrow-irrigated pods preserve more amounts of amino acids and free phenolic concentrations than drip-irrigated ones, whereas the maximum significant values were 75.53 and 183.2 mg 100g^{-1} FW after 15 and 25 d of storage, respectively. However, the drip-irrigated pods gave the maximum significant values of reducing sugars, proline and protein concentration (22.86, 21.8 and 77.1) after 15 and 25 d of storage, respectively.

Antioxidative enzymes activity:

Table (3) showed also that, activity of SOD gradually decreased at all storage periods in both pod types. Peroxidase activity increased until 10 and 15 d of storage in furrow and drip-irrigated pods, respectively. Catalase activity was increased until 10 d then decreased in furrow irrigated pods. No activity of CAT was detected after 10 and 20d of storage in furrow and drip-irrigated pods, respectively. The maximum activity of SOD was 2.36 unit 100 g^{-1} protein min. after 5 d of storage in drip-irrigated pods. The maximum activity of POD and CAT was 5.7 and 0.103 unit 100 g^{-1} protein min. after 10 d of storage in furrow-irrigated pods. SOD activity was higher during 10 d of storage in drip-irrigated pods than furrow-irrigated ones. Peroxidase and catalase activities were higher during 10 d of storage in furrow-irrigated pods than drip-irrigated ones.

Pods decay, rot (%) and chilling injuries disorders of furrow and drip-irrigated pods during storage:

Pod decay (%) was calculated in fruits as sum of fruit rot and chilling injuries disorders during 25 d of storage at 7±1ºC and 85%RH. Decaying of pods was induced by chilling injuries more than rotting (Table 4). Furrow-irrigated pods showed lower decay (%) and non-rotted pods than drip-irrigated ones at all investigated periods of storage. However, chilling injuries were observed on fruits as soggy tissues, brown spots and fruit shrinking. Furrow-irrigated pods showed less soggy tissue (%) than drip-irrigated ones at all investigated periods during storage. There weren't any brown spots on both types of pods until 20 d of storage but it was detected at the end of storage period. Shrinking of fruits wasn't observed in furrow-irrigated pods until the end of storage and up to 15 d of storage in drip-irrigated ones.

Anatomical characters of the pericarp at harvest:

Thickness of epidermis with cuticle, parenchyma between epidermis and fibers, fibrous tissue and vascular bundle at maximum radius of furrow-irrigated pods were higher than drip-irrigated ones (Table 5 and Fig. 1). All previous parameters weren't significantly different except the thickness of parenchyma between epidermis and fibers. Moreover, there weren't any differences in the thickness of pericarp in both furrow and drip-irrigated pods. Lysigenous intercellular spaces in pericarp weren't found and parenchyma cells were symmetric in both types of pods.

Anatomical characters of the pericarp at the end of storage:

Pericarp in furrow-irrigated pods was doubled in thickness (µm) compared to drip-irrigated fruits at the end of storage as shown in (Table 5 and Fig. 1). However, there weren't any differences in thickness of epidermis with cuticle, parenchyma between epidermis and fibers, fibrous tissue and vascular bundle at maximum radius between both types of pods. Lysigenous intercellular spaces and symmetric parenchyma were observed in furrow-irrigated pericarp compared to drip-irrigated pericarp.

DISCUSSION

Results showed that, pods of snap bean synthesized more secondary metabolites as vitamin C, phenolics and proline. These findings can be explained as plants under furrow irrigation had relatively suffered from water deficit due to the longevity of irrigation periods than drip-irrigated ones. This remark went parallel with that snap bean plant consumed about 477.6 ml of water/season or 7 ml of water/day in furrow irrigation compared to 895.5 ml of water/season or13.3 ml of water/day in drip irrigation. Also, the activity of SOD, the first antioxidant enzyme which converts superoxide to hydrogen peroxide was higher.

Table (4): Total decay, chilling injuries of snap beans at different storage periods at 7±1°C and 85%RH for 25days.

Visual appearances (%)		Furrow-irrigated pods					Drip-irrigated pods				
		Storage periods (day)					Storage periods (day)				
		5	10	15	20	25	5	10	15	20	25
Total decay		0 b	19.32 b	19.32 b	19.32 b	28.41 b	5.88 a	22.06 a	26.47 a	27.94 a	54.41 a
Pods rot		0	0	0 b	0	0 b	0	0	11.76 a	0	47.06 a
Chilling injuries	**Soggy tissues**	0 b	77.27 b	77.27 b	77.27 b	86.36 b	23.53 a	88.24 a	94.12 a	100 a	100 a
	Brown spots	0	0	0	0	27.27 a	0	0	0	0	23.53 b
	Shrinking	0	0	0	0 b	0 b	0	0	0	11.76 a	47.06 a

Values followed by the same letter within a row are not significantly different at L.S.D, P ≤ 0.05 level of probability

Table (5): Anatomical characters of the pericarp of furrow and drip-irrigated pods at harvest and after 25 days of storage.

Irrigation system	Thickness in µm of:					Lysigenous intercellular spaces	(Un)symmetric Parenchyma
	Epidermis with cuticle	Parenchyma between epidermis and fibers	Fibrous tissue	Pericarp	Vascular bundle at maximum radius		
				At harvest			
Furrow	5.23 a	85.23 a	5.23 a	253.33 a	8.90 a	-	Symmetric
Drip	4.77 a	66.67 b	4.30 a	255.57 a	5.70 a	-	Symmetric
				After 25 d of storage			
Furrow	3.83 a	62.86 a	5.70 a	248.86 a	15.56 a	+	Symmetric
Drip	3.83 a	62.86 a	5.23 a	177.76 b	13.33 a	-	Unsymmetric

Values followed by the same letter within a column are not significantly different at L.S.D, P ≤ 0.05 level of probability.

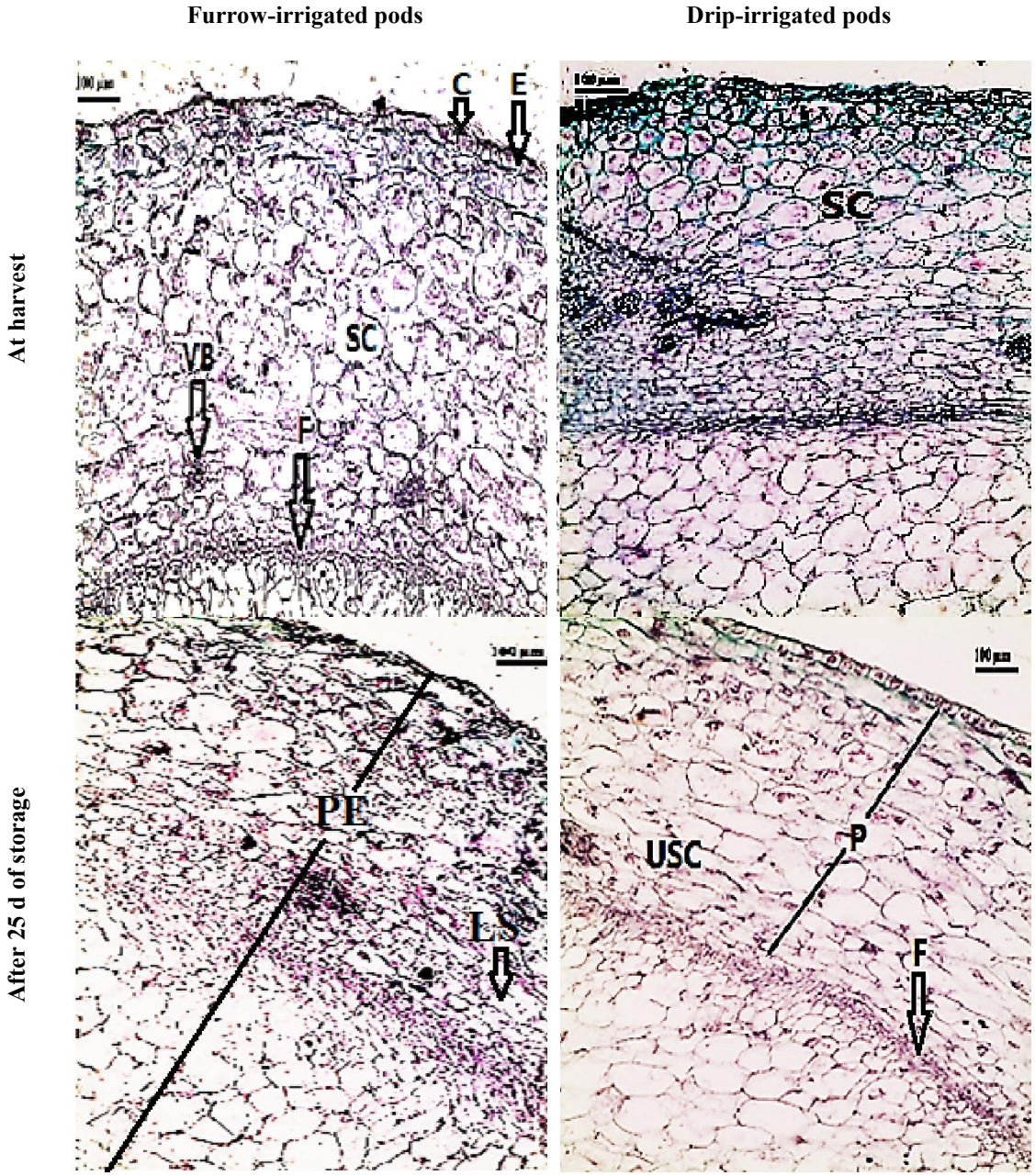

Fig. (1): Transverse sections **(100X)** of the pericarp of furrow and drip-irrigated pods of snap bean at harvest and after 25d of storage, **E** (Epidermis); **C** (Cuticle); **P** (Parenchyma); **PE** (Pericarp); **F** (Fibrous tissue); **VB** (Vascular bundle); **LS** (Lysigenous intercellular spaces); **SC** (Symmetric Parenchyma); **USC** (Unsymmetric Parenchyma).

Similar results were reported by Toivonen *et al*. (1994), Sorensen *et al*. (1995), and Taiz and Zeiger (2002). In this context, Harris (1975) reported that content of ascorbic acid and other nutrients of vegetable crops depended on irrigation and rainfall rate.

On the other hand, no differences were found in the concentration of all determined photosynthetic pigments as chlorophyll a, b, total chlorophylls, carotenoids, TA (%), TSS and reducing sugars between furrow and drip-irrigated pods. These results disagreed with Harris (1975), who reported that content of ß-carotene and essential amino acids differed according to irrigation and rainfall rate.

During storage, decaying of pods was induced by chilling injuries more than rotting (Table 2). These results may be due to the efficiency of chlorine sterilization (Soltan *et al*., 2006). Low decay % was accompanied by high initial concentration of furrow-irrigated pods in antioxidant enzyme, SOD and non-enzymatic compounds, vitamin C, proline and phenolics which quenched different types of reactive oxygen species (ROS), responsible for cell destruction (Shewfelt and Del-Rosario, 2000). Taiz and Zeiger (2002) added that, cuticle layer represented external barrier against pathogens.

Low soggy tissue contributed with the high water loss of furrow-irrigated pods compared to drip-irrigated ones. Therefore, its water content gradually decreased. Brown spots may not be correlated with formation of ROS in pod cells, which contributed with the minimum activity of SOD. Results are in agreement with Cantwell (2004) and Zong *et al*. (1992) who found that general

symptoms of CI in snap beans include opaque discoloration of the entire bean, surface pitting, russeting, brown elongated spots, and water loss. Also, at 5–7.5ºC, the most common symptom of CI is the appearance of isolated rusty brown spots. Low shriveling contributed with the lower loss of water and thereby cell turgidity (Table 4) as well as symmetric of cells, especially in furrow-irrigated pods. High water loss contributed with rapture of pod cell walls (lysigenous cells) as shown in cross section of furrow-irrigated pods compared to drip-irrigated ones (Table 5 and Fig. 1).

The lower water loss in drip-irrigated pods contributed with the high concentration of reducing sugars (Table 3) which cohesive the water molecules in cell vacuoles (Taiz and Ziger, 2002). Also, Kays (1991) found that, exposure of snap beans to chilling temperatures (at 0 or 5ºC) might have resulted in loss of cell membrane integrity and leakage of solutes and water, which often leads to manifest of CI symptoms such as pitting and wilting. In addition, weight loss was significantly decreased in all periods of storage for all treatments under study, due to reduction of transpiration and respiration rate under cooling (Taiz and Ziger, 2002).

The activity of SOD, POD and CAT enzyme decreased in most cases with storage due to the long-term of storage (25 d). No activity of CAT was determined in the final periods of storage, may be due to snap bean dependence on SOD which firstly quenched superoxide radicals and subsequent POD which transform hydrogen peroxide with ascorbic acid or phenolics as intermediate to water molecules and oxygen under cold stress. These results were coordinated with Ray (2006) who found that plants often develop thick cuticles when grown under water shortage conditions compared to adequate water conditions around the root zone. Burzo *et al*. (1994) found that, beans stored at 0 or 3ºC for 10 days developed CI pitting that showed deterioration of the epidermal and first layer of hypodermal cells and was later invaded by fungi, while pit-free tissue maintained its characteristic structure. Watada and Morris (1966) reported that, as the pod became yellow, the endocarp began to collapse and internal cavities formed. The quality declined more rapidly at the beginning of storage than later on, and after approximately 10–12 days at 15°C quality of cvs. Top Crop, Romano, Tender green and Blue Lake snap beans was considered fair. These results demonstrated that, furrow-irrigated pods were more tolerant to postharvest quality loss compared to drip-irrigated ones, due to preservations of its pericarp from collapse. Also, the cold storage improved the quality of pods, whereas its fibrous tissue was decreased.

CONCLUSION

Furrow irrigation system was beneficial tools to produce high nutritional snap beans compared to drip irrigation system. Furrow-irrigated pods can be stored for 25 d at 7±1ºC and 85% RH without decay or chilling injuries compared to drip-irrigated pods.

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الصفات الكيميائية والتشريحية لقرون الفاصوليا الخضراء تحت نظامي الري بالغمر والتنقيط أثناء الحصاد وما بعد الحصاد

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أظهرت دراسة الصفات الكيميائية والتشريحية لقرون الفاصوليا الخضراء تحت نظام رى الغمر والتنقيط عند الحصاد أن ثمار ري الغمر كانت أعلى في محتواها من فيتامين ج والفينولات والبروتين والبرولين بالإضافة إلى النشاط العالي لإنزيم السوبرأوكسيد ديسميوتيز مقارنة بقرون ري التنقيط. بينما أظهرت الأخيرة ارتفاع محتواها من الأحماض الأمينية بمقدار ٤ مرات ونشاط إنزيم الكتاليز بمقدار ١.٧ مرة مقارنة بقرون ري الغمر. تشابه كلا نوعى الثمار في محتوى الكلوروفيلات والكاروتينيدات والحموضة الكلية والمواد الصلبة الذائبة الكلية والسكريات المختزلة. كما تشابه كلا نوعى الثمار في الصفات التشريحية للغلاف الثمرى بإستثناء ثمار ري الغمر التي سجلت أعلى سمك للأنسجة البارانشيمية للغلاف الثمرى. أظهرت ثمار ري الغمر المخزنة على ٧±١°م ورطوبة نسبية ٨٥٪ لمدة ٢٥ يوم أقل نسبة مئوية من التلف الكلى والعفن والأنسجة المائية والكرمشة للثمار ولكنها أظهرت أكبر فقد للماء مقارنة بقرون ري التنقيط في جميع مراحل التخزين. إحتفظت قرون ري التنقيط بمحتوى عالي من الكلوروفيلات والكاروتينيدات مقارنة بقرون ري الغمر حتى ٢٠ يوم من التخزين. إحتفظت قرون ري الغمر بتركيز عالي من فيتامين ج في جميع مراحل التخزين. إزدادت النسبة المئوية للحموضة الكلية والمواد الصلبة الذائبة الكلية مع التخزين في كلا نوعى الثمار بدون أي اختلافات معنوية بينهما. أظهرت كلا نوعى الثمار تركيز متشابهفى المركبات العضوية ونشاط مضادات الأكسدة الإنزيمية. إحتفظت قرون ري الغمر بسمك الغلاف الثمرى و خلاياه المتماثلة الأقطار مقارنة بقرون ري التنقيط. ويتضح مما سبق أن نظام الري بالغمر هو النظام الأفضل لإنتاج فاصوليا خضراء ذات محتوى غذائي عالي كما يمكن تخزينها بدون إظهار تأثيرات ضارة لمدة ٢٥ يوم على ٧±١°م ورطوبة نسبية ٨٥% مقارنة بقرون ري التنقيط.