TECHNISCHE UNIVERSITÄT MÜNCHEN

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# Effect of Horticultural Practices on Improving Productivity and Fruit Quality of 'Crimson Seedless' Grapes

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# DEDICATION

To the spirit of my beloved mother, who learnt me the first words in my life, gave me her kindness, spent the nights to look after my childhood, and struggled in her life to breed, educate and humanize.

To spirit of my lovely father, who embraced me during his life and learnt me the manliness and endurance.

I dedicate all my achievements.

I ask ALLAH to bestow the grace upon them, even as they cherished and reared me when I was a child

Also, I ask ALLAH to forgive, and imparadise them.

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# 1 Introduction

## 1.1 Description of 'Crimson Seedless' grapes

'Crimson Seedless' grape (*Vitis vinifera)* is a late-season, attractive, red seedless grape cultivar with firm berries developed by David Ramming and Ron Tarailo of the USDA Fruit Genetics and Breeding Research Unit, Fresno, CA., USA. It was introduced in 1989, it fills the need for a red seedless cultivar for fresh market and provides a seedless alternative to 'Emperor', a late ripening, red and seeded grape (Ramming *et al.* 1995).

'Crimson Seedless' (previously known as selection C 102-26) is the result of five generations of hybridization of the U.S. Dept. of Agriculture, Horticultural Field Station in Fresno, California, starting in 1926 (Fig.1).

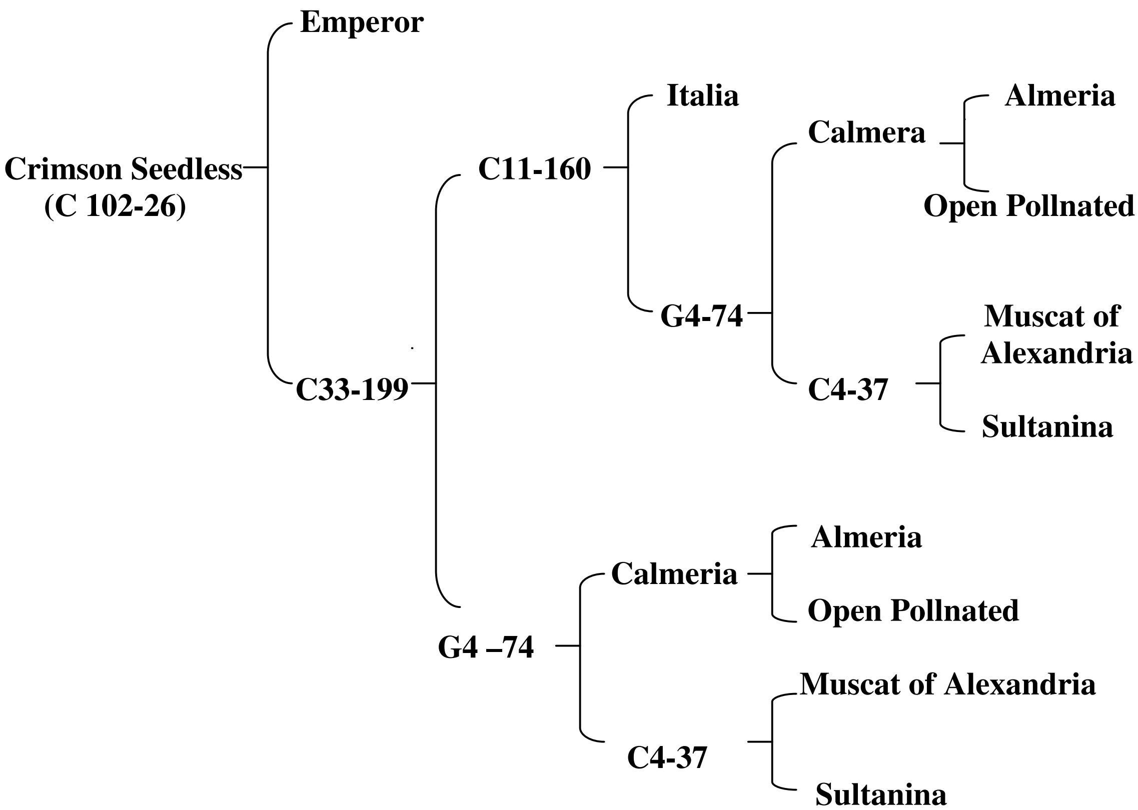



**Fig. 1.** Parentage of 'Crimson Seedless' grapes (Ramming *et al*., 1995).

The source of seedlessness is 'Sultanina' (Thompson Seedless), which was used as a parent in the first generation of crossing. C33-199, a late-ripening, white seedless grape (with all white grapes in its parentage), was used in the final hybridization with 'Emperor' to produce 'Crimson Seedless'. The cross was made in 1979 and consisted of 1222 emasculated and pollinated flowers that produced 151 seeds. The 85 resultant seedlings were planted in 1980 in research plots in cooperation with California State Univ., Fresno. 4 seedlings were selected (two had seeded red fruit, one had seedless white fruit, and one had seedless red fruit). 'Crimson Seedless' was selected in 1983 and tested as C102-26 (Ramming *et al.* 1995).

Recently, 'Crimson Seedless' is one of the most important table grape cultivars in California, with 8000 acres planted in the San Joaquin Valley since 1989. The vines are very vigorous on their own roots, the fruits ripen in mid-September and, weather permitting, can be held on the vine through mid-November and the vines produced medium sized, compact fruit clusters 0.5 kg in weight. The berries are bright red averaging 4 g, the flavor being sweet, neutral and very good and the variety holds significant promise for commercial producers due to excellent eating characteristics, late maturity, seedless, and berry texture is crisp and firm., but poor color and small berry size are the primary fruit quality problems (Dokoozlian *et al.* 2000).

### 1.2 'Crimson Seedless' grapes in the world

'Crimson Seedless' was evaluated for their suitability to production in different regions of the world. In Egypt, there is an expansion in growing area of 'Crimson Seedless' grape to meet demand because the Egyptian grape growers are looking at the potential of a new export window into the European markets in October and early November, in addition to their usual sendings in June and July. Aspects considered are: (1) Egyptian grape season (May to Nov.); (2) Egyptian trails with 'Crimson Seedless' grapes; (3) importance of Egypt as a source of grape varieties such as 'Superior Seedless' (Sugarone), 'Flame Seedless', and 'Thompson Seedless' grapes (MacCarthy, 1998). Also, Abdel-Hamid (2000) achieved to delay ripening and improve storability of 'Crimson Seedless' grapes. El-Baz *et al.* (2002) defined the suitable cane pruning level. In China, it was the best dessert for the area south of Tian Shan, Xinjiang and Jiouxuan district, Gansu (He, 1995). In various regions of Sao Paulo state, Brazil, the cultivar considered suitable for growing, it characterized as a mid-season cultivar with medium-sized clusters (460-620 g weight, 18-30 cm length) which are slightly compact. The berries are large, averaging 3.5-8.0 g, 16-21 mm in diameter and 18-30 mm in length, and are cylindrical to oval in shape (Pommer *et al.* 1999).

In southern Italy, the cultivation of 'Crimson Seedless' grapes is labor intensive. The trellis should be covered with a plastic film to optimize climatic conditions, and the bunches themselves should be thinned to allow space for remaining berries to develop (Colapietra, 2000 ; Colapietra and Amico 2000).

In the lower Sao Francisco Valley, Bahia state, Brazil, the duration of the phenological cycle of 'Crimson Seedless' grapes was 123 days and the corresponding to a thermal demand accumulated during this period of 1756.9 °C. The variety presented good characteristics of bunches and berries, had a TSS/acidity ratio suitable for market, and average yield of 13 kg /vine (De Souza-Leao 2002).

'Crimson Seedless' is fast becoming the preferred red seedless grape in supermarkets worldwide because of their exceptional shelf life as well as it has a very distinctive, sweet, juicy flavor and elongated, pale pink berries. They have a crisp, firm skin with a juicy pulp. It has a high sugar content, with half as glucose, and half as fructose. (Perfection Fresh, 2007).

### 1.3 Problems of 'Crimson seedless' grapes:

'Crimson Seedless' grapes include the following problems according to Dokoozlian *et al.* (2000):

(1) The primary problem associated with the production of "Crimson Seedless" that it lacks sufficient berry color.

(2) Small berry size can also be a problem and cultural practices that increase the berry size of "Crimson Seedless" (such as GA) further reduce the color of its berries.

(3) "Crimson Seedless" is highly vigorous. Vines become excessively vegetative growth when planted in deep, fertile soils. So, the soils of moderate vigorous are preferred for planting.

(4) The excessive N fertilization and irrigation should be avoided to reduce potential problems with excessive vigorous.

(5) This variety is low fruitfulness for spur pruning. As a result, most of the "Crimson Seedless" vineyards are head trained and cane pruned. Due to the low fruitfulness often observed on highly vigorous "Crimson Seedless", it may be necessary to retain up to 8 canes to insure adequate productivity.

(6) As a result to the high vigorous of this variety, The vine's productivity and fruit quality should be improved with the use of large, extensive trellis systems such as the Gable trellis system.

(7) The Canopy management practices are very necessary to improve the fruit quality of "Crimson Seedless".

## 1.4 Outline of the studied trails:

This study was conducted by fruitful cooperation between Unit of Fruit Science, Center of Life Sciences Weihenstephan (WZW), Technische Universtät München (TUM), Freising, Germany and National Research Center (NRC), Cairo, Egypt and supported by Egyptian Government, Ministry of Higher Education, Mission Dept. in Cairo and Cultural Dept. & Study Mission in Berlin, Germany.

It is well known that increasing yield and improving fruit quality of grapes have been often attributed to appropriate supply of mineral nutrients. Nitrogen and potassium are the two fertilizer elements that are most important in vineyards.

Furthermore, defoliation and fruit thinning play an essential role in improving fruit quality of grapevines. Therefore, the presented studies are divided into two parts of horticultural practices (N&K fertilization as well as defoliation & fruit thinning).

## 1.5 Objectives of this thesis:

This investigation was established to solve aforementioned problems of ‘Crimson Seedless’ grapes and further realize the following three specific objectives :

(A) Define the most efficient rate of N and K fertilization by studying the effect of different N and K fertilization rates on vine nutritional status, yield, bud behaviour, growth vigor, and fruit quality.

(B) Define the proper canopy management practices which improve fruit quality and study the effect of fruit thinning on the fruit quality.

(C) Determination and identification the flavonoids and other phenolic compounds in fruit which are responsible for color, flavor and antioxidant properties as affect by N and K fertilization, several severity of leaf removal and fruit thinning practices.

Considering the importance of N and K fertilization, defoliation and fruit thinning practices for ‘Crimson Seedless’ grapes, until now, little is known about how they can improve the productivity and fruit quality especially, flavonoid and other phenolic compounds in ‘Crimson Seedless’ grapes.

# 2 Review of literature

## 2.1 Function of nitrogen and potassium in plants

Professional fruit growing requires regular supplement of minerals to warrant fruit set and quality. Among the major nutrients, nitrogen and potassium are the most important elements in viticulture nutrition and play an essential role for vine production and grape quality. Downey *et al.* (2006) mentioned that of the three nutrients commonly applied as fertilizer in vineyards (nitrogen, potassium and phosphate) only nitrogen and potassium have thus far attracted viticultural research.

Concerning to the function of nitrogen in the plant, nitrogen is a primary nutrient to achieve maximum crop yield. Plants absorb nitrogen in the greatest amount of any essential nutrients. Depending on the plant species development stage and organ, the nitrogen content required for optimal growth varies between 2 and 5 % of the plant dry weight (Marschner, 1995). Excessive nitrogen fertilization supports tree and fruit growth and therefore is a prominent controlling tool for yield

Nitrogen is an essential constituent of metabolically active compounds such as proteins, enzymes, nucleic acids and chlorophyll. N plays a major role in cell division and improves photosynthesis process, which results in higher accumulation of organic matter in plant tissues. When nitrogen is a limiting factor, the rate and extent of protein synthesis are depressed and as result plant growth is affected, moreover, plant gets stunted and develops chlorosis. Inadequate nitrogen supply often is the growth-limiting nutritional stress in the field. Consequently, addition of N usually improves plant growth and yield.

Carbon and nitrogen metabolism are closely interlinked. Inorganic nitrogen is required to allow carbohydrates to be utilized for growth, and photosynthesis or, in non-photosynthetic tissues, carbohydrate breakdown provide reduction equivalents, ATP and carbon skeletons to support the assimilation of inorganic nitrogen and the synthesis of nitrogen-containing metabolites such as amino acids and nucleotides (Stitt and Krapp, 1999).

The quality of fruit produced by grapevine is strongly influenced by nitrogen availability. Soils with high nitrogen availability can promote excessive vigor, resulting shaded canopies and poor fruit quality. Vineyard soil management techniques can be adopted to reduce soil nitrogen levels where these would be deemed too high for production of quality grapes (Wheeler and Pickering, 2003).

Considering the importance of N fertilization for color of grape berries, excessive levels of nitrogen to vine delay ripening (Keller *et al.* 1999) and poorly colored fruit (Kliewer, 1977, Spayd *et al.* 1994). It caused also a more vegetative growth, which competes with sugar translocation and pigment accumulation to the grape. On the other side, low nitrogen levels have been shown to decrease color in grape berries (Kliewer 1977, Keller and Hrazdina 1998, Delgado *et al.* 2004). Generally, Martin *et al.* (2004) found that average dose of nitrogen (50 g N/vine) compared with the untreated control vine (0 g N/vine) and high dose (200 g N/vine) for 'Tempranillo' grapes increased the levels of anthocyanins in the skin.

Regarding to the function of potassium in the plant, potassium is the mineral nutrient required in the largest amount by plants. It is the most prominent inorganic plant solute and is the only mineral nutrient that is no constituent of organic structures. Its function is mainly in osmoregulation, the maintenance of electrochemical equilibria in cells and the regulation of enzyme activities (Hsiao and Läuchli 1986).

Potassium is an essential element for all living organisms. The important roles of K in plants can be grouped into four physiological-biochemical roles: (1) enzyme activation (Leigh and Wyn Jones 1984, Walker *et al.* 1996); (2) cellular membrane transport processes and translocation of assimilates (Salisbury and Ross 1992, Patrick *et al.* 2001); (3) anion neutralisation, which is essential in maintenance of membrane potential (Maathuis and Sanders 1996, Leigh 2001); and (4) osmotic potential regulation, which is one of the important mechanisms in the control of plant water relations, turgor maintenance and growth (Davies and Zhang 1991).

Potassium has a crucial role in the energy status of the plant, translocation and storage of assimilates and maintenance of tissue water relation (Marschner 1995). K plays a key role in production of crop quality. It improves the size of fruit and stimulates root growth. It is necessary for the translocation of sugars and formation of carbohydrates. K also provides resistance against pest and diseases and drought as well as frost stress (Imas and Bansal 1999).

In grape berries, potassium is the most abundant cation where it contributes to charge balance and may be involved in sugar transport (Lang 1983). Potassium reduces acid levels in berries and interacts with tartaric acid to form potassium bitartrate, which has limited solubility (Sommers 1977). Higher potassium supplies increased the total soluble solids content and decreased the total acidity of berries (Martin *et al.* 2004).

Adequate potassium nutrition helps to increase both coloring and polyphenolic content of berries (Mohammed et al. 1993), while high potassium has been reported to decrease color in grapes (Morris et al. 1983, Jackson and Lombard 1993).

The most likely mechanism for decreasing phenolic content at high nutrient levels of nitrogen and potassium is excessive vigor (Downey *et al.* 2006).

## 2.2 Effect of N and K fertilization on the nutritional status

The leaf is the major metabolic organ on the grapevine, and thus foliar mineral analysis has been used as a diagnostic tool to evaluate vine performance and grape quality for several decades (Fallahi 2005).

Numerous trails with *Vitis vinifera* cultivars have been conducted to investigate the effect of N fertilization on leaf N-content in the petioles. So, there is data indicating that N exerts a positive influence on N-uptake by vines (Ewart and Kliewer (1977) on several grape cultivars, Aceituno *et al*. (1987), on 'Pedro Ximenez' cv, Ahlawat *et al*. (1988) on 'Perlette', Wafik *et al*. (1989) on 'Rommy Red', Spayd *et al.* (2000) and Schreiber *et al.* (2002) on 'Riesling' vines, Davenport *et al.* (2003) and Cheng *et al.* (2004) on 'Concord' grapes, Salem *et al*. (2004) on 'Thompson Seedless').

This conclusion was also achieved by El-Garhy (1990) as well as Wasnik and Bharagava (1992) on 'Thompson Seedless', Yu and Cahoon (1990) and Gao and Cahoon (1991) on 'Concord', Maigre and Murisier (1991) and Jackson and Lombard (1993), James and John (1993) on 'Muscadine' grapes, Christensen *et al*. (1994) on 'Barbera', 'Grenache', 'French Colombard' and 'Chenin blanc', Nadia (1994) on 'Italia', 'Thompson seedless' and 'Roomy Red', Keller *et al*. (1995) on 'Riesling' grapevines, Yasuda *et al*. (1998) on 'Kyoho', Abd-El-Mohsen (2003) on 'Flame Seedless' grapes.

However, Licina (1999) showed that N-application rate had no significant effect on leaf N-content at the end of each season on 'Cabernet Sauvignon' grapevines.

Peacock *et al.* (1991) evaluated the effect of summer or late September N fertilizer applications on N utilization, vine response, and fruit development in four mature, cvs. 'Thompson Seedless' and 'Flame Seedless'. Ammonium nitrate (50 kg N /ha) was applied to soil either at budbreak, fruit set, veraison, late September (postharvest), or split (fruit set + late September) and compared to an unfertilized control over three years. They noticed that nitrogen applied to 'Thompson Seedless' at budbreak increased nitrate levels in petioles sampled at bloom 26% and was less effective than N applied at veraison or late September which resulted in a 54% and 67% increase, respectively.

However, Gay-Eynard (2000) stated that there were no significantly differences among treatments of N-fertilization; 0, 40, 80 and 160 kg N/ha. in the content of N in petioles of 'White Muscat' grapevines (0.66 , 0.92 , 0.98 and 0.97 % respectively) in 1996, but in 1997, the treatment of 80 kg N/ha. gave lowest value in the of N-content (1.17 %) than the control 0 kg N/ha. (1.35 %).

In examining the effect of potassium on nitrogen percentage in grape leaf petioles, Casu (1980) cleared that potassium treated vines resulted in higher N-content in the petioles than untreated one. This positive response can be explained on the basis of increasing the supply of a mobile ion sign can enhance the uptake of ions of the other sign. So, $K^+$ increases the uptake of $NO_3^-$. Another possibility was K function as a carrier for $NO_3^-$ during its absorption by plants (Ben-Zioni *et al.* 1971).

Moreover, Rabeh *et al.* (1994) and Omar (2000) worked on 'Thompson Seedless', found a gradual and significant increase in the leaf nitrogen content due to raising potassium application rates from 0 to 300 $K_2O$ kg/ha. but P-content was not affected.

On the other side, Brian and Mark (1983) reported that K fertilization reduced the level of nitrogen in petioles. However, Müller (1988) concluded that no direct dependence was observed between soil K application and N-content of plant tissues.

Regard to the effect of N-application on the P and K-leaf content, Perovic (1984) in 3-year trail on vines cv. 'Vranac' were treated with N at 90, 140, 190 kg/ha found that increasing N-fertilization had a little effect on leaf P and K-content.

Habeeb *et al.* (1987) studied the effect of 6 nitrogen rates 10, 20, 40, 80, 160, and 320 g N/vine on the N and K concentrations in the petioles of 'Romi Ahmar' grapevines and found that increasing N rates increased N- concentration in the petioles (0.47, 0.87, 1.04, 1.22, 1.32 and 1.15 % respectively). K-concentration was within the optimum range in the petioles of vines supplied with medium and high doses of Nitrogen; 40, 80, 160 and 360 g N/vine (3.4, 3.0, 2.9, and 2.5 % respectively), however, K was over the optimum range in the petioles of vines supplied with low nitrogen rate 10 or 20 g N/vine (3.8 and 3.7 % respectively).

Furthermore, Maatouk *et al.* (1988) and Wafik *et al.* (1989) on 'Rommy Red' grapes, showed that increasing the rate of N-application increased petioles N-content and reduced P and K-content. In addition, Nadia (1994) on 'Italia', 'Thompson Seedless' and 'Roomy Red' reported that potassuim percentage in leaf petioles was greatly affected by rate of N-fertilization. The low rate of N–fertilization cleary enhanced K percentage in leaf petioles while the reverse was true with respect the higher rate of N-application.

However, Yasuda *et al.* (1998) on 'Kyoho' grapevines cleared that K-content in bearing shoot was highest with the middle concentration of N (20 ppm) during harvest.

Delgado *et al.* (2004) and Martin *et al.* (2004) found that 'Tempranillo' grapevines treated with the higher nitrogen or potassium doses (200 g N/vine or 120 g $K_2O$/vine) had the highest nitrogen or potassium values in the leaves (3.07 % N and 0.83 % K respectively) compared with the N doses; 0 and 50 g N/vine (N-content was: 2.90 % and 2.93 % respectively) and compared with the K doses; 0 and 60 $K_2O$ g/vine (K-content was: 0.78 and 0.75 % respectively).

Gay-Eynard (2000) found that there were no differences among treatments of N-fertilization; 0, 40, 80 and 160 kg N/ha. in the content of K in petioles of 'White Muscat' grapevines (1.35, 1.30, 1.17 and 1.17 % respectively) in 1996, but in 1997, the treatment of 160 kg N/ha. gave lowest value in the of K-content (1.05 %) than both of 0 and 40 kg N/ha. (1.30 and 131 %, respectively).

On the contrary, Ghobrial *et al.* (1991), James and John (1993) and Spayd (1993) mentioned that leaf K-content was not affected by N-fertilization.

Conradie and Saayman (1989) reported that increasing N fertilization for 'Chenin blanc' vines from 16 to 96 kg N/ha. increased the N-concentration in petioles from 0.57 to 0.61 % , decreased the P-concentration from 0.094 to 0.080 % and did not effect on K-concentration.

Furthermore, Reynolds *et al.* (2005 a) studied the nutritional status of grapevine 'Concord' and 'Niagara' as affected by fertigated treatments. All treatments were treated with the same rate of nitrogen (80 kg N/ha) but in deferent times. They reported that petiole results in 'Concord' were nonsignificant for K (2.62 % for single application, 2.46 % for split application, and 2.70 for weekly application compared with control 2.53 %). Weekly fertigation increased petiole N to 1.12 % compared with control 0.95 %. Single application fertigation increased petiole P to 0.088 % compared with control 0.072 %. Fertigation began each season shortly after bud burst, at Eichhorn and Lorenz stage 12 (referred to as EL-12). The petiole results in 'Niagara' were no significant for K (3.50 % for fertigation from EL-12 to veraison, 3.48 % for fertigation from bloom to veraison and 2.89 % for fertigation variable material from EL-12 to veraison compared with control 3.02 %). Two variable rate fertigation treatments increased petiole N (0.78 % for fertigation from bloom to veraison and 0.86 % for fertigation variable material from EL-12 to veraison compared with control 0.73 %). P in petioles increased by fertigation variable material from EL-12 to veraison (0.088 %) compared with control (0.067 %).

With the respect to the effect of N-application on leaf content of P, it was previously mentioned by Baveresco *et al.* (1986) and Bell (1991) that decrease in petiole P was due to increase in N-fertilization. The reduction in leaf content of P with increasing the applied rate of N could be due to the antagonism exist between the two elements (Faruque and Stayamayana 1974).

However, Ghobrial *et al.* (1991) as well as James and John (1993) recorded that there was no direct relation between different rates of applied nitrogen and leaf P-content.

Gay-Eynard (2000) found that there were no differences among treatments of N-fertilization; 0, 40, 80 and 160 kg N/ha. in the content of P in petioles of ‘White Muscat’ grapevines (0.14, 0.13, 0.13 and 0.13 % respectively) in 1996, but in 1997, the treatment of 160 kg N/ha. had the lowest value in the of P-content (0.12 %) than both of 0, 40 kg N/ha. (0.16 % for both of them).

Concerning the response of P-leaf content to K-fertilization, Löhnertz (1988), Omar (1994) and Omar (2000) reported that there were no significant differences between leaf P-content and all of the K-fertilizer treatments.

Regarding a combined NK-application effect on P leaf content, Müller (1988) showed that increasing NK applications had only a minor effect of leaf P-content while P-content not affected by increased K-applications alone.

On the other hand, Girgis *et al.* (1998) studied 9 treatments of N:K fertilization (g/vine); 40:20, 40:40, 40:80, 80:40, 80:80, 80:160, 160:80, 160:160, and 160:320 on ‘Thompson Seedless’ grapevines and mentioned that P-content in the petioles did not influenced by N and K fertilization (0.27 to 0.30 % in 1993 and 0.28 to 0.32 % in 1994). N-content increased with increasing N-fertilization from 2.88 to 3.95 % in 1993 and from 3.01 to 3.36 in 1994. Increasing N-fertilization also increased K-content from 2.20 to 3.03 % in

1993 and from 2.12 to 2.74 % in 1994, however, K-application variant themselves did not effect on the K-content in the petioles.

Taking potassium fertilization in account, Haeseler *et al.* (1980) disclosed that applied K substantially increased petiole K-concentration. Morris and Cawthon (1982) on Concord grapevine mentioned that vines receiving K fertilization (450 kg/ha.) showed the most rapid accumulation of $K^+$ in leaf tissues during two season of this study.

Furthermore, Morris *et al.* (1983) concluded that excessive K fertilization increased the K-content of petiole, leaves and cane of 'Concord' cv.

A similar trend was found by many authors, Perovic (1984) on 'Vranac' grapevines, Varnai *et al.* (1985) on 'Thompson Seedless', Morris *et al.* (1987) on 'Arkansas' grapes, Ryser *et al.* (1989) on 'Chasselas' cv., Shikhmany *et al.* (1990) on 'Thompson Seedless', Soyer (1992) in long term vineyard trails, since they reported that the percentage of K in leaf petiole was significantly increased as K application increased.

Moreover, Hung *et al.* (1992) found that $K^+$ content was increased by applying potassium alone or in combination with N fertilization to 'Muscat Hamburg' cv.

On the other side, Terra *et al.* (2000) concluded that the potassium application did not affect macronutrient concentration in dray matter of petiole of 'Niagara Rosada' grape cultivar.

Bravdo and Hepner (1987) studied the effect of different sources of four N and K application on nutritional status of 'Caberent Sauvignon' grapevine; 320 N and 520 K (kg/ha) as Urea KCl, 100 N and 240 K (kg/ha) as $KNO_3$ , 100 N and 240 K (kg/ha) as Urea KCl , 44 N (kg/ha) as $(NH_4)_2 SO_4$. They found that nitrogen was significantly increased in the petioles of treatment of 320 N and 520 K (kg/ha) as Urea KCl than both of 100 N and 240 K (kg/ha) as $KNO_3$ or 100 N and 240 K (kg/ha) as Urea KCl.

In addition to the above-mentioned literature, Knoll *et al.* (2006) determined the effects of 3 foliar application of potassium on K-content in petioles of 'Zweigelt' grapes. They found that K-content decreased at veraison from 0.95 % to 0.52 % in 2003 and to 0.66 % in 2004. the lowest K-content occurred at harvest 2003 (0.47 %). There were no differences among treatments [(1) Agripotash (Phosyn, Pocklington, UK; 32% K) (2.08 kg K/ha);(2) Nutrileaf 10-5-40, (Miller Chemical & fertilizer Corporation; 33.2% K) (1.66 kg K /ha) and (3) $KNO_3$ (1.55 kg K/ ha)].

## 2.3 Effect of N and K fertilization on productivity

Many researchers have dealt with the effect of nitrogen fertilization on the yield of several grapevines cultivars, indicated that vine yield was influenced in positive correlation by the level of nitrogen fertilizers [Abdel-Al (1967), Eid (1978), El-Garhy (1990), and Ghobrial *et al.* (1991) on 'Thompson Seedless', Spayd *et al.* (1993) and Spayd *et al.* (2000) on 'White Riesling' grapes as well as, Chen and Cheng (2003), Cheng *et al.* (2004) and Xia and Cheng (2004) on 'Concord' grapes].

The same observation on 'Roomy Red' cv have been reported by many investigators, viz, Ahmed *et al.* (1988) who conducted reported that there was a gradual increment in the cluster number and the yield per vine as a result of increasing nitrogen level from 75 to 175 g/vine. Wafik *et al.* (1989) and Abdel-Hady (1990) who found a significant increase in yield when the applied nitrogen doses were raised from 20 up to 120 g N/vine.

Also, Wasnik and Bharagava (1992) noticed that the heighest fruit yield (31.3 t/ha.) of 'Thompson Seedless' was resulted with the high N-application (800 kg N/ha.). Morover, Xianji (1999) mentioned that application of N after flower withering prevented flower and fruit drop and increased yield and quality of 'Jufeng' grape, while applied N in spring resulted in widespread flower and fruit drop.

Bell and Robson (1999) applied five rates of nitrogen fertilizer (0, 50, 100, 200, and 400 g N/vine) to irrigated 12-year-'Cabernet Sauvignon' vines over three seasons. Two-third of the nitrogen was applied at late budbreak and the rest at two weeks after flowering. They found that the highest yield came from vines received moderate rates of nitrogen fertilization (100 g/vine) in the second season, however, N had no effect on total vine yield in the first and last season. Additional applications of 200 g and 400 g N/vine increased the yield no further. It appeard that moderate N fertilizer (100 g/vine) could have a beneficial effect on vine productivity in situations where vine N status was low. In contrast, applying excessive N fertilizer (200 and 400 g/vine) was an unprofitable exercise as it provided no furter benefits in terms of vine productivity.

Furthermore, Salem *et al.* (2004) reported that the yield of Thompson Seedless was greatest for vines received 200 kg N/ha. and was significantly higher compared to those subjected to 150 Kg N/ha.

The effect of N in increasing yield of vineyards was also achieved by Nijjar and Ram (1970) as well as Faruque and Stayamayana (1974) on ‘Anab-El-shahi’ grapevines, Alnasove (1970) on ‘Siroka Melniska’ cv., Licul (1974) on ‘Teran Crni’ cv., Velicnhko (1979) on ‘Aligote’ cv., Chauhan *et al.* (1983) on ‘Beauty Seedless’ cv., Neilsen *et al.* (1987) on ‘Foch’ grapes cv., Löhnertz (1991) and Spayd *et al.* (1993) on ‘White Riesling’ grapevines, Dhillon *et al.* (1992) on ‘Perlette’ grapes; Saayman and Lamberechts (1995) on ‘Barlinka’ grapes; Louisolo *et al.* (2000) on ‘Bianco’ grapes and Abd-El-Mohsen (2003) on ‘Flame Seedless’ grapes.

However, it had been reported by Morris *et al.,* (1983), Gao and Cahoon (1991), Chambrs *et al.* (1995), Licina (1999), Keller *et al.* (1999), Gay-Eynard (2000) mentioned that nitrogen fertilization did not improve yield of the vines.

Habeeb *et al.* (1987), On ‘Romi Ahmar’ (Rommy Red cv) found that number of clusters per vine was not influenced by N rates 10, 20, 40, 80, 160,and 320 g N/vine.

Gay-Eynard (2000) reported that number of clusters of ‘White Muscat’ grapevines was not influenced by N rates 0, 40, 80, 160 kg N/ha. in 1995 and 1997, but in 1996, the treatment of 160 kg N/ha. gave high number of cluster /vine (10.9) than the control (9.2).

Conversely, Badr (1990) and Celik *et al.* (1995) noticed that vines treated with N fertilizers produced a significantly lower yield than the control.

Many investigators have extensively studied the benefit of using potassium in grapevine nutrition. In this respect Balo *et al.* (1982) found that applying 400 Kg $K_2O$/ha. before planting increased the mean grape yield from 12.8 to 18.3 t/ha.

Also, Morris and Cawthon (1982) studied the effect of potassium fertilization with 0 or 450 Kg/ha on yield of 14-year old ‘concord’ (*Vitis labrusca* L.) grapes and found that vines receiving K fertilization showed a response of application through increased yields and vine size.

Moreover, Shardakova and Shardakova (1983) confirmed that the average yield of ‘Rkociteli’ grapevines treated with 240 kg $K_2O$ /ha was higher than that of basal dressing only or untreated ones.

Perovic (1984) in 3-year trail on vines cv. ‘Vranac’ were treated with $K_2O$ at 120, 190, 260 kg/ha found that increasing K-fertilization from 120 to 190 increased yields but there was no further increase with 260 kg/ha.

It also stated by Valenzuela and Ruiz (1984) and Morris *et al.* (1987) that the treatments with K fertilizer increased the yield and /or the number of clusters per grapevine.

Meanwhile, El-Sese *et al.* (1988) in a trial on 'Thompson Seedless' pointed out that the yield increased significantly with increasing K level. They also noticed that raising the rate of K application to 150 g/vine enhanced the yield about 45% and 53% of the control. They suggest that improvement of fruit yield/vine might be due to increase in both numbers of cluster/vine and/or cluster's weight. Also, Conradie and Saayman (1989), Omar (1994) and Omar (2000) confirmed similar influences when K fertilization was considered.

In addition to the above-mentioned literature, Reynolds *et al.* (2005 a) found that slight yield increases; about 10 % in 'Concord' and 29 % in 'Niagara' grapevines in fertigated treatments (80 kg/ha) were attributable to increased cluster numbers, cluster weights, and berry weight.

On the other hand, Kliewer *et al.* (1983) evaluated the influence of two levels of K fertilization (0 and 2.2 $K_2O$ kg/vine) on 'Carigana' grapevines over a period of three years. They mentioned that potassium fertilization reduced yields slightly, but no significant reduction was detected in either cluster number or cluster weight compared to no K fertilization.

Also, Rühl *et al.* (1992) studied the effect of K fertilization on fruiting grapevines of 'Riesling','Chardonnay' and 'Cabernt Souvignon' grown under controlled conditions in a greenhouse. He indicated that higher K fertilization had no effect on fruit yield.

In addition, Terra *et al.* (2000) mentioned that the potassium application did not affect the yield of 'Niagara Rosada' grapevines.

Many researchers have studied the effect of nitrogen and potassium fertilization application together on the yield of grapevine. In this respect Pomohoci *et al.* (1976) on 'Tokay' grapevines concluded that the application of N and $K_2O$ at 150 Kg/ ha from each nutrient gave the best yield. A similar trend was also reported by Avoramove *et al.* (1977) on 'Merlot' grape cv.

Furthermore, Ostanov and Sidbzarov *et al.* (1977) suggested that fertilization of 'Kishmis Belyi Chernyi' vines with N and K fertilization (90 and 60 kg/ha, respectively) was responsible for obtaining the highest yield.

Chauhan *et al.* (1983) during 3-year trail on 'Beauty Seedless' grapevines were treated with N-supply from 100 up to 300 g N/vine reported that the mean 3-years yield rose from 10.7 kg/vine in the control (PK only) to 13.38 kg/vine at 300 g N/vine, 150 g N/vine was considered the most economic rate and gave 12.7 kg/vine.

Monga *et al.* (1990) studied the effect of N and K fertilizer combinations on fruit yield of 'Perlette' grapevines during 3-year trails. The vines received N-fertilization at 125-500 g/vine, K-fertilization 125-500 g/vine and they stated that the mean 3-year yield ranged from 11.9 kg/vine in the control to 13.4 kg/vine on plotes receiving 500 g N/vine + 500 g K/vine.

Girgis *et al.* (1998) recorded that the yield of 'Thompson seedless' was increased significantly with vines received moderate combined level of N and K fertilizer (supplied with N: K at 80:40 and 80:80 g/vine) compared with vines received low and high level of N and K fertilizer (supplied with 40:20, 40:40, 80:160, 160:80, 160:160 and 160:320 g/vine).

Salem *et al.* (2004) reported that the yield was greatest for vines of 'Thompson Seedless' received 200 kg N/ha and was significantly higher compared to those subjected to 150 Kg N/ha, however the enhancement of vine yield production was closely associated with the level of either P and K combined with nitrogen rate whereas the maximum NPK ratio i.e. 1:1:3 based on N at 200 kg/ha., the yield attained on increase per vine reached to about 67.2 % of that reached at the least NPK ratio 1:½:1 based on 150 kg N/ ha.

In addition, there are many similar studies aimed to reach the most suitable and balanced combinations from N and K fertilizer which can give the maximum of yield per vine by Takhomozov and Askenderov (1977) on 'Boyan Sherei'; Verma and Nijjar (1978) on 'Perlette', Colapietra (1987) on 'Monte-Pulciano' and 'Uva di Troia' grapevines; Shashkov *et al.* (1987) on 'Aligote', Papric (1991) on 'Italian Riesling', 'Muscat de Hambourg' and 'Aluzi-Ali'; Huang *et al.* (1992) on 'Mmuscat Hamburg', Apostolova (1998) on 'Pamid' grapevine and Orphanos (1998) on 'Mavro, 'Carignane noir' and 'Lefkas' grapevine.

In contrast, Delgado *et al.* (2004) and Martin *et al.* (2004) studied the influence of combined application of different doses of N and K on cv. 'Tempranillo' and reported that the rate of fertilization applied did not significantly affect either the vigor or productivity capacity of vines or the size of berries.

Also, Bravdo and Hepner (1987) on ‘Cabernet Sauvignon’ grapevines conducted four NK treatments; 320 N and 520 K (kg/ha) as Urea KCl, 100 N and 240 K (kg/ha) as $KNO_3$, 100 N and 240 K (kg/ha) as Urea KCl and 44 N (kg/ha) as $(NH_4)_2 SO_4$. They mentioned that the NK treatments did not affect yields of

## 2.4 Effect of N and K fertilization on bud behavior

Many researchers mentioned the essential role of nitrogen and potassium fertilization on the percentage of bud burst, bud fertility and fruitfulness. In this respect, El-Shourbagy and Ismail (1961) found that increasing N application from 90 up to 150 g/vine of ‘Roomy Red’ grapes increased the percentage of bursted buds and the number of fruiting buds, which developed into bearing shoots.

Abdel-Hady (1990) reported the same observation on ‘Roomy Red’ vines whereas the percentage of bud burst, bud fertility and fruitfulness increased when nitrogen was increased from 20 to 120 g/vine.

However, Wafik *et al.* (1989) on ‘Roomy Red’ grapevines appeared that increasing the dose of N up to 100 g/vine increased the fertility of buds while highes amount decreased fertility.

Dynzhev *et al.* (1973) found that fertilizing ‘Riesling’ grapevines with N and K at 100 Kg/ha. from each of them produced the highest number of fruiting buds.

Habeeb *et al.* (1976) indicated that increasing of N-application increased the percentage of opened buds on ‘Rkotsiteli’ and ‘Italia’ grapevines.

Furthermore, Ahmed (1991) proved that the percentage of fruiting buds of ‘Thompson Seedless’ grapevines increased by increasing soil application of N and K fertilization, especially when they were applied together.

Celik *et al.* (1995) pointed out that the percentage of opened buds per vine was influenced in positive correlation by the level of nitrogen fertilization. Increasing N rate per vine clearly increased the percentage of opened buds. Apostolova (1998) found that the fertilizer application of N and K had a direct effect on ‘Pamid’ grapevines bud production.

Moreover, Shaker (2001) confirmed that N-applications at 150 kg/ha reduced number of fertile buds of on ’Thompson Seedless’ compared to 200 kg/ha.

In contrast, Habeeb *et al.* (1987) on 'Romi Ahmar' applied by N-rates (10, 20, 40, 80, 160, 320 g/vine) stated that changes in the average percent of buds remaining dormant (non-opened bud %) were almost constant during 4-year period. The changes from one season to another were marked in both non-bearing and bearing shoots. Bearing shoot were larger at low N rates, being largest at 40 g N/vine. Percent of fruitful buds developing into non-bearing shoots generally increased with increasing N rate application, being largest at 320 g N/vine. The number of each monocluster and di-cluster shoots per node was not influenced by N-application.

Motosugi and Lin (1990) found that increasing nitrogen application decreased the percentage of bursted buds of 'Kyoho' grapevines.

Peacock *et al.* (1991) found that delaying N fertilization at postharvest did not affect cane fruitfulness of 'Thompson Seedless' and 'Flame Seedless', and simulation of late season shoot growth was not observed.

Girgis *et al.* (1998) observed that fertility coefficient of 'Thompson seedless was increased significantly with vine received moderate combined level of N and K fertilizer (supplied with N:K at 80:40 and 80:80 g/vine) compared with vines receiving low and high level of N and K fertilizer (supplied with 40:20, 40:40, 80:160, 160:80, 160:160 and 160:320 g/vine).

The same observation was found by Shaker (2001) who mentioned that bud burst percentage of 'Thompson Seedless' grapevines decreased gradually with increasing N-application from 150 to 200 Kg N/ha.

However, Giorgessi *et al.* (2000) ensured that increasing N application did not significantly influence the bud burst percentage and numbers of inflorescence per shoot

## 2.5 Effect of N and K fertilization on growth

### 2.5.1 Leaf area

Many investigators suggested that N fertilization was responsible for raising the total leaf area in different grape varieties, since they revealed that leaf area expansion progressively increased with the amount of N fertilized applied (Krusteva-Kastova, 1977, Maatouk *et al.* 1988 and El-Garhy, 1990).

Tisdale *et al.* (1985) found that a linear relationship between leaf area and N application especially when combined with P and K. This may reflect the role of N as constituent of amino acids and protein as well as the important role of P and K in encouraging cell division and development of meristimatic tissue.

Ahmed (1991) noticed that the application of 139.5 g N/vine, and 144 g $K_2O$ /vine achieved the maximum leaf area of ‘Thompson Seedless’ vines.

Bell and Robson (1999) applied five rates of nitrogen fertilizer (0, 50, 100, 200, and 400 g N/vine) to irrigated, 12-year-‘Cabernet Sauvignon’ vines over three seasons. Two-third of the nitrogen was applied at budbreak and the rest at two weeks after flowering. They found that moderate rates of nitrogen fertilization (100 g/vine) stimulated vine growth and vigor resulting in increase in leaf area and canopy density (leaf layer number), however, leaf area and canopy density of vines supplied with 200 and 400 g N/vine were not different to those vines supplemented with 100 g N/vine.

Gay-Eynrad (2000) studied the effect of 4 rates of N-fertilization as ammonium sulphate in a single application; 0, 20, 40, 80 and 160 kg/ha on the leaf surface area of ‘White Muscat’ grapevines and confirmed that the net photosynthesis was lower at lowest N rates than at 80 and 160 Kg/ha. The leaf surface was the highest with highest N levels 160 kg/ha (224 $cm^2$) compared with the other N-fertilization treatments 0, 40, and 80 kg/ha (163, 177 and 176 $cm^2$, respectively).

Keller *et al.* (2001) observed that high soil nitrogen increased vine leaf area, photosynthesis, transpiration and stomatal conductance of ‘Müller Thurgau’ grapevines.

Cheng *et al.* (2004) suggest that total leaf area of ‘Concord’ vines increased with increasing N-supply.

Salem *et al.* (2004) reported that increasing nitrogen rate from 150 to 200 kg/ha resulted in an obvious increase in ‘Thompson Seedless’ leaf area.

Grechi *et al.* (2007) mentioned that ‘Merlot’ vines grown in the highest N condition had a larger individual leaf area than the lowest N condition that markedly reduced leaf area.

### 2.5.2 Cane thickness

Several investigators were interested in evaluating the efficiency of nitrogen on thickness of canes in various grapevine cvs. Ismail *et al.,* (1963) reported that ‘Sultana’ cane thickness proportionally increased as the rate of nitrogen fertilization was increased.

Chadha and Singh (1971) mentioned that fertilizing 'Thompson Seedless' grapevines with 100 g N/vine effectively enhanced the cane thickness.

Nijjar (1985) found that the action of N and K increased the thickness of canes, this could be attributed to their effect on carbohydrates and protein synthesis and accumulation as well as on their role in the formation of cellulose and lignin which are playing an important role in encouraging cell division and building new tissues in the plants.

Maatouk *et al.* (1988) applied 5 rates of nitrogen application during 2 years with 75, 100, 125, 150 g/vine and found that increasing rate of N fertilization considerably increased cane thickness of 'Red Roomy' grapevine.

Abdel-Hady (1990) reported that the thickness of 'Red Roomy' canes gave pronounced increase with increasing the rate of N fertilization from 20 to 120 g/vine.

El-Garhy (1990) on 'Thompson Seedless' grapevines mentioned that vines received 100 g N/vine produced the thickest cane as compared to those treated with lower or higher levels.

Ahmed *et al.* (1993) observed that cane thickness of 'Thompson Seedless' grapevine increased by increasing rate of N and K fertilization treatments especially when both of them were applied together.

Zonathy *et al.* (1996) confirmed that the thickest canes of 'Rhine Riesding' cv was produced by middle N rate (90 kg/ha).

Salem *et al.* (2004) recorded that raising N rate from 150 to 200 kg/ha positively increased the ultimate cane thickness of 'Thompson Seedless'.

## 2.6 Effect of N and K fertilization on cluster characteristics:

### 2.6.1 Cluster weight

Research results for grapevines have shown that the rate of applied nitrogen was responsible for the cluster weight. In this respect, Habeeb *et al.* (1987) studied the effect of 6 nitrogen rates 10, 20, 40, 80, 160, and 320 g N/vine on the cluster weight of 'Romi Ahmar' grapes and found that cluster mean weight significantly increased at 40 g N/vine over the other N rates applied.

Neilsen *et al.* (1987) stated that nitrogen fertilization increased cluster weight of 'Foch' grapevine. Also, Ahmed (1987) found that the cluster weight of 'Thompson Seedless' grapevine was increased by all nitrogen application as compared with control. Ahlawat and Yamdagni (1988) revealed that the greaters cluster weight of 'Perlette' grapes (340,4 – 435,5 g) was obtained with N at 500 g per vine. Ahmed *et al.,* (1988) mentioned that 'Roomy Red' cluster weight was increased with increasing nitrogen levels.

Saayman and Lambrechts (1995) ensured that N application rate of about 100 kg/ha appeared to optimum for growth and fruit quality of 'Barlinka' table grapes. Bunch and crop mass benefit from increased N level apparently due to enhanced fruit set.

Schaller (2000) found that N-supply effected cluster weight of 'White Riesling'. There was a close correlation (R = 0.67) between yield and N-supply.

Giorgessi *et al.* (2000) noted that nitrogen raised the average of cluster weight of 'White Pinot' grapes. Al-Khayat and Al-Dujail (2001) reported that the highest bunch weight of 'Haluani' and 'Kamali' grape cvs was obtained with highest nitrogen level.

Reynolds *et al.* (2005 a) stated that fertigation nitrogen treatment (80 kg/ha) enhanced cluster weight of 'Concord' and 'Niagara' grapevines.

This conclusion is consistent with reports of Kozma and Polyak (1975) on 'White Riesling' cv., Wassel *et al.* (1985) and Abdel-Hady (1990) on 'Roomy Red' cv., Badr (1990) on 'Ruby Seedless', El-Garhy (1990) and Shaker (2001) on 'Thompson Seedless' grapevine and Abd-El-Mohsen (2003) on 'Flam Seedless' grapes.

On the other hand, Gao and Cahoon (1991) proved that N application has no effect on cluster weight of 'Concord' grapevine. Celik *et al.* (1995) found that cluster weight was lower with N application than without N application. Gay-Eynrad (2000) mentioned that cluster weight of 'White Muscat' grapevine was not affected by N-application; (0, 40, 80, 160 kg/ha) in 1995 and 1996, but was affected by the high N-application; (160 kg/ha) in 1997.

Regarding the effect of K fertilization in increasing cluster weight, Christensen (1964), El-Sese *et al.* (1988) and Omar (2000) ensured that cluster weight significantly increased by increasing K-application for 'Thompson Seedless' grapevines.

Also, Shardakova and Shardakova (1984) reported that $K_2O$ at 270 kg/ha produced the heaviest clusters of 'Aligote' grapevines.

Dhillon *et al.* (1999) on ‘Perlette’ grapes found that cluster weight increased with each level of K applied from 100 to 500 g of $K_2O$ per vine and the heaviest cluster was obtained with highest K application (500 g of $K_2O$ per vine).

The effect of N and K fertilization on cluster weight has been evaluated by many Authors. In this respect, Nijjar and Chand (1969) found that the N and K-application at 100 kg/ha per each of them gave the heaviest clusters of ‘Anab-El-Shahi’ grapevines. Also, Carl *et al.* (1980) and Ahmed (1991) noticed that N and K application increased cluster weight.

Furthermore, Srivastava and Soni (1988) found that N and K applications increased cluster weight of ‘Perlette’ grapes. The same trend have been found by Dhillon *et al.* (1992) who reported that the cluster weight of ‘Perlette’ grapevines was greatest with using 100 g N and lowest from the control. El-Shahat (1992) indicated that nitrogen fertilization alone or combined with K increased cluster weight than the control. The more pronounced effect on cluster weight was obtained when N and K-application was used on ‘Thompson Seedless’ grapevines.

Similar trend have been reported by Girgis *et al.* (1998) who observed that cluster weight was increased significantly for ‘Thompson Seedless’ grapevines supplied with moderate combined level of N and K fertilizers (supplied with N:K at 80:40 and 80:80 g/vine) compared with vines received low and high level of N and K fertilizer (supplied with 40:20, 40:40, 80:160, 160:80, 160:160 and 160:320 g/vine).

Terra *et al.* (2000) showed that over a six years experiment with ‘Niagara Rosada’ grapevines, all treatments of N and K-fertilization proved an increase in average cluster weight grapevine yield when compared to the control.

Salem *et al.* (2004) demonstrated that the vines of ‘Thomposon Seedless’ produced the heaviest cluster when N rates increased from 150 to 200 kg/ha and these response increased with N:K fertilization at 1:3 ratio (200 : 600 kg/ha).

### 2.6.2 Cluster dimension

Habeeb *et al.* (1987) studied the effect of 6 nitrogen rates 10, 20, 40, 80, 160, and 320 g N/vine on the cluster dimension of ‘Romi Ahmar’ grapes and found that cluster length significantly increased at 40 g N/vine over the other N rates applied.

Ghobrial *et al.* (1991) studied three nitrogen rates; (40, 80 and 160 g N per vine) in a sandy vineyard of ‘Thompson Seedless’ grape. They suggested that medium level of N application (80 g N/vine) had the highest cluster length and width than the other treatments.

On the other side, Girgis *et al.* (1998) mentioned that cluster length and width of ‘Thompson Seedless’ grapes appeared to have no significant response to moderate combined level of N and K fertilizer.

### 2.6.3 Number of berries per cluster and Cluster Compactness

Ramming *et al.* (1995) and Pommer *et al.* (1999) found that cluster of ‘Crimson Seedless’ grapes are medium in length and therefore are slightly compact.

Moreover, El-Baz *et al.* (2002) reported that the number of berries per cluster of ‘Crimson Seedless’ grapes was found between 98-107.5. Also, cluster compactness coefficient was 4.6-5.1 %.

Habeeb *et al.* (1987) reported that the number of berries per cluster in ‘Romi Ahmar’ grapes significantly increased at 40 g N/vine over the other N rates applied (10, 20, 80, 160, and 320 g N/vine).

Ahlawat and Yamadani (1988) studied the effect of four rates of N- fertilization (125, 250, 500, 1000 g/vine) and three potassium rates, 0, 150, 300 g/vine on berry set, berry drop and quality of grape cultivar ‘Perlette’. They proved that the maximum berry set and minimum bery drop were obtained with meduim N-application at 500 g/vine, but K-fertilization had no influence on these indicates.

Also, Srivastava and Soni (1988) cleared that the berry numbers within cluster were increased with N-application. Moreover, Spayd *et al.* (1993) found that vines which received N had more berries per cluster than non-fertilized ones.

El-Sese *et al.* (1988) indicated that increasing the potassium fertilization up to 100-150 g/vine increased the number of clusters, and their flowers, as well as the percentage of fruiting setting and consequently the berries per cluster.

Bell and Robson (1999) mentioned that moderate rates of N fertilization (100 g/vine) produced higher berry numbers per bunch than the control and low rate of N fertilization (0, 50 g/vine ) as well as than the excessive N fertilitazion (200, 400 g/vine). were associated with the increase in total vine yield. It appeared that berry numbers per cluster associated with increase in total vine yield.

Salem *et al.* (2004) cleared that the number of berries /cluster was inversly related to N fertilization rate, whereas vines treated with 150 kg N/ha. had higher berry numbers than those treated with 200 kg N/ha.

Reynolds *et al.* (2005 a) claimed that fertigation nitrogen treatment (80 kg/ha.) for 'Concord' and 'Niagara' grapevines enhanced number of berries per cluster than the control.

## 2.7 Effect of N and K fertilization on fruit quality

The growth pattern of developing grape berries (*Vitis vinifera* L.) can be described as a double sigmoidal curve with an initial rapid increase in size followed by a lag period during which berry volume does not increase. The lag is followed by a second phase of growth during which ripening occurs, and viticulturists use the French word *vérasion* to describe the inception of berry ripening. During the ripening, the increase in volume is accompanied by an increase in berry softness, accumulation of hexoses in the berries, and a decrease in the level of malic and tartaric acids, and in red grape varieties the skin becomes colored due to the accumulation of anthocyanins (Coombe, 1992; Fig. 2 ).

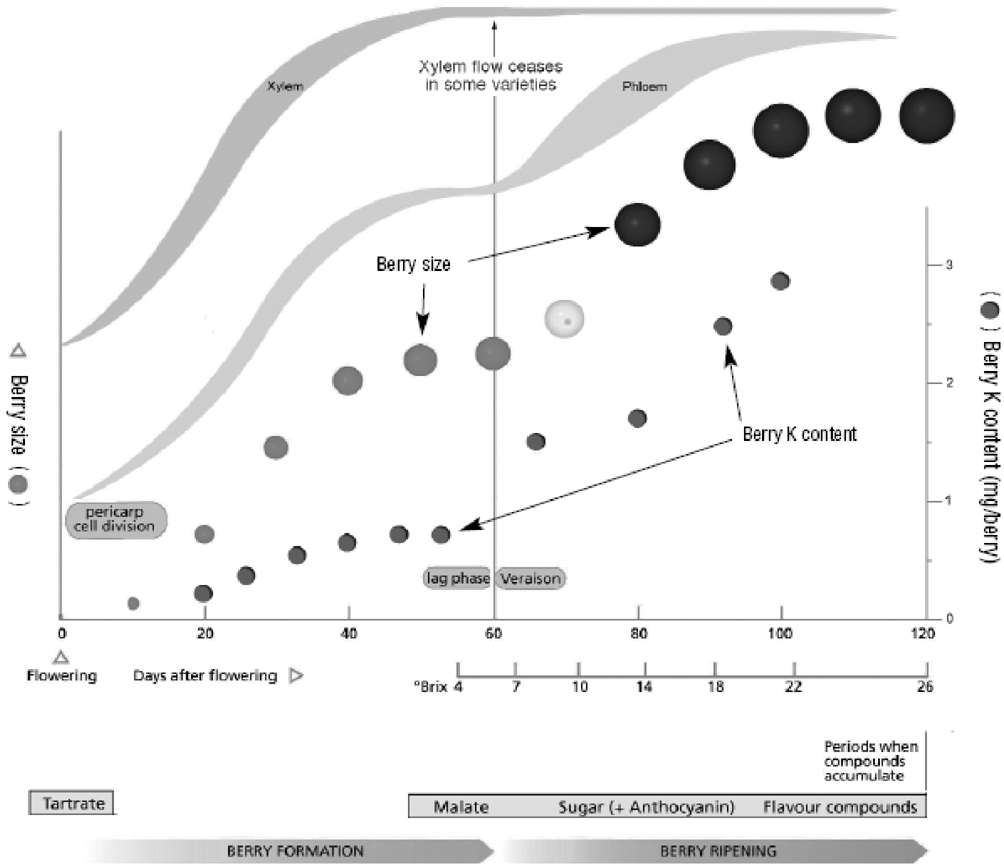



Fig.(2): Grape berry growth and development [was taken from Coombe (2001) with slight modification, data on berry K accumulation according to Mpelasoka *et al.*(2003)]

### 2.7.1 Fruit physical properties

#### 2.7.1.1 Berry dimension, size and weight.

Badr and Ramming (1994), Ramming *et al.,* (1995), Badr (1997) and Dokoozlian *et al.* (2000) proved that the berries of 'Crimson Seedless' were meduim in weight with an average 4.0 g and 16.6 mm in diameter.

Peacock and Simpson (1995) reported that berry weight of 'Crimson Seedless' vines was 2.4 - 7.4 g, berry diameter was 14 to 20 mm and berry length was 20.0 to 27.0 mm.

Dokoozlian (1998) stated that berry weight of untreated vines ranged from 4.4 to 4.7 g and in treated vines with $GA_3$ ranged 4.9 to 5.5 g. Berry diameter of of untreated vines ranged 17.4 to 18.1 mm and in treated vines with $GA_3$ ranged from 17.8 to 18.6 mm.

Also, El-Baz *et al.* (2002) who found the berry weight ranged 3.31 to 3.70 g and berry diameter ranged 16.3 to 17.6 mm.

Increasing berry dimensions as a result of vine nutrition was mentioned by Ahmed *et al.* (1988) who reported that diameter and length of 'Rommy Red' berries increased with increasing level of N-supply.

However, on the same cultivar 'Romi Ahmar', Habeeb *et al.* (1987) mentioned that the berry weight significantly increased at 40 g N/vine over the other N rates applied (10, 20, 80, 160, and 320 g N/vine).

Roy *et al.* (1989) found that N and K-application increased the fruit diameter of 'Bangalore Purple' grapevines.

Ahmed *et al.* (1991) stated that 'Thompson Seedless' berries increased in size with increasing N and K fertilization.

Salem *et al.* (2004) proved that size of 'Thompson Seedless' berries was increased with increasing N fertilization from 150 to 200 kg/ha as well as with a high ratio of N:K 1:3 (200:600 kg/ha).

Reynolds *et al.* (2005 a) on 'Concord' and 'Niagara' grapevines claimed that berry weight was increased by fertigation nitrogen treatments (80 kg/ha.) only in 1999; but in the other seasons (1998, 2000, 2001 and 2002) no differences were observed or the berry weights of control equaled or exceed those of fertigation nitrogen treatments.

However, Srivastava and Soni (1988) found that berry size of 'Perlette' grape increased by N- application, but K had no effect.

It was stated by Eid (1978) that raising nitrogen rates from 100 to 300 g/vine was effective in obtaining the heaviest berries of 'Thompson Seedless'grapevines. This increase in the average berry weight as a result of increasing nitrogen could be attributed to the effect of nitrogen in producing new cells and tissues as well as to its effect in increasing cell enlargment (Follet *et al.* 1981).

A similar trend was also found by El-Sayed (1980) who mentioned that 'Thompson Seedless' berries increased in size as a result of increasing nitrogen from 75 to 225 g/vine.

The findings of Abdel-Hady (1990) on 'Rommy Red' as well as of El-Garhy (1990) on 'Thompson Seedless' grapevines showed that N fertilization increased weight and dimension of the berries.

Similar results were found by Dhillon *et al.* (1992) on 'Perlette' vines. Furthermore, the results of Spayd *et al.* (1993) showed that 'White Riesling' grapevines which received N had larger berries than non-fertilized ones.

Yasuda *et al.* (1998) reported that N-application at a medium concentration produced the greatest berries of 'Kyoho' grapes. Also, Saayman and Lambrechts (1995) found that 'Barlinka' , berry mass seems to be negatively affected by high N level.

In contrast, Morris *et al.* (1983), Gao and cahoon (1991) and Ghobrial *et al.* (1991), Khattari and Shata (1993), Keller *et al.* (1999), Gay-Eynrad (2000) found that N fertilization did not effect berry weight.

Concerning the effect of potassium fertilization on the berry weight, many investigators suggst that the sugar content of grape raises progressively by increasing application of K to grapevines soils; thus, the osmotic potential increases and enhance the movement of water into the berries and, consequently, enhanced berriy volume. (Mpelasoka *et al.* 2003)

Potassium is required for the synthesis and translocation of carbohydrates. Soil application of potassium had a measurable effect on improving the berry weight of 'Thompson Seedless' grapevines (Omar, 2000 ).

In addition, Conradie and Saayman (1989) in a trial over 11 years on ‘Chenin Blanc’ grapevines, reported that K-application (45 kg/ha) significantly increased yield by about 6.1 % due to larger berries.

On the other hand, El-Sese *et al.* (1988) mentioned that berry weight of ‘White Banati‘ table grape (local name of ‘Thompson Seedless’) was not significantly affected with K treatments.

Also, Srivastava and Soni (1988) observed that K-application had no significant effect on berry weight and volume of ‘Perlette’ grapes.

Haeseler *et al.* (1980) mentioned that berry weight of ‘Concord’ grapes was increased by N and K treatments. Also, the same result was found by Ahmed (1991) and Salem *et al.* (2004) on ‘Thompson Seedless’ grapes.

#### 2.7.1.2 Berry firmness and adherence

Ramming *et al.* (1995) reported that the pedicel of berries in ‘Crimson Seedless’ grape is medium in length and thickness. The brush is medium in length and is yellow-green. The berries are bright red and the flesh is light yellow, translucent, meaty, and firm. The skin is thick, medium tough, and does not separate from flesh.

Dokoozlian *et al.* (2000) indicated that ‘Crimson Seedless’ vines which have compact fruit clusters with about 0.5 kg in weight, bear more crisp and firm berries.

El-Baz *et al.* (2002) claimed that the number of berries per cluster of ‘Crimson Seedless’ grapes was found between 98 and 107,5. Also, their cluster compactness coefficient was 4.6-5.1 %, their berry adherence was 681 to 724 g.

### 2.7.2 Fruit chemical properties

#### 2.7.2.1 T.S.S %

Many investigators draw attention to the fact that the application of nitrogen fertilizer especially at high level reduced total soluble solids percentage (T.S.S %) in the berries [Ahmed (1987), El-Sayed (1980), El-Garhy (1990), Ahmed (1991) and Salem *et al.* (2004) on ‘Thompson Seedless’ grapes, Ahmed *et al.* (1988) and Abdel-Hady (1990) on ‘Rommy Red’ grapevines ; Dhillon *et al.* (1992) on ‘Perlette’ grapes, Christensen *et al.* (1994) on ‘Barbera’, ‘Grenache’, ‘French Colombard’, and ‘Chenin blanc’ grapevines, Spayd *et al.* (1994) on ‘White Riesling’ grapes, Saayman and Lambrechts (1995) on

'Barlinka' table grapes, Keller *et al.* (1998) on 'Cabernet Sauvignon' cv, Reynolds *et al.* (2005 a) on 'Concord' and 'Niagara' grapevines].

However, many researchers found that soil N-fertilization did not affected T.S.S % [Gao and Choon (1991), Maigre and Murisier (1991), Khattari and Shatat (1993), Keller *et al.* (1999), Gay-Eynard (2000)].

On the other side, Morris *et al.* (1983) and Badr (1990) observed that fruit produced on vines treated with N fertilizer had significantly higher percent of soluble solids than control fruit.

In addition, Spayd *et al.* (2000) and Treeby *et al.* (2000) indicated that accumulation of soluble solids by 'Shiraz' grapes were enhanced by N-supply.

Concerning the effect of K-fertilization on soluble solids percentage, it had been reported that T.S.S increased as the potassium fertilization increased because it promotes the translocation of products of photosynthesis in the plant (Omar, 2000).

T.S.S % increased in the fruit yielded of plants which received K-fertilization. In a study on 'Thompson Seedless' grapevines, El-Sese *et al.* (1988) reported that berry total soluble solids increased significantly as potassium level increased. The same result has been found by Ahlawat and Yamadagni (1988) on 'Perlette' grapes and by Omar (2000) on 'Thompson Seedless' grapevines.

Moreover, Delgardo *et al.* (2004) and Martin *et al.* (2004) suggest that higher potassium supplies increased the total soluble solids content of berries of 'Tempranillo' vines.

In contrast, Cline and Bradt (1980) as well as Kliewer and Freeman (1983) pointed out that K-fertilization had no significant effect on the berry total soluble solids concentration.

Regarding the effect of NK on T.S.S, many authors pronounced that total soluble solids in the juice of grapes increased as NK-application increased (Colapietra, 1987, Srivastava and Soni 1988, Monga *et al.* 1990, Papric 1991, Apostolova 1998).

On the other hand, total soluble solids appeared to have insignificant response with increasing N and K fertilization (Neilsen *et al.* 1987 on 'Foch' grapes, Girgis *et al.* 1998 on 'Thompson Seedless' grapevines).

#### 2.7.2.2 Acidity

The increase in juice acidity was in proportion to the increase in the applied rate of nitrogen [Abdel-Al (1967), Eid (1978), Ahmed (1987) and El-Garhy (1990) and Salem *et al.* (2004) on 'Thompson Seedless' cv grapevines, Abdel-Hady (1990) and Ahmed *et al.* (1990) on 'Rommy Red' vines, Lovisolo *et al.* (2000) on 'Moscato Bianco' vines, and Keller *et al.* (2001) on 'Müller Thurgau' grapes].

These observations tended to confirm those mentioned by Dhillon *et al.* (1992) who found that total acids was better at lower rates of N on 'Perlette' grapevines.

In addition, Reynolds *et al.* (2005 a) mentioned that a slight elevation in titratable acidity over the control was evident in several fertigated treatments of nitrogen.

However, Morris *et al.* (1983), Keller *et al.* (1998), Delgardo *et al.* (2004) observed that N fertilization tended to reduce the acidity in berries.

Nevertheless, Gao and Cahoon (1991) on 'Concord' grapes, Spayed *et al.* (1994) on 'White Riesling' vines, Saayman and Lamberchts (1995) on 'Barlinka' table grapes, Treeby *et al.* (2000) on 'Shiraz' grapes, Spayd *et al.* (2000) on 'Riesling' vines noticed that juice acid levels were not affected by N fertilization rate.

Moreover, Gay-Eynard (2000) found that N-applications 0, 40, 80, 160 kg N/vine did not affect acidity of 'White Muscat' grapevines during 1995 and 1996, but in 1997 the treatment with 160 kg N/vine produced higher acidity than the others.

It is interesting to mention that potassium reduces acid levels in berries and interacts with tartaric acid to form potassium bitartrate, which has limited solubility (Sommers, 1977). Many authors mentioned the role of potassium fertilization in reducing the acid levels in berries, in this respect, Morris *et al.* (1983) working on 'Concord' grapevines, Ahlawat and Yamadagni (1988) on 'Perlette' vines, El-Sese *et al.* (1988), Omar (2000) and Salem *et al.* (2004) on 'Thompson Seedless' grapevines, observed a decrease in titratable acidity with increasing K-fertilization level. This could be due to the reduction in tartaric acid which might have converted into potassium tartarate.

Also, Rühl (2000) mentioned that the grape juice with low acidity results from K fertilization supply.

In addition, Martin *et al.* (2004) reported that higher potassium fertilization decreased the total acidity of 'Tempranillo' grape berries.

On the other hand, Conradie and Saayman (1989) observed that potassium fertilization from 45 to 90 kg/ha induced higher acidity of 'Chenin Blanc' grapes. Dhillon *et al.* (1999) reported that acid content increased with increasing K application rate but did not significantly increase between 200 to 500 g/vine during first year and between 200 to 400 g/vine during second year.

Cline and Bradt (1980), Morris and Cawthon (1982) as well as Jackson and Lombard (1993) showed that acidity was not affected by K-fertilization in their experiments.

Morris *et al.* (1987) established a study on five cultivars: 'Cabernet Sauvignon', 'Gewürztaminer', two French-American hybrid cultivars (Seyval and de Chaunac), and a *Vitis aestivalis* cultivar (Cynthiana) to determine their yields and quality responses to a high level of potassium fertilization (2.7 kg $K_2SO_4$ /vine). They found that 'Gewürztaminer' prouduced juice with the lowest acidity, and 'Cynthiana' prouduced the highest acidity values; however these effects were not observed in other cultivars.

Concerning the effect of combined N and K fertilization, Pire and Rivas (1987) on 'Ferano Pires' grape, Apstolova (1998) on 'Pamid' cv. Salem *et al.* (2004) on 'Thompson Seedless' grapes reported that high levels of N and K application decreased acidity in the fruit.

However, Colapietra (1987) mentioned that the acidity level was generally little affected by N and K fertilizer rates.

Also, Neilsen *et al.* (1987) on 'Foch' grapvines and Girgis *et al.* (1998) on 'Thompson Seedless' grapevines concluded that titratable acidity in fruit was not consistently affected by NK-fertilization.

In contrast, Bovha (1997) proved that acidity of 'Lastki Rizling' grapes was greater with increasing NK application but T.S.S content was lower.

#### 2.7.2.3 TSS/acid ratio

Salem *et al.* (2004) on 'Thompson Seedless' grapes found that an increasing amount of N applied from 150 to 200 kg N/ha reduced TSS/acid.

However, Badr (1990) found that TSS/acid ratio was not significantly affected by any treatments of N-fertilization.

El-Sese *et al.* (1988) and Omar (2000) on 'Thompson Seedless' found that increasing $K_2O$ significantly increased TSS/acidity. Also, the same result was reported by Dhillon *et al.* (1999) as well as Salem *et al.* (2004).

### 2.7.2.4 Sugar fractions

The accumulation of sugar in the form of glucose and fructose within the vacuole is one of the main features of the ripening process in grape berries and is a major commercial consideration for the grape grower and dried fruit producer. Sugar accumulation in climacteric fruit has received considerable attention, but little is known about the process in nonclimacteric fruit such as grape. In grapevines, sucrose produced as a result of photosynthesis in the leaf is transported via the phloem to the berry (Swanson and Elshishiny 1958).

During grape berry (*Vitis vinifera* L.) ripening, sucrose transported from the leaves is accumulated in the berry vacuoles as glucose and fructose. In grape berries, hexose accumulation begins 8 weeks postflowering and continued until the fruit was ripe at 16 weeks. Invertase activity increased from flowering to a maximum 8 weeks postflowering and remained constant on a per berry basis throughout ripening. Although vacuolar invertases are involved in hexose accumulation in grape berries, the expression of the genes and the synthesis of the enzymes produces the onset of hexose accumulation by some weeks, so other mechanisms must be involved in regulating this process (Davies and Robinson 1996).

Martin *et al.* (2004) found that the higher nitrogen doses delayed the accumulation of sugars during ripening compared to the other treatments.

### 2.7.2.5 Phenolic compounds (bioactive compounds)

#### 2.7.2.5.1 Phenolic compounds and human health:

Grapes contain a large amount of different phenolic compounds in skins, pulp and seeds, that are partially extracted. They play an important role in the fruit quality of grape, in which they contribute to colour and sensory properties such as bitterness, astringency and some flavors. Furthermore, several studies have pointed out that many of them show biological properties of interest, related to their antioxidant properties.

In this respect Hülya-Orak (2007) mentiond that the grape is becoming increasingly popular as a fruit and is a significant source of nutritional antioxidant, such as polyphenols, anthocyanins as well as bilogically active dietary components.

Phenolic plant metabolites are generally accepted to be relevant for human health. In many studies they were shown to have benficial effects. The nutritional values of fruits, vegetables and other plant foods or beverages like tea or fruit juices can be attributed to their phenolic constituents. In several aspects, the action of phenolics is vitamin-like. Phenolics as well as secondary plant products, do not fit into the definition of vitamins, therefore they are now called "bioactive compounds" (Treutter 2007).

These important compounds are an integral part of the human diet, and could be helpful against human cancers, arteriosclerosis, ischaemia and inflammatory disease, which are partially caused by exposure to oxidative stress (Namiki 1990, Halliwell 1996).

The growing interest in the antioxidant properties of the phenolic compounds in vegetables and fruits derives from their strong activity and low toxicity compared with those of synthetic phenolic antioxidants, such as BHT (butylated hydroxytoluene) (Nakatani 1996, Marinova and Yanishlieva 1997).

Epidemiological studies have shown that consumption of fruits and beverages rich in phenolics, such as grape and tea, is correlated with reduced coronary heart disease mortality (Hertog *et al.* 1995, Balentine *et al.* 1997, Serafini *et al.* 2000, Cul *et al.* 2002).

The protectve effects of fruit, vegetables and beverage consumption against coronary artery disease and certain types of cancer are partly attributed to the flavonoid content of these foods (Frankel *et al.* 1993 , Bell *et al.* 2000).

The presence of bioactive compounds in grapes mainly phenolic compounds, and the synergistic effects among them, have been related to these properties (Frankel *et al.*, 1995, Soleas *et al.* 1997).

### 2.7.2.5.2 Flavonoids in grapes

Montealegre *et al.* (2006) mentioned that flavonoids as polyphenolic compounds play an important role in the quality of grapes that are responsible for color and stringency, bitterness, flavor in grapes as well as have attracted much interest due to their antioxidant properties and their potentially beneficial effect for human health.

Flavonoids are a large and diverse group of secondary metabolism compounds that, by their presence or absence, contribute greatly to grape quality (Downey *et al.* 2006).

The concentration of flavonoids as phenolic compounds in grapes depends on the variety of grapevine and is influenced by viticulture and environmental factors (Cheynier *et al.* 1998, Broussaud *et al.* 1999, Ojeda *et al.* 2002, Downey *et al.* 2006).

Flavonoids occur widely in plants and are a biologically important and chemically diverse group of secondary metabolites that can be divided into subgroups including chalcones, dihydrochalcones, flavones, flavanols, flavanones, dihydroflavonols, anthocyanidins, isoflavonoids and pterocarpans (Harborne 1994).

Phenolic compounds can be divided into two groups: non-flavonoid (hydroxybenzoic and hydroxycinnamic acids and stilbenes) and flavonoid compounds (anthocyanins, flavan-3-ols and flavonols). Anthocyanins are a family of polyphenols that directly responsible for colour in grapes. Flavan-3ols (monomeric catechin and epicatechin and proanthocyanidins) are another large family of polyphenolic compounds, which are mainly responsible for the stringency, bitterness. The last group of flavonoids are flavonols (quercetin, myricetin, kaempferol, isorhamnetin and their glycosides), which seem to contribute to bitterness (Montealegre *et al.* 2006).

Flavonoids in grape range from simple compounds (monomers) to complex tannin-type substances (oligomers and polymers). Flavonoids antioxidant compounds present in grape have been identified as phenolic acids (benzoic and hydroxycinnamic acids), stilbene derivatives (resveratol), flavan-3-ols (catechin, epicatechin and proanthocyanidins), flavonols (kaempferol, quercetin, myricetin and isorhamnetin) and anthocyanins (Miller *et al.* 1995, Vinson and Hontz 1995, Ghiselli *et al.* 1998).

The phenolic acids of grape are hydroxycinnamic acids which are in the form of esters of the tartaric acid in the skin and pulp (Ribereau-Gayon 1965).

Moreover, the stilbene derivatives (resveratol) are only located in the skin of the grapes ( Jeandet *et al.* 1991, Lamuela-Raventos *et al.* 1995).

In addition, the flavan 3-ols include a range of polyphenolic compounds ranging from small oligomeric forms to large proanthocyanidin polymers (condensed tannins). These oligomers and polymers are composed of monomeric subunits analogous to flavan 3-ol monomers such as catechin and epicatechin (Downey *et al.* 2006).

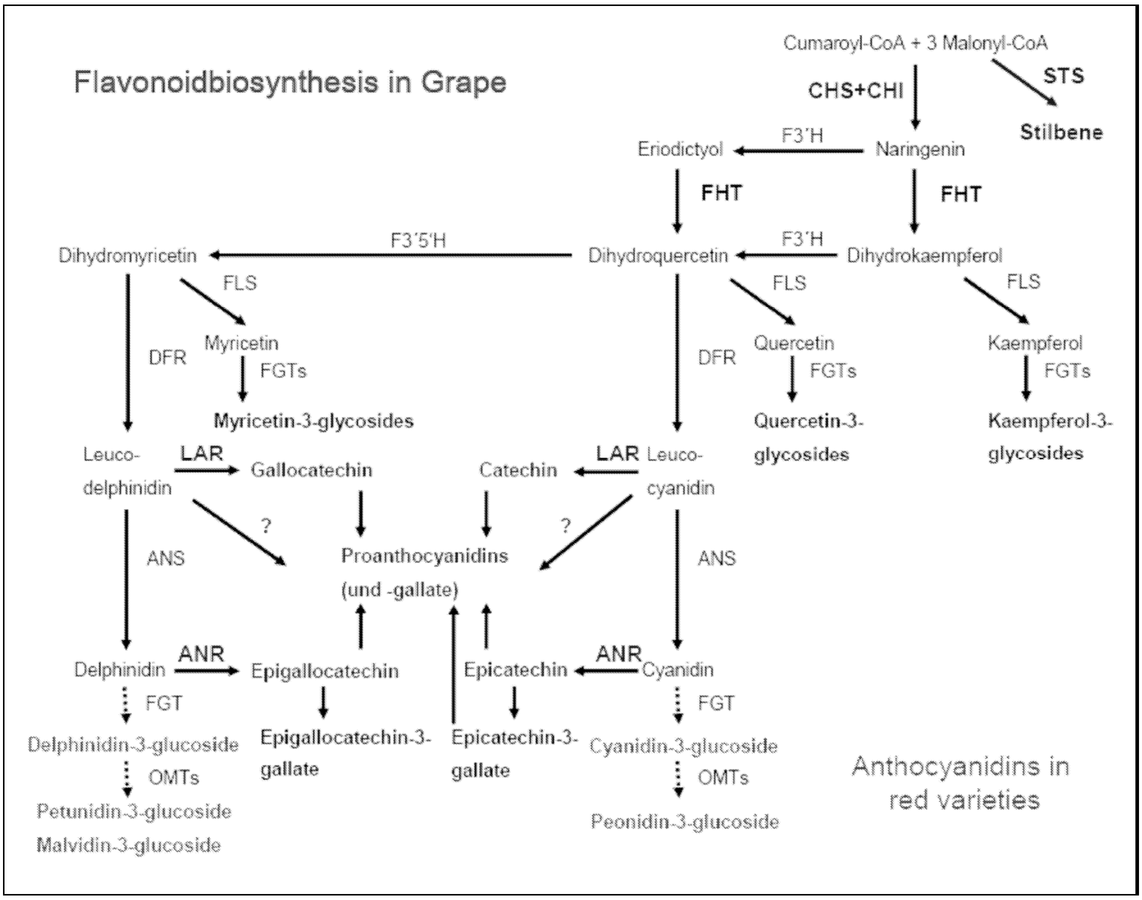



Fig. (3): Flavonoidbisosynthesis in grape according to Fisher *et al.* (2005)

The flavan 3-ol, catechin is one of the most abundant of these phenolic compounds in grape (Singleton and Essau, 1969 ; Singleton, 1988).

The flavan 3-ol are mainly localised in the seeds and skin (Thorngate and Singleton 1997).

Although traces of monomers and dimers of the flavan 3-ol have been detected in the pulp (Bourzeix *et al.* 1986, Ricardo Da Silva *et al.* 1992).

Furthermore, the flavonols present in the white and red grape are localised only in the skin (Wulf and Nagel 1980, Cheynier and Rigaud 1986). Moreover, the anthocyanins present only in red grapes, are generally localised in the skin (Amrani-Joutei 1993) and for some type of vines, in pulp (Pecket and small 1980).

### 2.7.2.5.3 Basic defintion

Phenolic compounds are characterised by at least one aromatic ring (phenyl ring) with at least on Hydroxyl-group (OH) (Fig. 4).

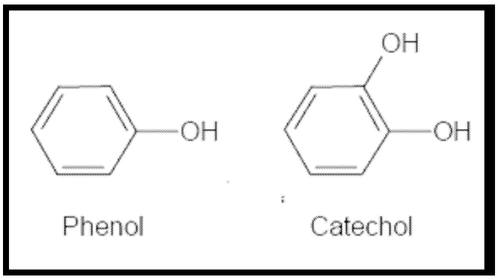



Fig.(4): Simple phenols

Phenol does not occure in plants. Catechol (*ortho*-Dihydroxyphenol) is a structural component of many bioactive phenols with high antioxidant capacity (Treutter 2007).

### 2.7.2.5.3.1 Non- flavonoid compounds group

### 2.7.2.5.3.1.1 Hydroxybenzoic acids

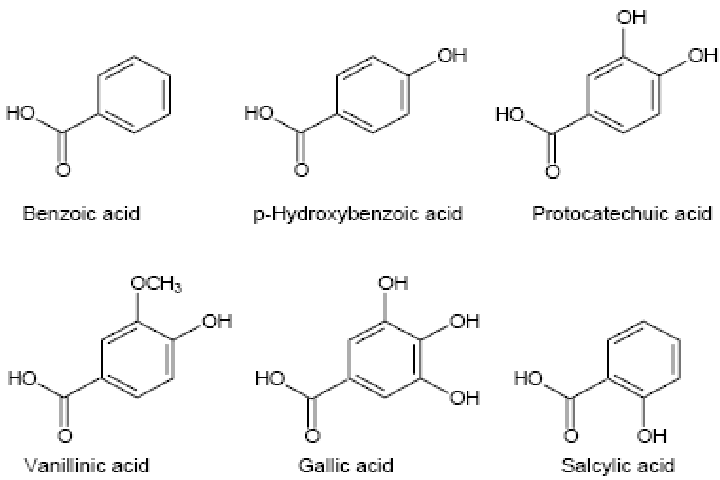



Fig.(5): Prominent benzoic acids

### 2.7.2.5.3.1.2 Hydroxycinnamic acids (phenylpropanoids):

The hydroxycynnamic acids play a central role in the biogenesis of plant phenolics. They are derived from cinnamic acid which is built from the amino acid phenylalanine by desamination (Fig. 6).

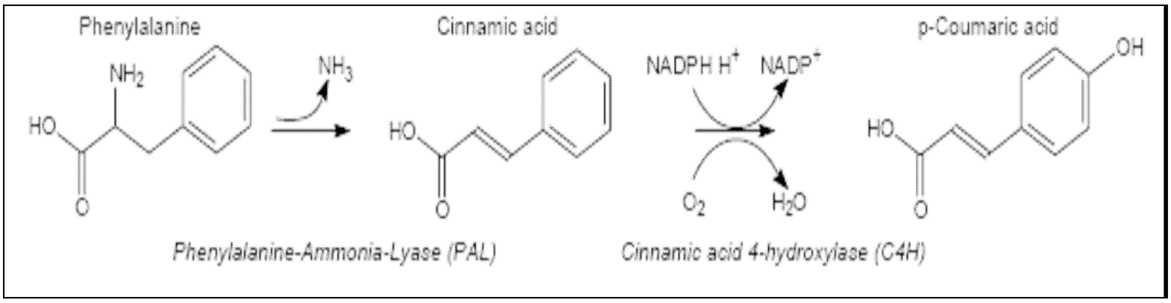



Fig. (6) Biosynthesis of *p*-coumaric acid from phenylalanine via cinamic acid.

This reaction is catalysed by phenylalanine ammonia lyase (PAL) which is regarded as the key enzyme for the complete biosynthesis of phenylpropanoids inculding the flavonoids and lignin. This reaction marks the frontier to the primary metabolism. The cinnamic acid is rapidly hydroxylated in para-position to p-coumaric acid (Treutter 2007).

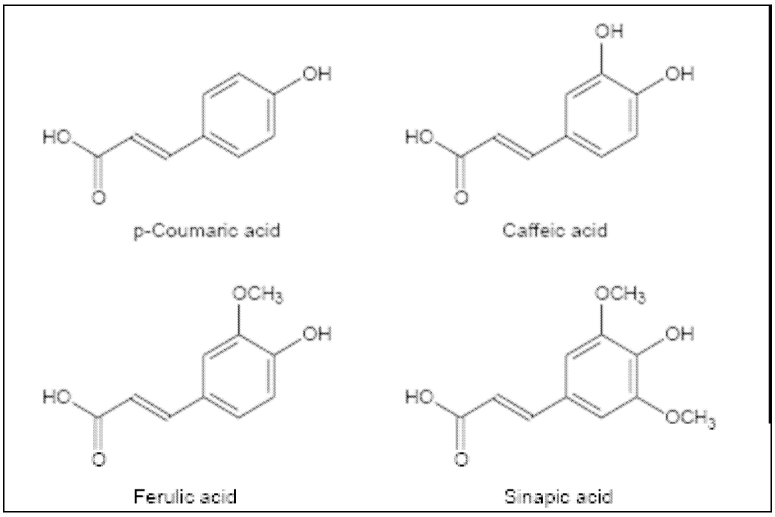



Fig.(7): Prominent hydroxycinnamic acids (phenylpropanoids)

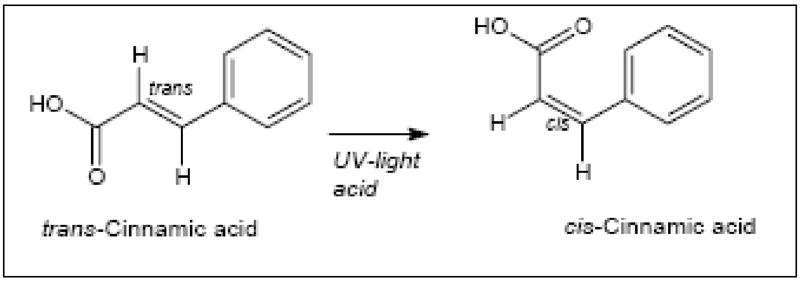



Fig.(8): *cis*-*trans*-Isomerie of phenylpropanoids

### 2.7.2.5.3.1.3 Stilbenes (resveratrol)

Stilbenes are directly synthesised from hydroxycinnamic acids. The enzyme stilbene synthase (STS) required p-coumaroyl-CoA and 3 molecules of malonyl-CoA as substrates (Fig. 9). The enzyme is closely related to chalcone synthase (CHS) that is the first compound in flavonol and anthocyanin pathway (Fig. 10).

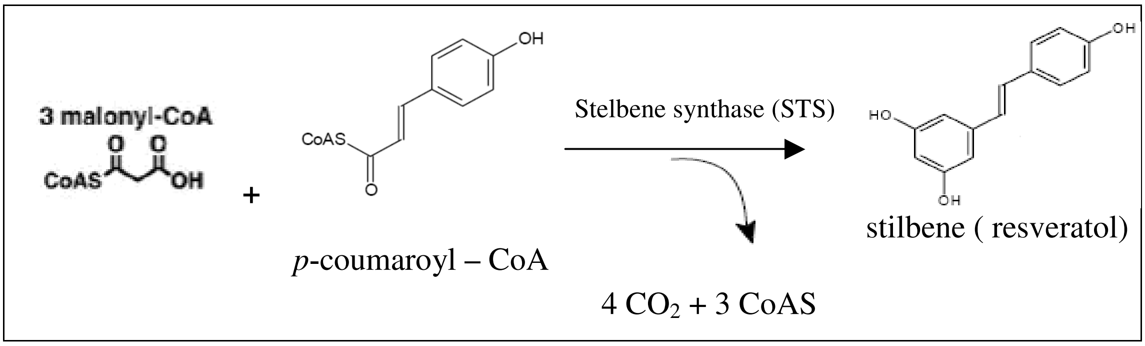



Fig.(9): Stilbenes (resveratrol) biosynthetic pathway.

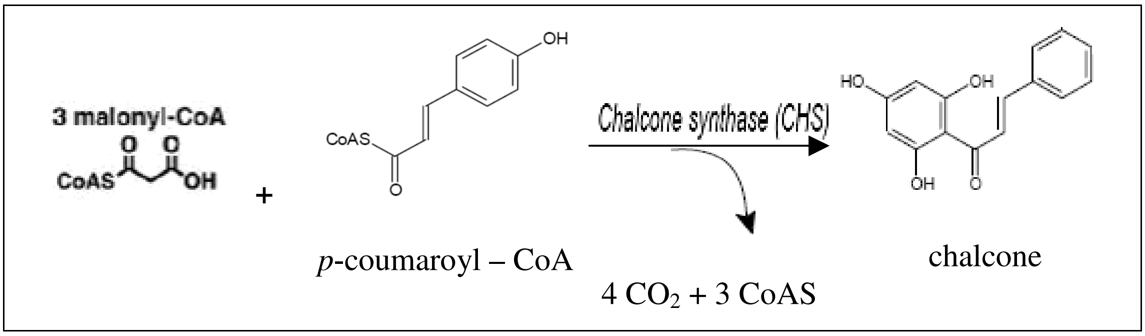
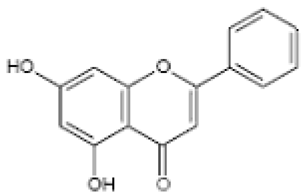
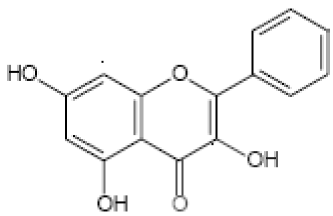


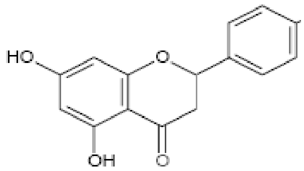

Fig.(10): Biosynthesis of chalcone.



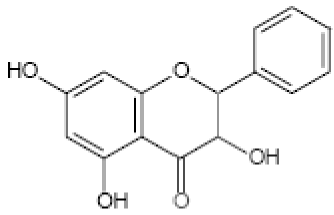
flavones



flavonols

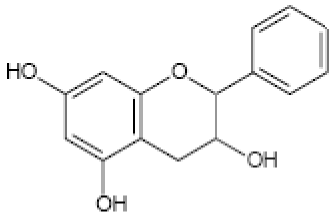


flavanones

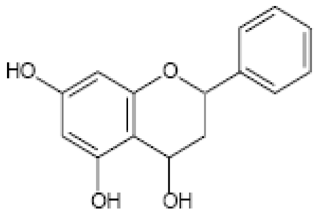


flavanonoles

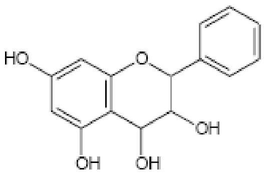
(dihydroflavonols)



(flavan 3-ol)

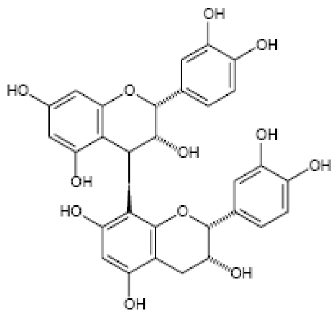


flavan 4-ol



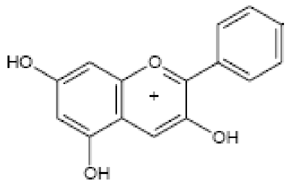
flavan 3,4-diol

(leucoanthocyanin)

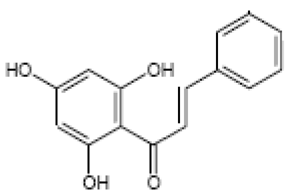


Proanthocyanidins

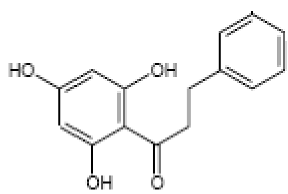
(Tannins)



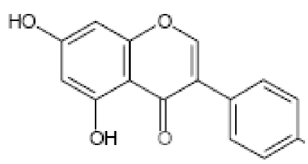
Anthocyanidins



chalcones



dihydrochalcones



Isoflavones

Fig. (11) : Flavonoids

### 2.7.2.5.3.2 Flavonoids compound group

Flavonoids are a group of compounds based on the polyphenolic flavan skeltone. Fig.(12)

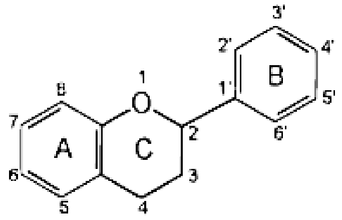
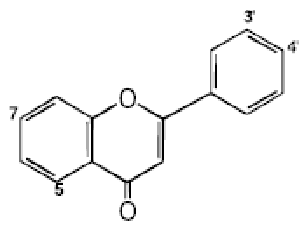



Fig (12): Flavan skeltone 'The basic of flavonoid structure'

#### 2.7.2.5.3.2.1 Flavones

The mostly yellow flavones (flavus (latin) = yellow) were obviously the first compound among the group of flavonoids, which were detected in nature and identified. They are structurally characterised by the keto-group (=O) in the hetrocycle (Treutter 2007). Fig. (13).




| **Flavone** | **5** | **7** | **3'** | **4'** |
|---|---|---|---|---|
| Apigenin | OH | OH | H | OH |
| Luteolin | OH | OH | OH | OH |
| Chrysoeriol | OH | OH | $OCH_3$ | OH |

Fig. (13): Basic flavones structure

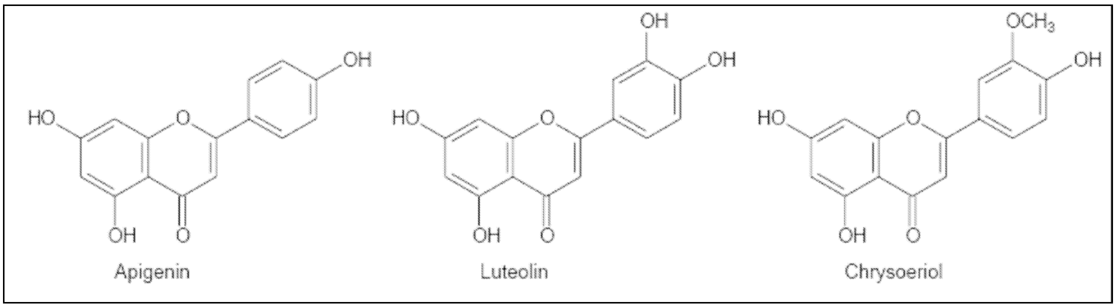
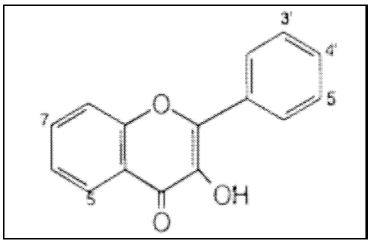



Fig. (14): Flavones

### 2.7.2.5.3.2.2 Flavonols

Treutter (2007) mentioned that another yellow classes of flavonoids was found: the flavonols. Beside the keto-function they possess an alcoholic OH-group (Fig. 15).




| **Flavonol** | **5** | **7** | **3'** | **4'** | **5'** |
|---|---|---|---|---|---|
| Kaemferol | OH | OH | H | OH | H |
| Quercetin | OH | OH | OH | OH | H |
| Myricetin | OH | OH | OH | OH | H |
| Isorhamnetin | OH | OH | $OCH_3$ | OH | OH |

Fig. (15) : Basic Flavonols structure

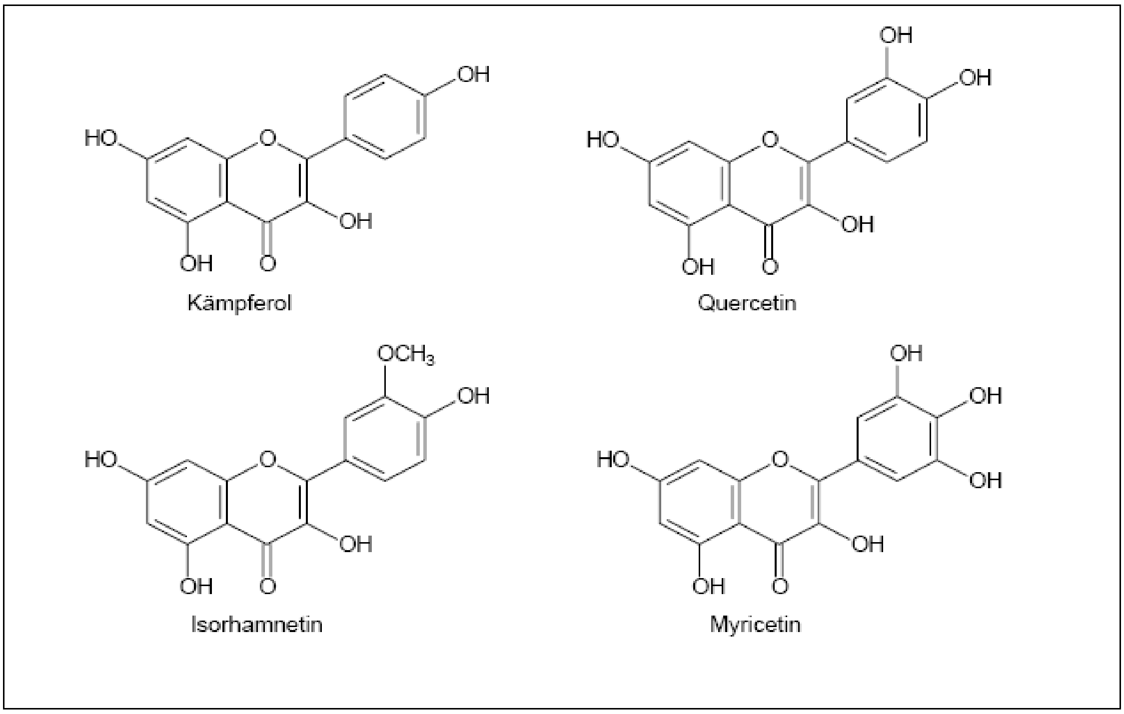



Fig. (16): Flavonols

Makris *et al.* (2006) stated that flavonols constitute a group of flavonoid that vary in color from white to yellow and are closely related in structure to the flavones. They are represented mainly by kaempferol, quercetin and myricetin, while simple *O*-methylated derivatives such as isorhamnetin (quercetin 3´- methylether) are also common (Fig. 16).

**2.7.2.5.3.2.3 Dihydroflavonols:**

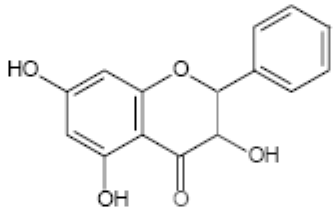



Fig. (17): Basic dihydroflavonols structure

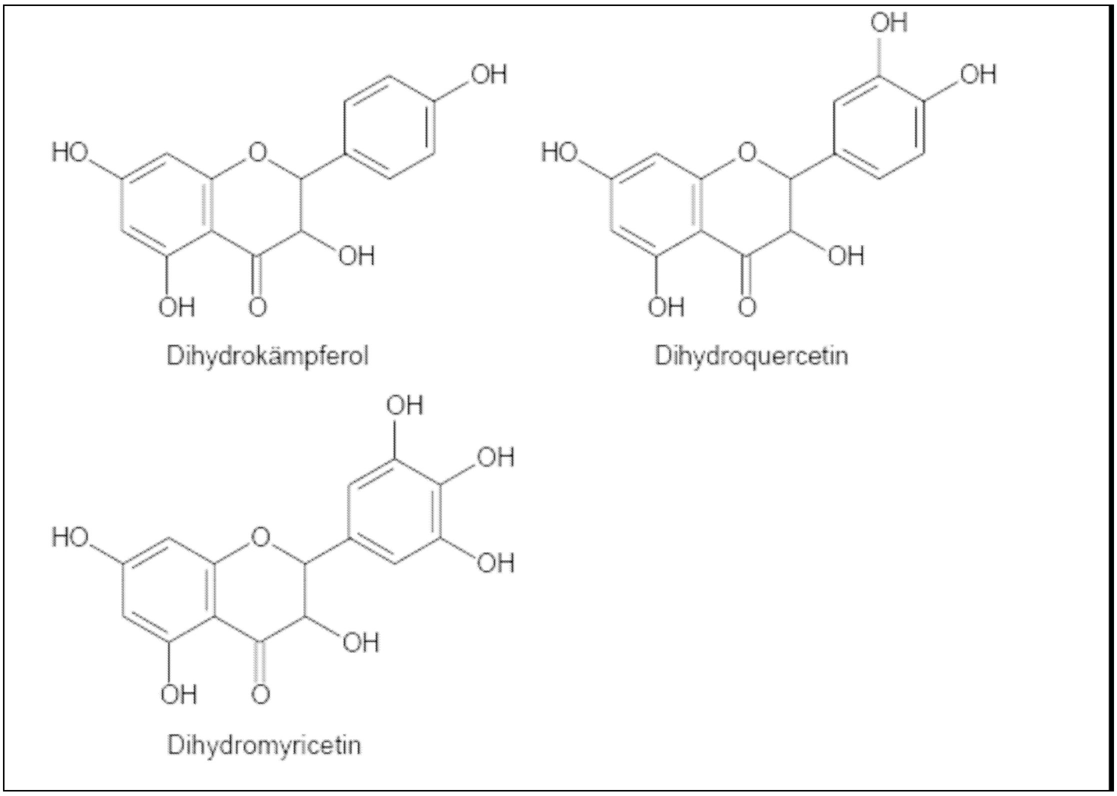
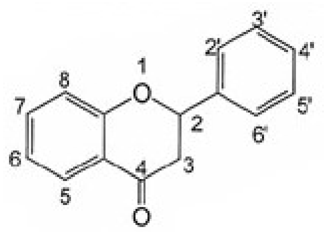



Fig. (18): Dihydroflavonols

### 2.7.2.5.3.2.4 Flavanones:

Beside the yellow classes flavones and flavonnols several colourless of flavonoids such as flavanones. Fig. (19).




| Flavanone | 5 | 7 | 3' | 4' | 5' |
|---|---|---|---|---|---|
| Naringenin | OH | OH | H | OH | H |
| Eriodictyol | OH | OH | OH | OH | H |
| Hesperetin | OH | OH | OH | $OCH_3$ | H |
| Pentahydroxyflavnone | OH | OH | OH | OH | OH |

Fig. (19): Basic flavanone structure

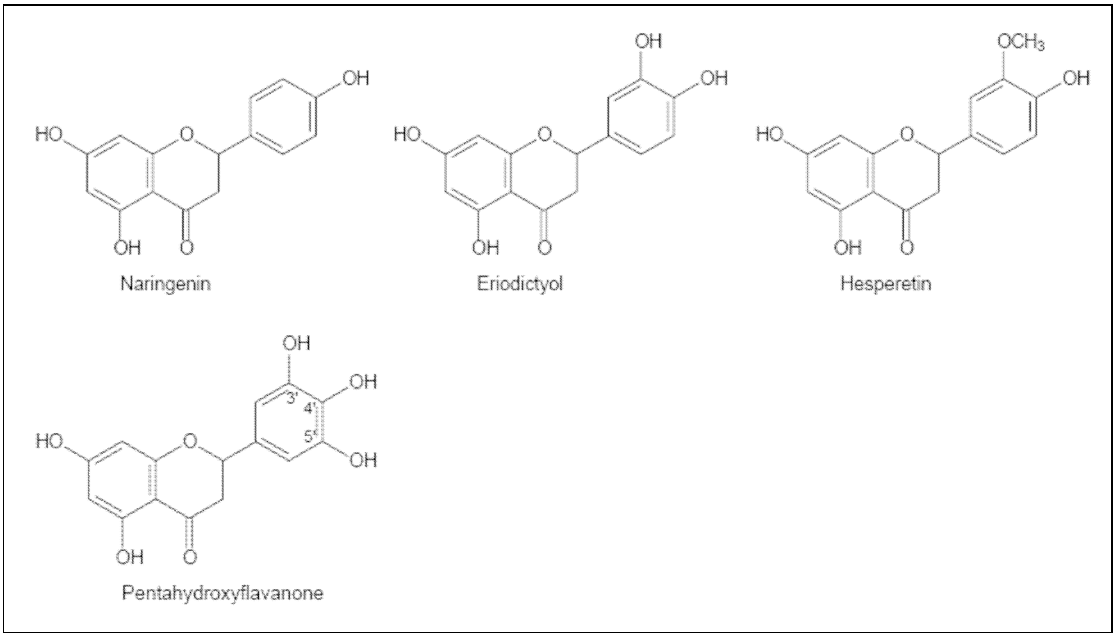



Fig. (20): Flavanones

The flavanone 3-hydroxylase (FHT) enzyme introduces a OH-groupe at position 3, which results in the structure of dihydroflavonol (flavanonol).

### 2.7.2.5.3.2.5 Flavan 3-ols

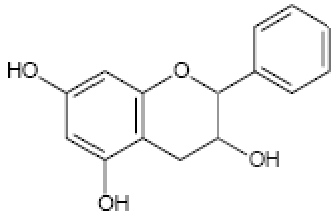



Fig. (21): Basic flavan 3-ols structure

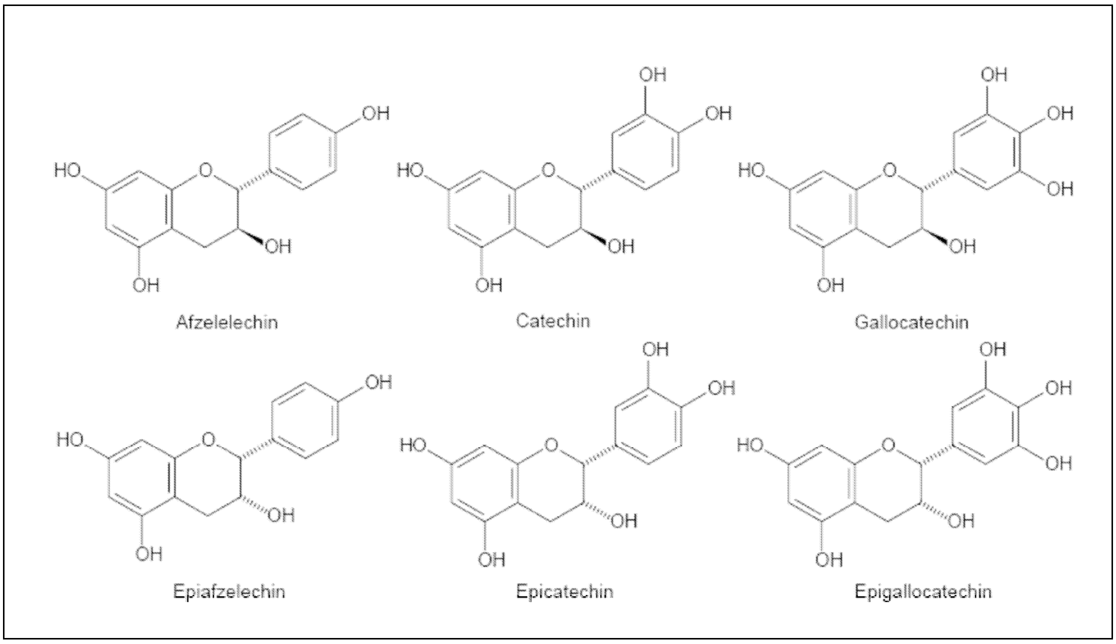



Fig. (22): Flavan 3-ols

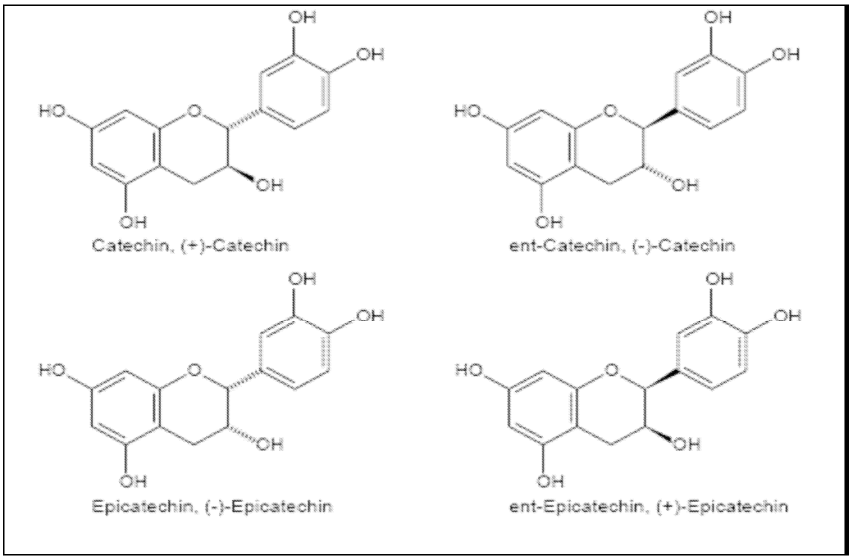



Fig.(23): Flavan 3-ols and epiflavan 3-ols

### 2.7.2.5.3.2.6 Flavan 4-ols:

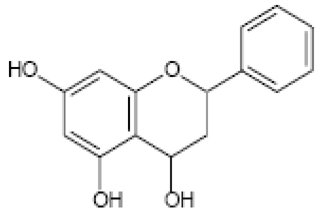



Fig. (24): Basic flavan 4-ols structure

### 2.7.2.5.3.2.7 Flavan 3,4-diols (Leucoanthocyanidins)

Many red and blue pigments of plants belong to the groupe of anthocyanidins. These are synthesised from flavan 3,4-diols (leucoanthocyanidins) by the enzyme anthocyanidin synthase (ANS).

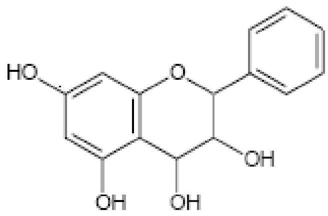



Fig. (25): Basic flavan 3,4-diols structure

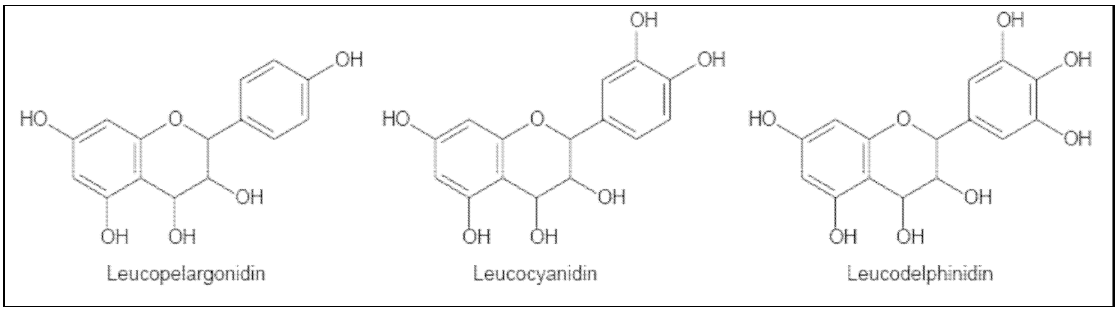



Fig.(26): Flavan 3,4-diols (Leucoanthocyanidins)

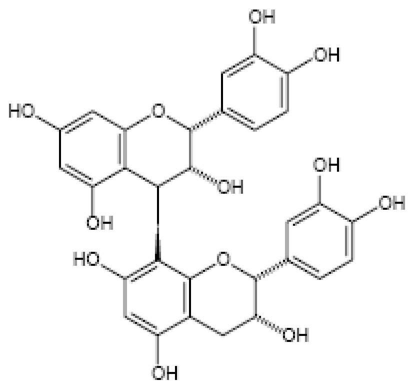
### 2.7.2.5.3.2.8 Proanthocyanidins (condensed tannins)

The proanthocyanidins consist of flavanol-moieties with terminal unit such as epicatechin or catechin, which was extended by flavan 3,4-diols as extension unit while water was eliminated (condensation). Therefore, these compounds are also called condensed proanthocyanidins or condensed tannins.

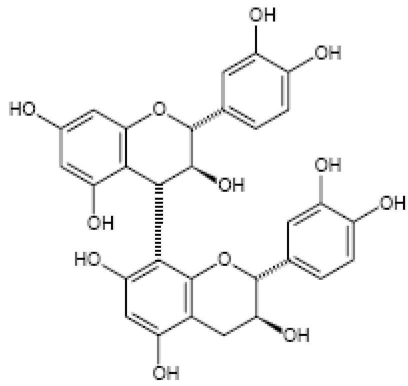
The flavan–3 ols group include a range of polyphenolic compounds ranging from small oligomeric forms to larg proanthocyanidin polymers (condensed tannins). These oligomers and polymers are composed of monomeric subunits analogous to flavan 3-ol monomers such as catechin and epicatechin (Downey *et al.* 2006).

Table (1): prominent procyanidin structures according to Treutter (2007).

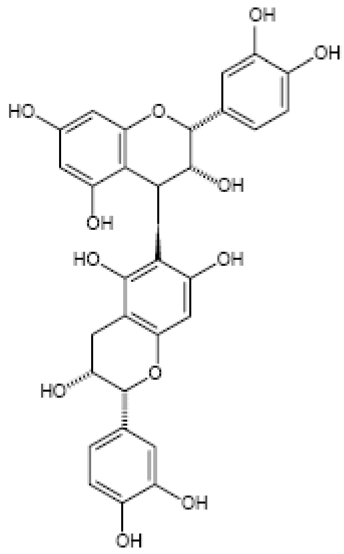
| **Trivial name** | **Structural name** |
|---|---|
| **Procyanidin B1** | Epicatechin-(4β → 8)-Catechin |
| **Procyanidin B2** | Epicatechin-(4β → 8)-Epicatechin |
| **Procyanidin B3** | Catechin-(4α → 8)-Catechin |
| **Procyanidin B4** | Catechin-(4α → 8)-Epicatechin |
| **Procyanidin B5** | Epicatechin-(4β → 6)-Epicatechin |
| **Procyanidin B6** | Catechin-(4α → 6)-Catechin |
| **Procyanidin B7** | Epicatechin-(4β → 6)-Catechin |
| **Procyanidin B8** | Catechin-(4α → 6)-Epicatechin |
| **Procyanidin A1** | Epicatechin-(2β → O→7, 4β →8)-Catechin |
| **Procyanidin A2** | Epicatechin-(2β → O→7, 4β →8)- Epicatechin |
| **Procyanidin C1** | Epicatechin-(4β → 8)-Epicatechin-(4β → 8)-Epicatechin |
| **Procyanidin C2** | Catechin -(4α → 8)- Catechin -(4α → 8)- Catechin |



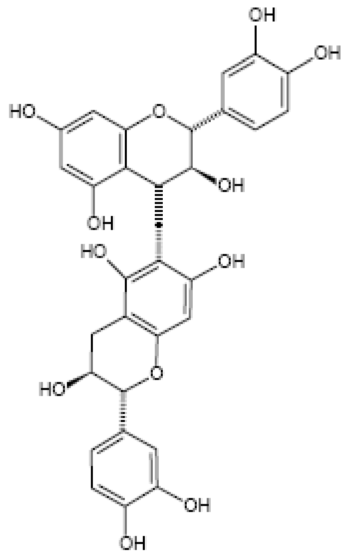
Procyanidin B2



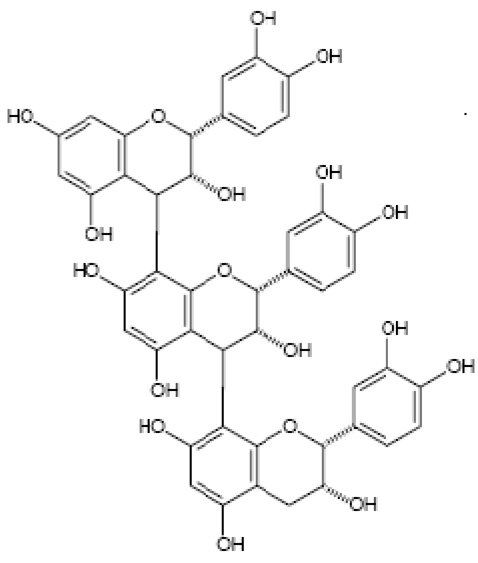
Procyanidin B3



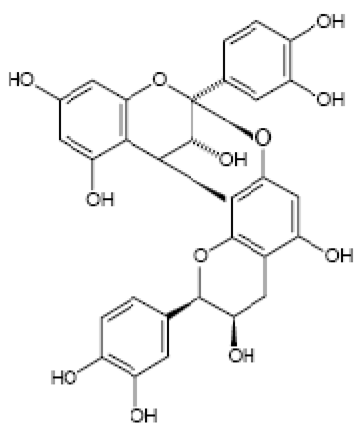
Procyanidin B5



Procyanidin B6



Procyanidn C1



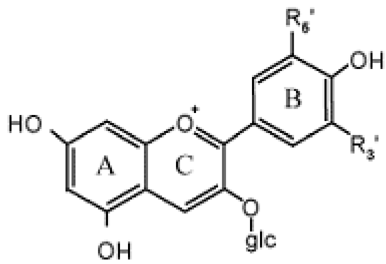
Procyanidin A2

Fig. (27): Formulae of selected procyanindins

### 2.7.2.5.3.2.9 Anthocyanins

Anthocyanins are plant secondary metabolites providing pigmentation to flowers, fruits, seeds and leaves (Winkel-Shirley 2001).

Anthocyanins are a wide family of pigments present in plants and fruits. They naturally occur as glycosides of flavylium salts differing in the methoxyl and hydroxyl substitution pattern of ring B (Fig. 28). The more widespread anthocyanins in fruits are glycosilated in the 3-OH position (3-*O*-monoglycosides) and, in less extension, in both position 3-OH and 5-OH (3,5-*O*-diglycosides). Their chromatic features are importantly affected by the substituation of ring B. For example, the increase of the hydroxylation pattern results in a bathochromic shift from red to violet color (Pelargonidin → Cyanidin→ Delphinidin). The nature of sugar (e.g. glucose - glc, arabinose - ara, rutinose - rut, sambubiose – samb), acylated or not, and its position in aglycone skeleton are also important structural factors that infulence the hue of these pigments. All this structural factors vary between species (De Freitas and Mateus, 2006).




| **Anthocyanidin** | R3' | R5' |
|---|---|---|
| Pelargonidin | H | H |
| Cyanidindin | OH | H |
| Delphinidin | OH | OH |
| Paeonidin | $OCH_3$ | H |
| Petunidin | $OCH_3$ | OH |
| Malvidin | $OCH_3$ | $OCH_3$ |

Fig. (28): Basic anthocyanin structure

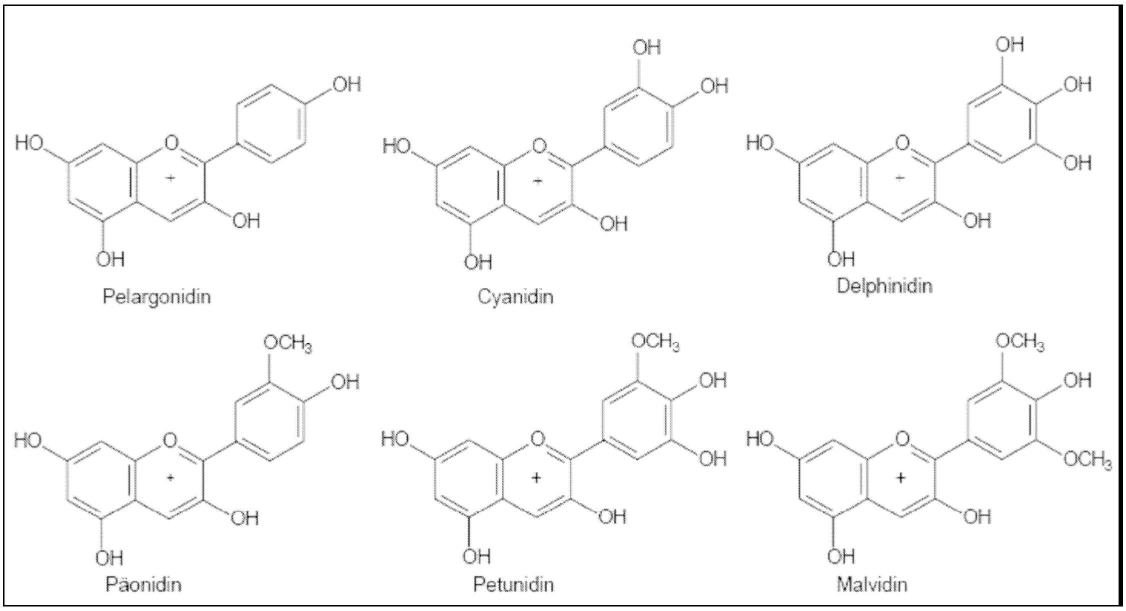



Fig. (29): Anthocyanidins

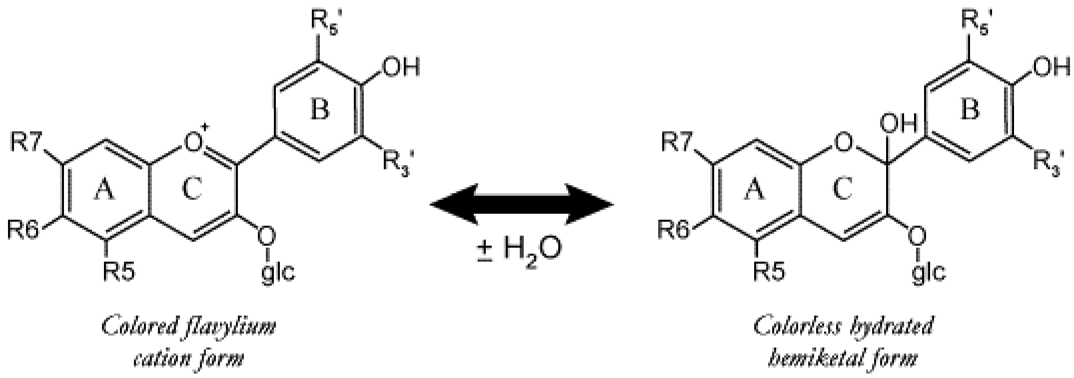



Fig.(30): Colored flavylium cation and colorless hydrated bemiketal form of anchocyanins ( according to Bouillard *et al.* 1977).

Bouillard *et el.* (1977) mentioned that the second major class of compounds found in red grapes are anthocyanins. They have a positive charge on the molecule, which enables it to absorb light and thus have color. An anthocyanin has a carbohydrate (sugar, usually glucose) esterified at the 3 position. An anthocyanidin, termed the aglycone, does not have a sugar at the 3 position. Naturally occurring pigments from grapes always have a sugar bonded at the 3 position, though other compounds such as hydroxycinnamates and acetate may be involved. The presence of this sugar helps the anthocyanin maintain solubility in water. If the sugar is hydrolyzed or lost, the solubility decreases and the molecule will be destabilized and lost.

### 2.7.2.5.3.2.10 Hydrolysis of procyanidins:

Haslam *et el.* (1988) suggested that condensed tannins (polyphenolics) are not stable to hydrolysis. The conditions (low pH, high acidic conditions) favor hydrolysis at the 4–>8 positions or the 4–>6 positions.

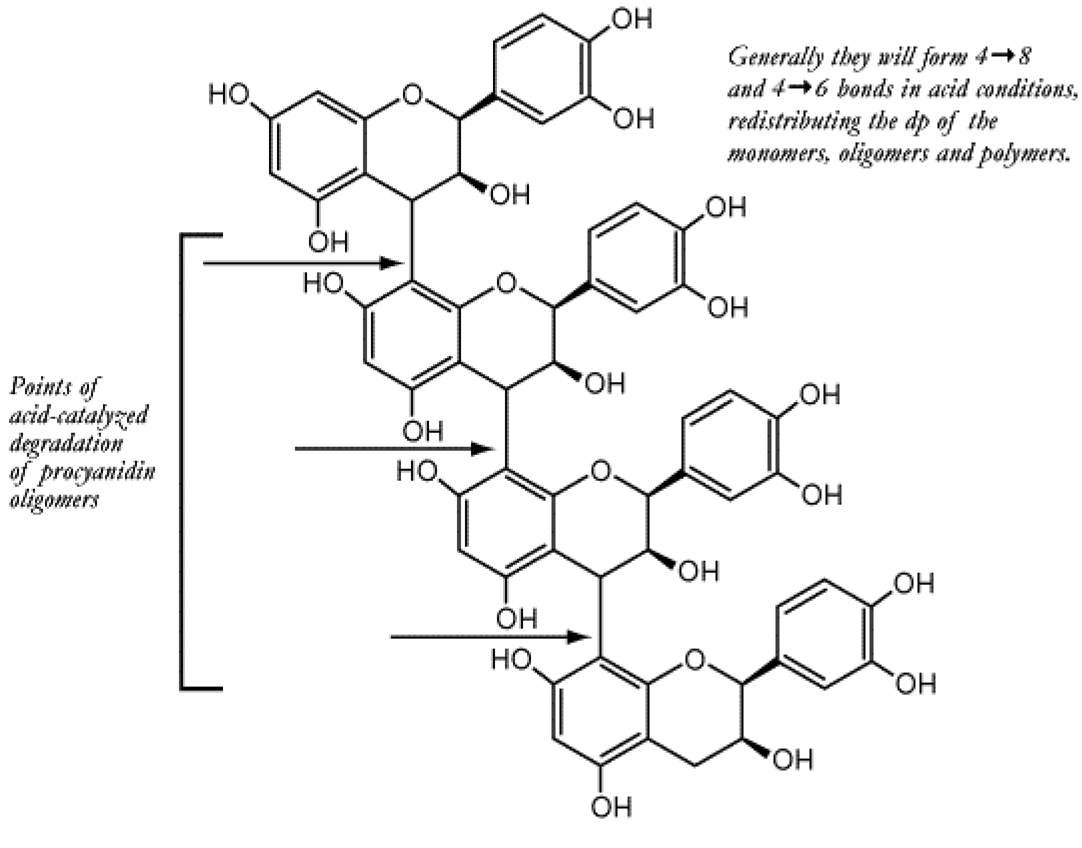



Fig (31): Hydrolysis of Procyanidins.

### 2.7.2.5.3.2.11 Anthocyanin biosynthetic pathway:

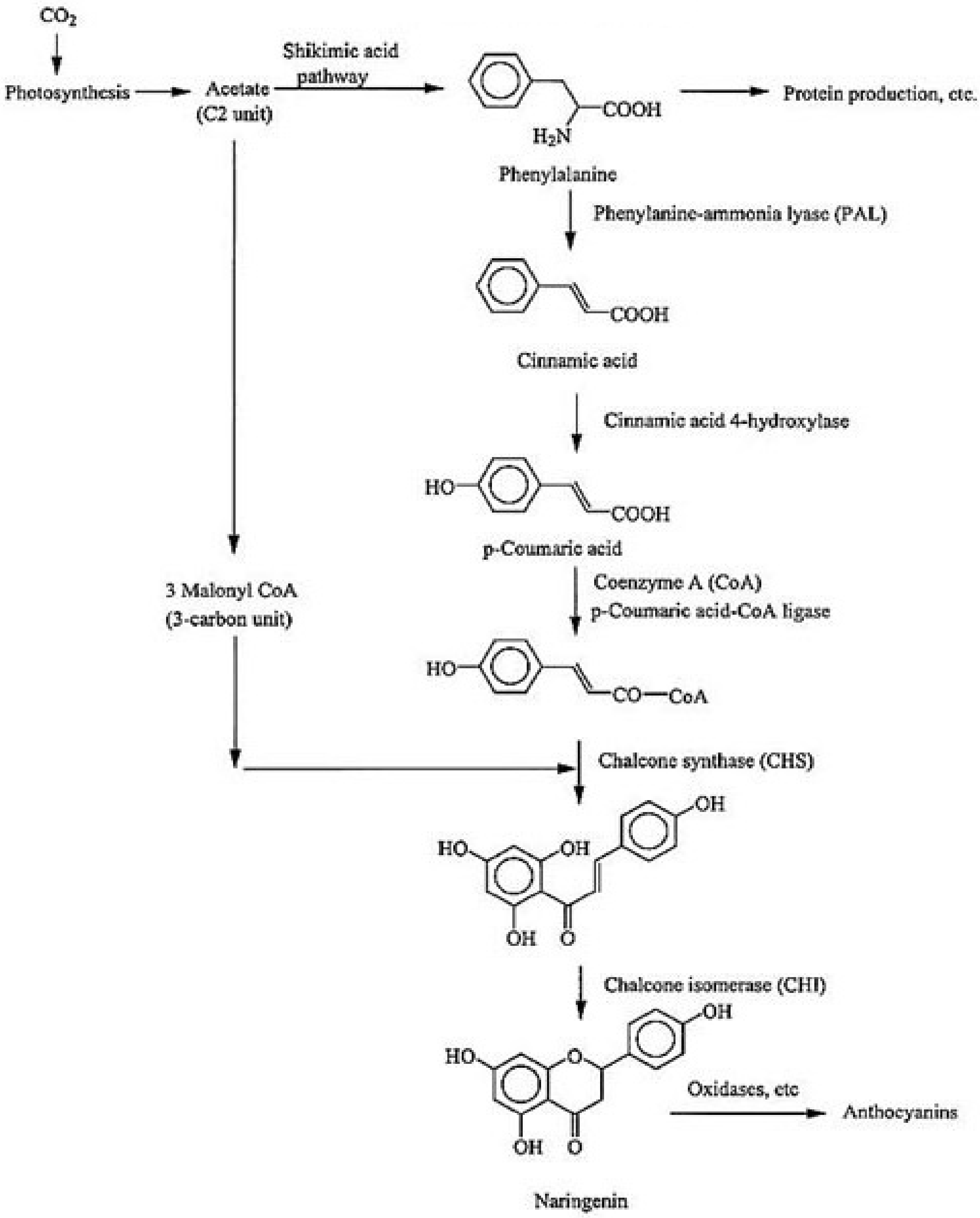



Fig.(32): Anthocyanin biosynthetic pathway.

## 2.7.2.5.3.2.12 Flavonol and anthocyanin biosynthetic pathway:

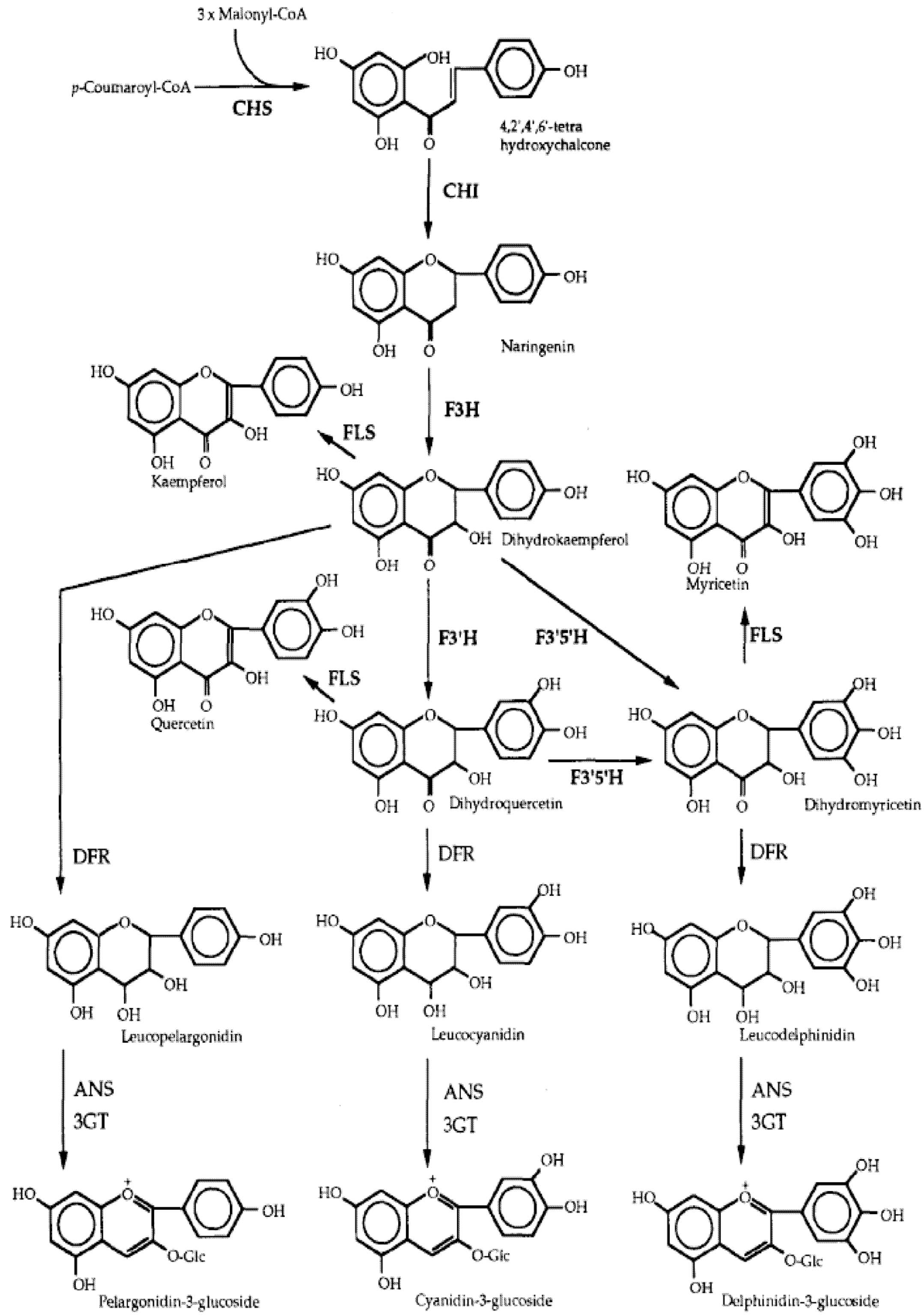



Fig.(33): Flavonol and anthocyanin biosynthetic pathway.

The enzyme dihydroflavonol reductase (DFR) reduces the keton-groupe in position 4 of the dihydroflavonols leading to flavan 3,4-diols. These are also called leucoanthocyanidins since they are the colourless precursors of anthocyanidin.

The anthocyanidins have been regarded as end-products of the flavonoid pathway. Meanwhile, it has been found in several plants that anthocyanidins are the metabolic precursors of epi-flavanols, such as epicatechin.

### 2.7.2.5.3.2.13 Catechin, epicatechin, cyanidin biosynthetic pathway

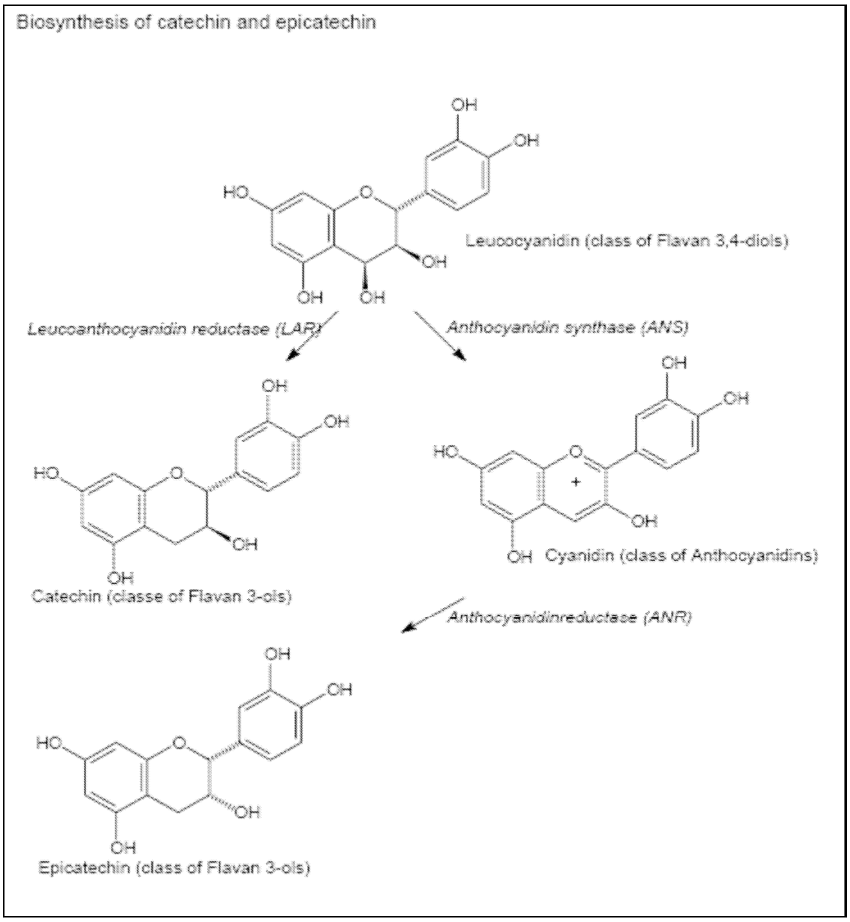
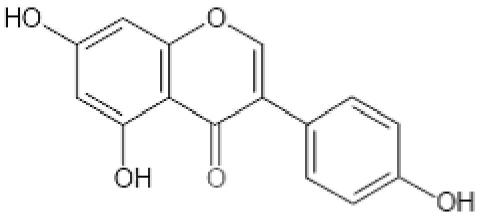


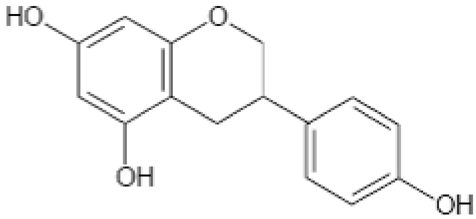

Fig.(34): Biosynthesis of catechin, epicatechin and cyanidin.

### 2.7.2.5.3.2.14 Isoflavonoids :

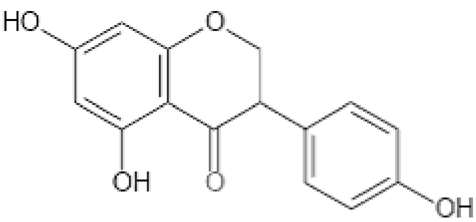
Isoflavonoids are derived from flavanones by the action of the enzyme isoflavone synthase. The basic isoflavone structure can be extended by further ring systems such as in rotenoids, pterocarpans and coumestans.



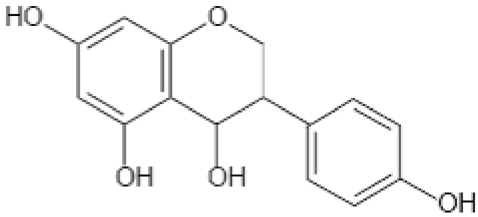

isoflavone




isoflavan

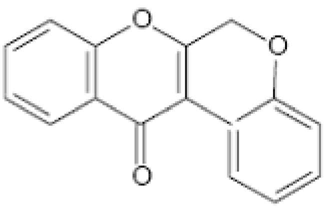



isoflavanone

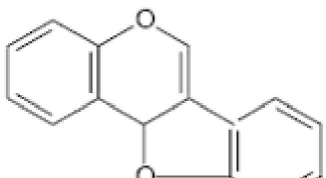



isoflavanol

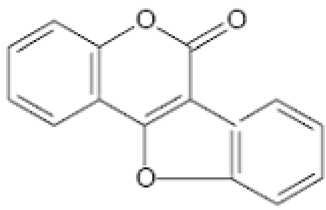
Fig.(35): Basic isoflavonoids structure




rotenoids




ptrocarpans




coumestans

Fig.(36): Structures derived from isoflavonoids: rotenoids, ptrocarpans and coumestans

### 2.7.2.5.4 Determination the flavonoids in grapes

Cantos *et al.* (2002) determined the ancothyanin, flavonols, flavan-3-ols and hydroxycinnamic acid derivatives of seven table grape cultivars (4 red varieties: ‘Red Globe’,‘Flame Seedless’,‘Crimson Seedless’ and ‘Napoleon’ and 3 white vareities: ‘Superior Seedless’, ‘Dominga’ and 'Moscatel Italica’. They found that the main anthocyanin in all of red varieties was peonidin 3-glucoside and the other most abundant anthocyanins were cyanidin 3-glucoside and malvidin 3-glucoside. Total anthocyanins ranged from 151 mg/kg fresh weight (fw) in ‘Flame Seedless’ (the richest source) to 68 mg/kg fw for ‘Crimson Seedless’ (the poorest varety together with ‘Napoleon’) (Table 2). The main flavonols found in all the table grape vareities were quercetin 3-glucuronide, quercetin 3-glucoside and quercetin 3-rutinoside. quercetin 3-glucuronide was the dominant flavonol in ‘Flame Seedless’ and ‘Napoleon’ varieties, wherease it was in the same concentration as the other two quercetin derivatives in ‘Crimson Seedless’ and ‘Moscatel Italica’ varieties. ‘Red Globe’, ‘Superior Seedless’, and ‘Dominga’ grapes contained quercetin 3-glucuronide in smaller amounts than quercetin 3-glucoside plus quercetin 3-rutinoside (Table 3).

Table (2): Anthocyanin content of 4 table grape vareities according to Cantos *et al.* (2002). Values are expressed as mg/kg of fresh weight of grape berry (skin+flesh)

| Anthocyanin (mg/kg of fresh weight ) | Red Globe | Flame Seedless | Crimson Seedless | Napoleon |
|---|---|---|---|---|
| Delphinidin 3-glucoside | 4.7 | 34.3 | 1.1 | 1.9 |
| Cyanidin 3-glucoside | 28.9 | 32.7 | 6.6 | 11.1 |
| Petunidin 3-glucoside | 2.71 | 17.9 | 0.9 | 1.4 |
| Peonidin 3-glucoside | 65.4 | 32.4 | 45.2 | 40.6 |
| Malvidin 3-glucoside | 9.25 | 33.4 | 8.8 | 17.8 |
| Cyanidin 3-*p*-coumaroylglucoside | 1.4 | 0.0 | 1.2 | 00 |
| Peonidin 3-*p*-coumaroylglucoside | 2.9 | 0.0 | 4.7 | 5.9 |
| Total anthocyanin | 115.3 | 150.7 | 68.5 | 75.7 |

Table (3): Polyphenolic compounds of 7 table grape vareities according to Cantos *et al.* (2002). Values are expressed as mg/kg of fresh weight of grape berry (skin+flesh).

| | Red globe | Flame Seedless | Crimson Seedless | Napoleon | Superior Seedless | Dominga | Moscatel Italica |
|---|---|---|---|---|---|---|---|
| Quercetin 3-glu* | 24.0 | 34.2 | 5.0 | 22.7 | 20.9 | 5.66 | 18.4 |
| Quercetin 3-glu/rut | 37.3 | 19.9 | 7.8 | 9.7 | 26 | 27.0 | 20.4 |
| Kaempferol-3-gal | Traces | Traces | Traces | Traces | 3.4 | Traces | 0.5 |
| Kaempferol-3glc | Traces | Traces | Traces | Traces | 12.3 | Traces | 4.7 |
| Isorhamnetin-3-glu | Traces | Traces | Traces | Traces | 1.4 | Traces | 3.7 |
| Total Flavonols | 61.3 | 53.8 | 12.8 | 32.4 | 64.0 | 32.7 | 47.7 |
| Caffeoyltartaric acid | 5.2 | 28.6 | 5.7 | 5.7 | 3.5 | 15.9 | 10.4 |
| Derv-a | 1.1 | 4.4 | 1.1 | 1.0 | 1.8 | 2.5 | 2.1 |
| *P*-Coumaroyltartaric acid | 2.1 | 14.6 | 2.7 | 2.8 | 3.7 | 6.6 | 3.8 |
| TH | 8.4 | 47.6 | 9.5 | 9.5 | 9.0 | 25.0 | 16.3 |
| Total flavan-3-ols | 40.4 | 109.1 | 41.1 | 18.3 | 62.7 | 57.2 | 81.1 |
| Total phenolics | 225.4 | 361.2 | 131.9 | 135.9 | 135.7. | 114.9 | 145.1 |

* glu = glucuronide, rut= rutinoside, gal= galactoside, glc= glucoside.

Derv-a = Hydroxycinnamic acid derivatives

TH = Total Hydroxycinnamic acid derivatives.

Montealegre *et al.* (2006) studied the polyphenolic compounds content in the skins of white grapes (‘Chardonnay’, ‘Sauvignon’, ‘Moscatel’, ‘Gewürztraminer’, ‘Riesling’ and ‘Viogner’) and in the skins of red grapes (‘Cencibel’, ‘Cabernet Sauvignon’, ‘Merlot’ and ‘Shiraz’) (Table 4&5). They mentioned that six compounds were quantified in the group of non- flavonoids phenolic acids. Protocatechuic acid was the only hydroxybenzoic acid found only in skins of red grapes. The others belonged to the group of tartaric esters of caffeic, coumaric and ferulic acids. The *trans* isomers presented higher concentration than the *cis* isomers in all cases (the *trans* isomer of ferulic was only detected in the skins of white grapes and in small quantities). As regards the family of flavanols, it was observed that the main monomer compound in the skins of white grape varieties was catechin (10-20 mg/kg), flowed by epicatechin (0-10mg/kg), which in some cases was below the quantification level. No quantifiable quantities of procyanidin B2 were found, the concentrations of procyanidin B1 and B3 varied between 12- 48 mg/kg and the concentration of procyanidin B3 were slightly higher, with the exception of ‘Gewürztraminer’. ‘Viogner’ variety contained no quantifiable amounts of any of the monomers and dimers of flavanols and no quantifiable amounts of epicatechin were found in those of the Riesling variety. The concentration of flavan-3-ol in red grape skins was of the same order as in white grape skins.

Table (4): Polyphenolic compounds (mg/kg of fresh grape) in the skins of white grape varieties according to Montealegre *et al.* (2006) .

| | Chardonnay | Sauvignon | Moscatel | Gewürztraminer | Riesling | Viogner |
|---|---|---|---|---|---|---|
| *cis*- Caftaric | 0.85 | 0.39 | 0.62 | 0.70 | 1.3 | Traces |
| *trans* – Caftaric | 20 | 5.2 | 14 | 13 | 31 | 24 |
| cis-Coutaric | 2.9a | 2.5a | 5.9b | 2.1a | 2.5a | 1.6a |
| *trans* – Coutaric | 7.9 | 4.9 | 18 | 6.1a | 7.0a | 1.9a |
| *trans*-Fertaric | 1.1 | 0.30 | 0.61 | 0.87 | 2.6 | Traces |
| Catechin | 23b | 9.5a | 16ab | 19ab | 14ab | Traces |
| Epicatechin | 5.8ab | 3.4a | 2.6a | 8.3b | Traces | Traces |
| Procyanidin B3 | 37 | 25 | 23 | 21 | 29 | Traces |
| Procyanidin B1 | 23 | 16 | 21 | 48 | 12 | Traces |
| Quercetin glucuronide | 25a | 12a | 54b | 17a | 30a | 67b |
| Quercetin glucoside | 17a | 8.9a | 20a | 24a | 22a | 66b |
| Kaempferol | 8.4a | 2.0a | 17b | 6.7a | 2.9a | 26c |
| Isorhamnetin glucoside | 0.48 | 0.78a | 0.72 | 2.3b | Traces | Traces |
| Total hydroxycinnamates | 33 | 13 | 38 | 22 | 4.5 | 5.8 |
| Total monomers flavan-3-ol | 28 | 12 | 19 | 28 | 14 | 9.7 |
| Total dimers flavan-3-ol | 60 | 41 | 44 | 69 | 41 | Traces |
| Total flavan-3-ols | 89 | 54 | 63 | 97 | 55 | 9.7 |
| Total flavonols | 53 | 25 | 98 | 50 | 56 | 170 |

The concentration of procyanidin B3 was slightly higher and with similar concentration to those found in white grape skins and small amount of procyanidin B2 were quantified in red grape skins. The total content of polyphenolic compounds in the skins of white grapes was lower than in red grape skins because myricetin glucuronide and glucoside and quercetin glucosylxyloside appear in red grape skins but not present in white grape skins.

Table (5): Polyphenolic compounds (mg/kg of flesh grape) in the skins of red grape varieties according to Montealegre *et al.* (2006).

| | Cencible | Caberenet Sauvignon | Merlot | Shiraz |
|---|---|---|---|---|
| Protocatechuic acid | 1.5a | 2.4b | 1.7ab | 2.4b |
| *cis*- Caftaric | 0.25 | 0.44 | 0.46 | 0.17 |
| *trans* – Caftaric | 5.7a | 9.5b | 7.0ab | 4.9a |
| *cis*-Coutaric | 2.7c | 2.0b | 0.94a | 1.5ab |
| *trans* – Coutaric | 10c | 5.8b | 3.2a | 6.1b |
| Catechin | 22 | 17 | 25 | 8.5 |
| Epicatechin | 8.4 | 6.2 | 13 | 6.9 |
| Procyanidin B3 | 39 | 27 | 35 | 16 |
| Procyanidin B1 | 22b | 12ab | 21b | 8.4a |
| Procyanidin B2 | 1.5ab | 0.99a | 2.2b | 0.75a |
| Myricetin glucuronoide | 10b | 10b | 5.8a | 7.3a |
| Myricetin glucoside | 26b | 22b | 13a | 21b |
| Quercetin glucuronide | 29a | 59b | 43ab | 35a |
| Quercetin glucoside | 32b | 48ab | 31a | 55b |
| Quercetin glucosylxyloside | 12a | 12a | 9.0a | 18b |
| Kaempferol | 14 | 13 | 8.0 | 13 |
| Isorhamnetin glucoside | 11 | 28 | 17 | 48 |
| Total hydroxycinnamates | 19 | 18 | 12 | 13 |
| Total monomers flavan-3-ol | 30 | 23 | 38 | 15 |
| Total dimers flavan-3-ol | 63 | 40 | 58 | 25 |
| Total flavan-3-ols | 92.83 | 63.03 | 96.28 | 40.77 |
| Total flavonols | 130 | 190 | 130 | 200 |

Pineiro *et al.* (2006) mentiond that the mean of *trans*-resveratrol in ‘Viura’ grapes was 2.18 mg /kg.

Hülya-Orak (2007) evaluated total anthocyanin, total phenols, total sugar and acidity contents in 16 grape cultivars and found that the total anthocyanin varied from 40.3 mg/kg (Md. Jean Matthias grapvines) to 990.8 mg/kg (cabarnet Sauvignon vines) (Table 6). The phenol concentration was determined between 965 (Tekidag Cekirdeksizi) and 3062 (Mourvedre) µg/gallic acid equivalent of phenolic compounds in 1 ml of the methanol extracts. The high sugar content value (24.46 %) was detected in Gewürztraminer and the lowest value (13.89 %) was in Bogazkere. The total organic contents of grape cultivars vared from 3.31 g/l (Md. Jean Matthias) to 9.53 g/l (Papazkarasi) tartaric acid equivalents.

Table (6): Anthocyanin, total phenols, sugar % and acidity of 16 grape cultivar according to Hülya-Orak (2007) .

| cultivars | Total anthocyanin (mg/kg) | Total phenols (µg/ml GAE) | Total Sugar (%) | Acidity (g/l) |
|---|---|---|---|---|
| Md. Jean Matthias | 40.3 e | 1535 l | 20.37 e | 3.31 i |
| Öküzgözü | 938.5 b | 2429 d | 17.50 gh | 5.11 gh |
| Muscat Hamburg | 384.6 hi | 1279 m | 20.31 e | 3.97 i |
| Cabernet Sauvignon | 990.8 a | 2348 e | 21.75 cd | 5.97 fg |
| Tekidag Cekirdeksizi | 173.8 j | 965 n | 22.92 bc | 4.21 hi |
| Gewürztraminer | 58.6 k | 2083 f | 24.46 a | 3.54 i |
| 2B/56 | 155.8 j | 817 o | 20.37 e | 6.54 c-f |
| Kalecik Karasi | 354.3 i | 2036 g | 22.23 c | 7.20 b-d |
| Carigan | 783.2 e | 2057 fg | 18.90 fg | 6.84 c-f |
| Kokulu Siyah | 813.3 c | 2038 g | 20.53 de | 7.36 bc |
| Alphonse Lavallee | 733.3 e | 1728 h | 16.82 gh | 3.81 i |
| Bogazkere | 631.4 f | 2649 c | 13.89 j | 8.09 b |
| Adkarasi | 420.6 h | 2695 b | 16.08 i | 6.19 ef |
| Papazkarasi | 390.6 hi | 1697 i | 16.93 hi | 9.53 a |
| Mourvedre | 475.8 g | 3062 a | 19.93 ef | 7.05 c-e |
| Cinsaut | 605.6 f | 1597 k | 20.20 e | 6.22 d-f |

Cadot *et al.* (2006) determined the flavan-3-ol in grape berries of *vitis vinifera* L. cv ‘Cabernrt Franc’ before veraison. It varied between 1040 to 1470 mg/ kg grape skin.

Caillet *et al*. (2006) evaluated three grape extracts from seed, skin, and whole grape. They found that the total phenols in seed and skin were greater than in the whole of grape (80.7, 79.2 and 49.6 g/100g respectively).

Makris *et al.* (2006) reported a critical rieview about flavonols in red and white grapes as well as in white and red grape juices . The critical review presented in Table (7).

Table (7): Flavonols in grape , grape juice according to Makris *et al.* (2006).

| cultivars | Compound (s) | Average | References |
|---|---|---|---|
| Red grapes | Quercetin-3-*O*-galactoside<br>Quercetin-3-*O*-glucoside | 34.95 (mg/kg) | Oszmianski and Lee (1990) |
| Red grapes | -------- | 12.89 (mg/l) | Meyer *et al*. (1997) |
| Red grapes | Quercetin-3-*O*-glucoside<br>Quercetin-3-*O*-glucuronide | 21.16 (mg/kg) | Cantos *et al.* (2000) |
| Red grapes | Quercetin, Myircetin<br>Kaempferol , Isorhamnetin<br>Glycosides thereof | 162.43 (nmol/g) | Burns *et al.* (2001) |
| Red grapes | Quercetin, Myircetin, Kaempferol | 24 (mg/kg) | Pastrana-Bonilla *et al.* (2003) |
| White grape | --------- | 8.2 (mg/l) | Meyer *et al.* (1997) |
| White grape | Quercetin, Myircetin, Kaempferol | 65 (mg/kg) | Pastrana-Bonilla *et al.* (2003) |
| White grape juice | Quercetin glycosides | 7.2 – 9 (µg/l) | Spanson and Wrolstad (1992) |
| White grape juice | -------- | 7.15 (mg/kg) | Frankel *et al*. (1998) |
| White grape juice | Quercetin-3-*O*-glucuronide | 0.5 (mg/kg) | Betes-Saura *et al*. (1996) |
| White grape juice | Quercetin, Myircetin, Kaempfero | 9.9 (mg/kg) | Talcott and Lee (2002) |
| Red grape juice | ---------- | 22.85 (mg/kg) | Frankel *et al*. (1998) |
| Red grape juice | Quercetin, Myircetin, Kaempfero | 57.15 (mg/kg) | Talcott and Lee (2002) |

### 2.7.2.5.5 Flavonoids in grapes as affected by N and K fertilization.

The concentration of flavonoids as phenolic compounds in grapes depends on the variety of grapevine and is influenced by viticulture and environmental factors (Cheynier *et al.* 1998, Broussaud *et al.* 1999, Ojeda *et al.* 2002, Downey *et al.* 2006).

The flavonoids consider very important components in grape berries that by their presence or absence, contribute greatly to grape quality, since they are responsible for color and stringency, bitterness, flavour as well as have attracted much interest due to their antioxidant properties and their potentially beneficial effect for human health (Montealegre *et al.* 2006).

Anthocyanin consider one of the important flavoniods classes. Red and black grapes owe their attractive color to their anthocyanin pigments. Moreover, anthocyanin levels and the other flavonoid classes in grape skin are parameters avaiable for evaluating grape quality. These levels are influenced by several environmental, cultural, physiological, and genetic factors. More important among the environmental factors affecting the coloration of grapes are air temperature, solar reduction, nitrogen and potassuim fertilization that are the two main nutriton elements in vineyards (Downey *et al.* 2006),

Keller *et al.* (1999) studied 4 rates of N-supply (0, 30, 60, 90 kg/ha) on phenolic compound in the berries of 'Pinot Noir' grapevines. They found that high rate of N fertilization (90 kg/ha) reduced skin phenols, flavonols and anthocyanins in skins. Malvidin-3-glucoside was the most abundant anthocyanin in skins. It accounted for 75 % of total anthocyanins. High rate of N fertilization (90 kg/ha.) decreased anthocyanins in juice and increased the percentage of malvidin-3-glucoside. The best treatment for fruit quality, in terms of color and oxidative stability, was low rate of N fertilization and the worst was high N fertilization.

Delgardo *et al.* (2004) and Martin *et al.* (2004) reported that the average dose of nitrogen (50 g N / vine) increased the levels of anthocyanins in the skin compared with the untreated control vine (0 g N/vine).

Many authors mentioned that high rate of nitrogen reduced skin anthocyanins (Mark, 1977, Keller *et al.* 1999, Abd-El-Mohsen 2003)

The role of potassium fertilization on improving anthocyanin levels in the berry skin of grapes was reported by Scienza *et al.* (1981) who noticed that anthocyanin content of 'Schiava' grapevine increased with increasing K soil application.

In addition, Morris and Cawthon (1982) stated that K fertilization significantly improved colour of 'Concord' grape berries.

Furthermore, Chris *et al.* (1999) showed that anthocyanin was higher with any dose of K fertilization than the control of 'Shiras' grapevine cv.

Morover, Arutyunyan (1978) ensured that high N fertilization depressed pigment accumulation in the berries, but increasing K fertilization improved grape colour.

### 2.8 The benefit of defoliation and cluster thinning:

Many authors mentioned the benefit of canopy management. In this respect, Koblet (1984) mentioned that the light intensity required for maximum photosynthesis ranges from 30 000 to 50 000 lx. Since leaves in the canopy interior don't receive sufficient light, shoot positioning and leaf removal are important in canopy management. Young and old leaves produce less sugar than mature leaves. Light and temperature also influence bud fertility. Temperature has a positive influence on grape quality during ripening. Well-exposed fruits contain more sugar and less acid than poorly-exposed.

English *et al.* (1990) found that removing basal leaves slightly changed temperature, atmospheric humidity, wind speed, and leaf wetness around grape clusters.

The more shaded interior of non-defoliated vines probably also impeded nutrient supply from the leaves to the buds, decreasing bud fertility and bud capacity (Hunter *et al.* 1995).

Sunlight-exposed fruits are generally greater in total soluble solids, anthocyanins, and phenolics and lower in titratable acidity, and berry weight compared to nonexposed or canopy shaded [Smart *et al*. (1985) Crippen and Morrison (1986 a), Crippen and Morrison (1986 b), Reynolds *et al*. (1986), Jackson and Lombard (1993), Dokoozlian and Kliewer (1995), Bergqvist *et al.* (2001), Ferree *et al.* (2004), Kliewer and Dokoozlian (2005), Santesteban and Royo (2006), Prajitna *et al.* (2007)].

Guidioni *et al.* (2002) reported that anthocyanin concentration of grapes is an important fruit quality parameter for marketing. Anthocyanins contribute to grape quality by effecting both color intensity and color quality. Several studies have examined the effects of environmental factors and agronomic techniques on the concentration of total anthocyanins in grapes. The concentration of these substances in ripe berries is affected by cluster exposure to direct sunlight, water stress or irrigation schedules and pathogen and virus infection. Moreover, manipulations of plant assimilate partitioning through leaf or cluster removal and stem girdling above or below clusters induce significant modification of the concentration of total anthocyanin and other classes of flavonoids.

Herrera (2002) improved fruit quality by fruit thinning. He removed about one-half of each cluster (the lower part of the main stem) and let four or five branches in the clusters near the cluster's base. The lower part of the cluster is usually compact, and the berries ripen later than those on the upper part.

Main and Morris (2004) applied leaf removal treatments for four years on 'Cynathiana' grapevines (*Vitis aestivalis* Michx.) to determined if leaf removal would affect yield or fruit quality. They reported that leaf removal did not affect yield, but improved the fruit quality.

Müller (2004) reported that the foliage pruning considered a very important tool to control grape quality. Partial defoliation is a common foliage pruning technique in Switzerland, however not in Germany. The advantages of this tool are better light use, less Botrytis and enhence higher grape quality, while higher contents of fruit aroma and polyphenols are produced.

Downey *et al.* (2006) mentioned that there are many factors reputed to affect flavonoid composition of grape, defoliation is one of these factors, which have more effect.

## 2.9 Effect of defoliation and fruit thinning on cluster characteristics and fruit quality

### 2.9.1 Cluster weight

Many investigators studied the effect of canopy management practices and fruit thinning on cluster weight, in this respect, Vargas (1984) worked on 'Alphonse Lavallee' and 'Cardinal' grape cvs and clear that tipping (removal of 15 cm of the shoot apex) plus removal of lateral shoots increased average cluster weight in both cultivars compared to control.

In addition, Pondev (1987) claimed that mean cluster weight increased as a result of twice repeated breaking off shoots of grape cv. 'Rkatsiteli'.

Zoecklein *et al.* (1992) reported that leaf removed 'Riesling' vines had greater cluster weight than the control vines.

Abd El-Wahab *et al.* (1997) on 'Thompson Seedless grapevines stated that the treatment of head suckering + pinching main shoots + maintaining laterals resulted in the highest increase in cluster weight.

Vasconcelos and Castagnoli (2000) evaluated leaf canopy structure of mature 'Pinot noir' grapevines during two consecutive seasons: shoot tipping at full bloom (yes or no), lateral shoot length (no laterals, laterals cut back to four leaves at full bloom, laterals allowed to grow undisturbed), and cluster zone leaf removal (leaf removal in the cluster zone or no leaf removal). Treatments were carried out in factorial combinations. Shoot tipping at bloom increased cluster weight.

In contrast, Bledsoe *et al.* (1988) studied leaf removal of mature 'Sauvignon blanc' vines at fruit set, four weeks after fruit set, or seven weeks after fruit set. At each time, four levels of leaf removal were employed: Level 0 (control) , no leaves removed; Level

1, basal leaves removed; Level 2, basal leaves plus leaves from top of canopy removed; and Level 3, basal leaves plus approximately three consecutive leaves at the top of the south-facing portion of canopy removed to form a window. They found that cluster weight, was not significantly affected by the level of leaf removal.

Reynolds and Wardle (1989 c) confirmed that increased severity of summer hedging reduced the cluster weight of 'de Chaunac' vines in the second year. No discernible effect was noticed in the first or the third year.

Moreover, increasing leaf removal level decreased the weight of cluster according to Wolf *et al.* (1990) who noted that the cluster weight of 'White Riesling' grapevines was significantly lower in vines topped to 10 leaves than did vines topped to 20 leaves during two seasons

Howell *et al.* (1994) found that the cluster weight of 'Point noir' grapes was not significantly affected by basal leaf removal treatments.

Main and Morris (2004) ensured that leaf removal treatments had no effect on cluster weight of 'Cynthiana' grapevines.

### 2.9.2 Cluster dimensions

Abd El-Wahab *et al,* (1997) recorded that the treatment of head suckering + pinching main shoots + maintaining laterals increased cluster length and width of 'Thompson Seedless grapevines.

Inmyung *et al.* (2000) found that removing over the 6 $^{th}$ to 9 $^{th}$ node from the shoot bases of 'Cambel Early' grapevines after full bloom gave highest cluster length compared with shoots were removed over 3$^{rd}$ node from the shoot bases.

### 2.9.3 Number of berries per cluster

Vargas (1984) mentioned that tipping (removal of 15 cm of the shoot apex) plus removal of lateral shoots of 'Alphonse Lavallee' and 'Cardinal' cvs increased number of berries /cluster in both of them.

Vasconcelos and Castagnoli (2000) cleared that shoot tipping of 'Pinot noir' grapevines at bloom increased number of berries per cluster due to increasing the percentage of fruit set.

On the other side, Reynolds and Wardle (1989 c) reported that increased severity of summer hedging reduced the number of berries per cluster of ‘de Chaunac’ vines in the second year. No discernible effect was observed in the first or the third year.

Candolfi-Vasconcelos and Koblet (1990) found that removing all main leaves 2 weeks after full bloom for 'Pinot Noir’ grapevines declined the number of berries per cluster only in the second season (study consist of two seasons). The other leaf removal treatment had no effect.

Howell *et al.* (1994) as well as Koblet *et al.* (1994) found that the number of berries per cluster in ‘Point noir’ was not significantly impacted by basal leaf removal application.

### 2.9.4 Berry weight and dimensions

Reynolds and Wardle (1989 c) mentioned that summer hedging produced the highest berry weight of ‘de Chaunac’ vines in the first season. No clear differences were noted in the second or the third year.

Caspari *et al.* (1998) reported that removing of leaves increased berry weight of ‘Sauvignon blanc’ grapes.

In contrast, Vargas (1984) worked on ‘Alphonse Lavallee’ and ‘Cardinal’ cvs and stated that tipping (removal of 15 cm of the shoot apex) plus removal of lateral shoots decreased average berry weight by 14 % in both cultivars.

Williams *et al.* (1987) observed that defoliation had no significant effect on berry weight of ‘Thompson Seedless’ grapes.

Bledsoe *et al.* (1988) claimed that berry weight in ‘Sauvignon blanc’ was not significantly affected by increasing the level of leaf removal.

Wolf *et al.* (1990) noticed that increasing the leaf removal level reduced the berry weight since, they found that berry weight of ‘White Riesling’ grapevines significantly lower in vines topped to 10 leaves than did vines topped to 20 leaves. But, this difference was only significant in the last season of this study that carried out during three years.

Zoecklein *et al.* (1992) stated that leaf removal did not affect berry weight in ‘Chardonnay’ and ‘White Riesling’ grapevines.

Koblet *et al.* (1994) found that berry weight of 'Pinot noir' grapes decreased with increasing level of leaf removal. The same observation has been shown before by Sidahmed and Kliewer (1980) in 'Thompson Seedless' grapes.

Reynolds *et al.* (1996 a) proved that basal leaf removal had no significant on berry weight of 'Riesling' vines.

Main and Morris (2004) reported that leaf removal treatments had no effect on berry weight of 'Cynthiana' grapes.

Although, it is worth noting that decreases in berry weight have been observed in response to basal leaf removal and high fruit exposure in 'Gewürztraminer' grapevines [Reynolds and Wardle (1989 a), Reynolds and Wardle (1989 b), Reynolds *et al.,* (1989 d)]. The same trend has been found in 'Seyval Blanc' grapevines (Reynolds *et al.* 1986), in 'Pinot noir' vines (Candolfi-Vasconcelos and Koblet, 1990), in 'Caberent Sauvignon' grapevines (Hunter *et al.* 1991) and in 'Sovereign Coronation' table grapes (Reynolds *et al.* 2006).

Poni *et al.* (2006) showed that shoots tirmming to nod 6 and lateral retaining reduced berry weight of 'Sangiovese' and 'Trebbiano' grapes.

Concerning the effect of canopy management on the berry dimensions, Kingston and Van Epenhuijsen (1989) conducted 8 treatments of leaf removal on 'Italia' grapevines (nine, 13-, 11-, 9-, 7-, 5-, 3-leaf per shoot). They found that the nine, 11-, 13-leaf had significantly larger diameters than the other treatments. Plant with tree leaves per shoot always had a smaller berry diameter than any treatment. Berry weight exhibited similar trends to berry diameter. Berry weight of fruit from shoots with five or seven leaves were similar but significantly lower than those with shoots with nine, 11, or 13 leaves. Berry weights of fruit from three-leaf treatment were significantly lower than any other treatment.

Abd El-Wahab *et al.* (1997) found that head suckering + pinching main shoots + maintaining laterals increased berry dimensions of 'Thompson Seedless' grapes compared to other summer pruning treatments and control.

### 2.9.5 T.S.S % and acidity

Bledsoe *et al.* (1988) studied leaf removal of mature 'Sauvignon blanc' vines at fruit set, four weeks after fruit set, or seven weeks after fruit set. At each time, four levels of leaf removal were employed: Level 0 (control) , no leaves removed; Level 1, basal leaves removed; Level 2, basal leaves plus leaves from top of canopy removed; and Level 3, basal leaves plus approximately three consecutive leaves at the top of the south-facing portion of canopy removed to form a “window”. They found that the total soluble solids were significantly higher in fruit from vines with leaves removed. Titratable acidity was reduced by leaf removal. Earlier leaf removal tended to advance sugar accumulation.

The same trend was found before, since Mansfield and Howell (1981) found that fruit in control vines (all foliage removed) accumulated more sugar in on ‘Concord’ grapes and had significantly higher soluble solids than the other treatment in harvest, probably due to the small amount of fruit.

Reynolds and Wardle (1989 c) stated that total soluble solids increased as severity of summer hedging for ‘de Chaunac’ vines increased in the first and third years, however, TSS decreased by the same treatments in the second season. The summer hedging reduced the acidity in the second and third years but had not effect in the first year.

Wolf *et al.* (1990) observed that shoot tipping of ‘White Riesling’ grapevines resulted in greatest soluble solids concentration and reduced the acidity in berries.

Palliotti and Cartechini (2000) mentioned that early hedging improved TSS of ‘Caberent Sauvignon’ grapes.

Ezzahouni and Williams (2003) found that there was a slight increase in TSS of ‘Ruby Seedless’ grapes by defoliation treatments. Defoliation significantly decreased titratable acidity .

Main and Morris (2004) stated that titratable acidity of ‘Cynthiana’ grapes was reduced by leaf removal treatments.

Reynolds *et al.* (2005 b) reported that early shoot-thinning treatment in ‘Pinot noir’ resulted in increased soluble solids and titrable acidity in berries. Also, they found that early shoot-thinning treatments in ‘Caberent Franc’ grapes generally resulted in higher soluble solids and lower titrable acidity in berries.

Poni *et al.* (2006) claimed that shoot trimming to 6 nodes at the beginning of flowering and laterals retaining for ‘Sangiovese’ and ‘Trebbiano’ grapes increased TSS.

Fox (2006) concluded that the several level of defoliation for cultivar ‘Blauburgunder Samtrot ‘ grapes showed the lowest acidity.

Reynolds *et al* (2006) mentioned that basel leaf removal delayed berry maturity slightly but increased light penetration into the canopy. Increased berry maturity was associated with decreasing titrable acidity of 'Sovereign Coronation' table grapes.

However, Wolf et al. (1986) investigated the effect of shoot tipping as well as basel leaf removal in young 'chardonnay' grapevines and found that total soluble solids were similar among treatments. The lowest titratable acidity value were obtaind from fruit receiving lateral removal + tipping treatments. Also, the fruit from lateral shoot or basel leaf removal produced less acidity.

Sidahmed and Kliewer (1980) and Williams *et al.* (1987) reported that defoliation had no significant effect on soluble solids and titratable acidity in 'Thompson Seedless' grapes.

Candolfi-Vasconcelos and Koblet (1990) found that removing all main leaves 2 weeks after full bloom for 'Pinot Noir' grapevines decreased the total soluble solids than control. Also, the same treatment reduced the acidity, whereas the other leaf removal treatment had no effect on TSS or acidity.

Zoecklein *et al.* (1992) confirmed that leaf removal reduced fruit soluble solids concentration in 'Chardonnay' and 'White Riesling' grapes.

Koblet *et al.* (1994) found that ° Brix declined with increasing defoliation, however, the defoliation treatments had not effect on the total acidity of 'Pinot noir' grapes.

Howell *et al.* (1994) stated that total soluble solids and total acidity were not significantly influenced by basel leaf removal treatments in 'Pinot noir' grapevines. Percival *et al.* (1994) found the same result in 'Riesling' grapes. Also, the same result has been reported in 'Italia' grapevines by Kingston and Van Epenhuijsen (1989).

Hunter *et al.* (1995) found that partial defoliation had no effect on total soluble solids in 'Caberent Sauvignon' grapes, but increased acidity.

Reynolds *et al.* (1996 a) observed that basel leaf removal reduced TSS and acidity in 'Riesling' grapes.

Reynolds *et al.* (1996 b) ensured that leaf removal for 'Gewürztraminer' grapevines produced berries with lowest ° Brix (total soluble solids), and highest TA (titratable acidity).

El-Ghany (2000) found that Shoot topping in ‘Thompson Seedless’ grapevines (retaining 20 leaves per shoot) at one week after fruit set had no effect on acidity.

Vasconcelose and Castagnoli (2000) concluded that shoot tipping at bloom with removing laterals decreased total soluble solids of ‘Pinot noir’ grapes.

Naor and Gal (2002) reported that soluble solids in ‘Sauvignon blanc’ grapes increased with increasing leaf area. No consistent effect of the defoliation treatments was apparent in the three-experimental years.

Main and Morris (2004) ensured that leaf removal treatments did not affect soluble solids in ‘Cynthiana’ grapes during two seasons, but in the third season, leaf removal treatments had high soluble solids.

### 2.9.6 Sugar fractions

Hunter *et al.* (1991) noticed that the concentration of glucose and fructose were mostly significantly lower in ‘Cabernet Sauvignon’ grapes in non-defoliated vines than in those of partial defoliation. This result in accordance with those mentioned by Sidahmed and Kliewer (1980) who found that the total sugars per berry increased as affected by defoliation of 50 % leaves in ‘Thompson Seedless’ grapevines.

Zoecklein *et al.* (1992) investigated glucose/fructose ratio in ‘Chardonnay’ and ‘White Riesling’ grapes as affected by leaf removal during two years. In the first year, the fruit glucose/fructose ratio at harvest generally did not vary in ‘Chardonnay’ grapes, however, in ‘Riesling’ grapevines, the berries had a lower glucose/fructose. In the second year, there were no differences in fruit glucose/fructose ratio in ‘Riesling’ grapes, whereas, ‘Chardonnay’ berries had a higher glucose/fructose ratio.

Main and Morris (2004) studied the effect of leaf removal treatments (none, east side, and both sides) on sugars fraction in ‘Cynthiana’ grapes during three seasons. There were no differences in the first season. leaf removal on both sides resulted in berries with less glucose and fructose than other treatments in the second season. Leaf removal treatments (east side, and both sides) had juice with more glucose and fructose than the untreated vines (no leaf removal) in the last year of study.

### 2.9.7 Flavonoids

Reynolds and Wardle (1989 c) confirmed that in the first and last year of the experiment, the total anthocyanins increased in linear trend as severity of summer hedging for 'de Chaunac' vines increased, whereas in the second year, it was decreased by summer hedging.

Hunter *et al.* (1991) noticed that anthocyanin concentration in the grape skins of partially defoliated 'Caberent Sauvignon' vines tended to be higher than the control. However, the concentration and the amount of phenolics per berry skin were unaffected by partial defoliation.

Keller *et al.* (1999) studied shoot trimming on phenolic compound in the berries of 'Pinot Noir' grapevines. Shoots were topped either once (at fruit set), or twice (at fruit set and during thje lag-phase of berry growth). They found that malvidin-3-glucoside was the most abundant anthocyanin in skins. It accounted for 75 % of total anthocyanins. Repeated shoot topping have lower total phenols and anthocyanins. the best treatment for fruit quality, in terms of colour and oxidative stability, was single topping and the worst with repeated tooping.

Vasconcelose and Castagnoli (2000) found that shoot tipping at bloom with removing laterals decreased skin anthocyanin content of 'Pinot noir' grapes.

Guidioni *et al.* (2002) tested cluster thinning (removal of 50% of the cluster one month after bloom) of grapevine cv. 'Nebbiolo' for three consecutive years in a vineyard located in southern Piedmont, Italy. They found that berry weight and berry skin weight slightly increased following fruit thinning. Soluble solids and berry skin anthocyanins and flavonoids were more concentrated in berries from cluster-thinned plants. Cluster thinning increased the concentration of cyanidin-3-glucoside, peonidin 3-glucoside and to a lesser extent, petunidin-3-glucoside. The concentrations of malvidin 3-glucoside and of acylated anthocyanins were not affected by cluster thinning.

Main and Morris (2004) concluded that total pigment color of 'Cynthiana' grapes did not differ between treatments of leaf removal during two seasons, but in the third year due to warm temperatures, leaf removal treatments had better color than no leaf removal (the untreated vines).

Reynolds *et al.* (2005 b) reported that early shoot-thinning treatments on 'Caberent Franc' grapevines resulted in increased color intensity, total anthocyanin and total phenolics in berries.

Fox (2006) recorded that the several level of defoliation for cultivar 'Blauburgunder Samtrot ' grapes increased the phenol levels and improved the anthocyanin.

Poni *et al*. (2006) recorded that shoot trimming to 6 nod at the begin of flowering of **'**Sangiovese' and 'Trebbiano' grapes improved total anthocyanin.

Reynolds *et al.* (2006) mentioned that basel leaf removal increased color intensity, anthocyanin, phenols, methyle anthranilate, and total volatile esters.

However, Zoecklein *et al.* (1992) found that leaf removal did not affect fruit total phenols or flavonoid in 'Chardonnay' and 'White Riesling' grapevines.

The literatures pointed out that N and K fertilization as well as defoliation and fruit thinning practices in several grape cvs improved yield and fruit quality. Until now, little is known about how they can improve the productivity, fruit quality and, especially, flavonoid and other phenolic compounds in 'Crimson Seedless' grapes.

# 3 Materials and methods

## 3.1 Plant materials and vineyard site

The present investigation was carried out during the two consecutive seasons of 2004 and 2005 on 5-year-old "Crimson Seedless" grapvines (*Vitis vinifera* L.) grown in a private vineyard at Cairo- Ismailia Road at 73 Km, Egypt (Table 1&2). The vines were planted in a sandy soil under drip irrigation system, spaced 1.5 X 3 m (between vines X between rows) and trained to cane pruning under Gable trellis system. The selected vines for this study were normal growth, healthy, uniform and similar in vigorous and were pruned during the second week of February to leave a fixed number of buds / vine whereas 8 canes X 12 buds / cane were retained on each vine beside 8 renewal spurs X 2 buds.

Table (8): Mechanical analysis of soil samples.

| Depth (cm) | Sand % | Silt % | Clay % | Organic matter % | Texture |
|---|---|---|---|---|---|
| **0-30** | 72.35 | 14.05 | 12.75 | 0.85 | Sandy loam |
| **30-60** | 76,85 | 11,55 | 10.65 | 0.95 | Sandy loam |
| **60-90** | 77.65 | 10.65 | 10.95 | 0.75 | Sandy loam |

Table (9): Chemical analysis of soil samples.

| Depth (cm) | EC (m mhos/cm) | pH | $CaCo_3$ % | Cation (meq/L) | | | | Anions (meq/L) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $K^+$ | $Na^+$ | $Mg^{++}$ | $Ca^{++}$ | $Co^{--}$ | $Hco_3^-$ | $Cl^-$ | $So_4^{--}$ |
| **0-30** | 2.30 | 7.75 | 12.75 | 3.15 | 15.35 | 7.10 | 7.80 | — | 2.50 | 22.25 | 2.65 |
| **30-60** | 2.90 | 7.83 | 8.65 | 1.70 | 14.90 | 4.65 | 8.40 | — | 2.25 | 20.00 | 3.80 |
| **60-90** | 2.85 | 7.92 | 10.95 | 1.75 | 11.25 | 4.45 | 6.60 | — | 1.90 | 19.50 | 2.85 |

## 3.2 Treatments and experimental design

### 3.2.1 N&K fertilization experiment

It was designed to determine the influence of 3 rates of N fertilization 24, 36 and 48 Kg actual N/ha as ammonium nitrate ($NH_4$ $NO_3$, 33.5% actual N) combined with 3 levels of K fertilization 240, 285, 330 Kg actual $K_2O$/ha as potassium sulphate ($K_2$ $SO_4$, 50% $K_2O$). Thus, the experiment comprised of 9 treatments. All amounts of fertilization treatments were fractioned into differed dosed and added as soil applications. Application of N and K fertilization were divided between growing stages and applied as follows:

(a) 15 % of total seasonal N and K fertilization were applied after bud opining and before flowering.

(b) 50 % of total seasonal N and K fertilization were applied after fruit set to veraison.

(c) 25 % of total seasonal K fertilization were added between verasion and beginning of harvest.

(d) The rest of total seasonal N (35%) and K (10%) fertilization were added after harvest.

(e) All treatments were fertilized by recommended doses of P fertilization at the beginning of grower season, 22.5 Litres actual $P_2O_5$ / ha as phosphoric acid ($H_2PO_4$, 48 % $P_2O_5$) and this amount were partitioned into 9 equal weekly doses (2.5 Litre/ha/week) and added by fertigation during the first two months from the bud opening.

(f) To avoid any adverse effect on fruit set, all studied vines didn't receive any fertilization treatments during the period of blooming and fruit set (nearly 2 weeks).

The selected vines for N&K fertilization experiment were arranged in a randomized complete block design (RCBD) with 4 replicates. The treated vines received the same horticultural practices except N and K fertilization treatments.

### 3.2.2 Defoliation & fruit thinning experiment

It was designed to study the effect of canopy management practices and fruit thinning on the fruit quality of "Crimson Seedless". In this respect the following practices were applied:

Treatment 1 = Leaf Basal Removal.

Treatment 2 = Leaf Basal Removal + Hedging.

Treatment 3= Sterile Shoot Removal + Leaf Basel Removal.

Treatment 4= Sterile Shoot Removal + Leaf Basel Removal+ Hedging.

Treatment 5= Leaf Basal Removal + Fruit Thinning.

Treatment 6= Untreated Vines (control).

**(1)** **Leaf Basal Removal:** was done shortly before flowering, all subjacent leaves from the cluster to the basal of shoot were removed except the adjacent leaf to the cluster.

**(2)** **Hedging:** was performed immediately following veraison (1-5 % of the berries exhibiting color), and was done when the shoots have grown well beyond the top wire and were beginning to lean over. Shoots were commonly trimmed back to about 15 to 20 cm above the top wire. Hedging was done with a manually with long knives and both sides of canopy were trimmed. Hedging by removing the shoot tip stimulated growth of lateral shoots from the nodes immediately below the cut position. This was particularly true for vigorous shoots and the regrowth of laterals required repeated hedging.

**(3)** **Sterile Shoot Removal:** was preformed when shoots length reaches 25 to 30 cm. All non-fruiting shoots were removed in this time except the 1 $^{st}$ to 3 $^{th}$ non-fruiting shoots near the head of vine that were retained to become 2 canes and a renewal spur for the next season.

**(4)** **Fruit Thinning:** Large, heavily shouldered cluster were tipped to 5 rachis lateral (cluster branches) following fruit set. Large, prominent wings were removed from the cluster at this time. Berries and shoulder were removed from the compact regions of well-set clusters to reduce cluster tightness. Fig. (1,2) show the cluster before and after berry thinning according to Herrera (2002).

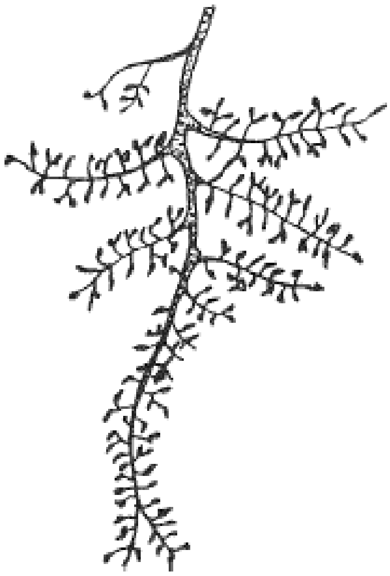


Fig. (37): Stage for berry thinning

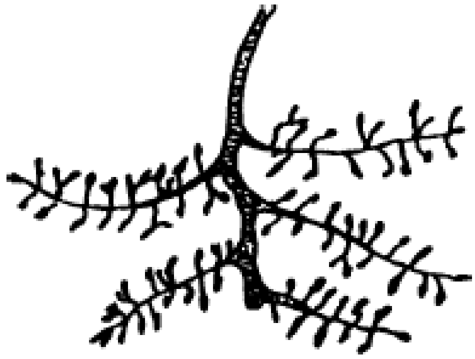


Fig. (38): Cluster after berry thinning

The selected vines for the second experiment were arranged in a randomized complete block design (RCBD) with 4 replicates. The selected vines were received the same horticultural practices except canopy management practices.

## 3.3 Measurement and Chemical analysis

### 3.3.1 Bud behavior measurements

After complete bud opening (15 April for both study seasons), and when shoots length was about 30 cm, the number of bursted buds and clusters per each vine were counted, then percentages of bud burst, fertility and fruitfulness percentage were calculated as follows according to El-Baz *et al.* (2002):

$$\text{Bud burst (\%)} = \frac{\text{No. of opened buds}}{\text{Total No. of buds}} \times 100$$

$$\text{Bud fertility (\%)} = \frac{\text{No. of clusters}}{\text{Total No. of buds}} \times 100$$

$$\text{Fruitfulness (\%)} = \frac{\text{No. of fruitful buds}}{\text{No. opened buds}} \times 100$$

Each vine had a fixed number of buds resulting from 8 canes (12 buds per cane) on each vine, beside 8 renewal spurs (2 buds).

### 3.3.2 Growth vigorous parameters

#### 3.3.2.1 Leaf area ($cm^2$)

In both seasons of this study, 5-7$^{th}$ leaves from the shoot top at 15 June were taken for leaf area measurements by the automatic leaves area meter (supplied by LICOR model LI-3000) and the average of leaf area was expressed as ($cm^2$).

#### 3.3.2.2 Cane thickness (cm)

At growth cessation of each season, Cane thickness in 5 cm from cane basal was measured using a Vernier caliper and data expressed as cm.

### 3.3.3 Productivity

**3.1 Number of clusters/ vine**

**3.2 Yield / vine (kg/vine)**

In both seasons of this investigation, when the clusters were attained their full-colored and soluble solids percentage in berry juice reached about 19-20 % according to Badr and Ramming (1994), number of cluster per each vine were counted to determine the total yield per vine (Kg).

### 3.3.4 Cluster characteristics

After determining the total yield /vine (kg) in both seasons of this study, representative random samples of 24 cluster from each treatment were taken to the Laboratory to determine the following:

Cluster weight (g).
Cluster length (cm).
Cluster width (cm).
Number of berries / cluster.
Cluster compactness coefficient.

Cluster compactness coefficient was determined using the following equation according to El-Baz et al. (2002):

$$\text{Cluster compactness coefficient} = \frac{\text{No. of berries/clusters}}{\text{Cluster length (cm)}}$$

### 3.3.5 Fruit quality parameters

A random sample of 100 berries was taken from each replicate for berry quality determination as follows:

#### 3.3.5.1 Fruit physical properties

Berry length (cm)

Berry width (cm).

Weight of 100 berries (g).

Volume of 100 berries ($cm^3$).

Juice weight of 100 berries (g).

Juice volume of 100 berries ($cm^3$).

Berry juice (%).

Berry firmness: (g/berry).

Berry adherence strength (g).

#### 3.3.5.2 Fruit chemical properties

Total soluble solids (T.S.S %) using hand refractometer.

Titratable acidity (g tartaric acid/100 ml juice) according to A.O.A.C. (1990).

T.S.S / acid ratio.

##### 3.3.5.2.1 Sugars fraction

##### 3.3.5.2.3.1 Sample prepration

Sugar fraction extracts were prepared from 5 grape berries which were weighed, homogenized in an Ultra-Turrax ART-Miccra D-8SI (ART-moderne Labortechnikin e.k., 79379 Müllheim-Hügelheim, Germany) after addition of 30 ml destilled water, then refilled to 250 ml. and shaked well. 1 ml from this extract was taken and centrifuged at 10 000 rotation mint $^{-1}$ for 10 min. in Hettich ZENTRIFUGEN MIKRO 22R (Andreas Hettich GmbH & Co. KG, Tuttlingen 78532, Germany), after there diluted to (1:200), and 25 µl was taken to analyze by Sugar-HPLC.

##### 3.3.5.2.3.2 Sugar - HPLC analysis

Sugar fraction analyses were performed using Sugar-HPLC Dionex (Dionex Corporation, Sunnyvale, 94085 CA, USA) which consist:

Pump : Dionex GP 50 Gradient Pump

Electrochemical Detector : Dionex ED 40 Gold Elektrode

Reference Electrode: Ag/Ag Cl

Wave form for pulsed amperometrie as follows:

| Time (sec.) | Potential (v) | Integration |
|---|---|---|
| 0.0 | +0.10 | |
| 0.2 | +0.10 | **Begin** |
| 0.4 | +0.10 | **End** |
| 0.41 | -2 | |
| 0.42 | -2 | |
| 0.43 | +0.6 | |
| 0.44 | -0.1 | |

Data processing: PeakNet Version 5.11

Columns: 1. 50mm*4mm filled with BoratTrap

2. 50mm*4mm filled with Carbopac P100

Solvent: 10 mM NaOH

#### 3.3.5.2.4 Total anthocyanins in the berries

Four berries from each sample were weighed, homogenzed in a solution of MeOH: formic acid (95:5) by Ultra-Turrax ART-Miccra D-8SI under cooling conditions, put in ultrasonic bath Bandelin Sonorex Transistor (SCHALLTEC GmbH, 64546 Mörfelden-Walldorf, Germany) at 4 °C for 30 min. The extracts were centrifuged at 5 000 rotation mint $^{-1}$ for 10 min. at 4 °C in a Sigma 2KD centrifuge (SIGMA Laborzentrifugen GmbH, 37507 Osterode am Harz, Germany), filtered through a folded filter paper Schleicher & Schuell 595½ (Whatman®, 3354 Dassel, Germany), then refilled to 25 ml., shaked well and absorbance at 520 nm by Unikon 931 Spectrophotometer (Kontron, 85386 Eching/Munich, Germany) to determined the total anthocyanin. The obtaind data compared with the standerd curve of cyanidin and expressed as mg cyanidin / kg fresh weight.

The above mentioned extract (25 ml) for all samples was used also by HPLC, whereas, the extract of 6 g grape berries in 100 µl MeOH for all samples was used to identify the phenolic compounds in ‘Crimson Seedess’ grape by HPLC.

For example, weight of 4 berries was 9.9 g in the extract of 25 ml, the volume required for HPLC analysis will be 15.2 ml.

Then, the rotary evaporator under cooling was used to evaporate MeOH. The dried samples were dissolved in a solution of ethyle acetate and water (1:1), then the extracts rewind in separating funnel and shaked 3 times to separate the sugars that dissolved in the water. After sepreating process, the ethyle acetate as well as the very little rest of water were evaporated again by the rotary evaporator under cooling. The extracts were dissolved again in 1 ml MeOH and rewind in Eppendorf Safe-Lock Tubes 2,0 ml (Eppendorf AG, 22331 Hamburg, Germany).

Then, the samples were dried by UNIVAPO 150 H equipment (UniEquip GmbH, 82152 Martinsried/Munich, Germany). In the end, the dried extracts were dissolved in 100 µl MeOH to analyze by the high performance liquid chromatography (HPLC) to identify the phenolic compounds in 'Crimson Seedess' grape by HPLC.

#### 3.3.5.2.5 Phenolic compounds in the skin of berries

##### 3.3.5.2.5.1 Sample prepration

The grape samples were lyophilised until reaching a constant weight by P10-L equipment (Dieter Piatkowski – Forschungsgeräte , 80997 Munich, Germany). Grapes were peeled with a sharp knife, and the skins were stored in exsiccator untill analyzed. 100 mg skin was ground with 500 µl 3-Methoxyflavon (0.05 mg/ml) in MeOH and put in Eppendorf Safe-Lock Tube 2,0 ml then put in ultrasonic bath Bandelin Sonorex Transistor at 4°C for 30 min., centrifuged at 10 000 rotation mint $^{-1}$ for 10 min. at 4 °C by Hettich ZENTRIFUGEN MIKRO 22R (Andreas Hettich GmbH & Co.KG, 78532 Tuttlingen, Germany).

The extraction was tilted in new Eppendorf tube and dried by UNIVAPO 150H equipment (UniEquip GmbH, 82152 Martinsried/Munich, Germany). The dried sample was dissolved in 100 µl MeOH and 10 µl from the extract was injected in HPLC.

##### 3.3.5.2.5.2 HPLC analysis

Phenolic compound analyses was performed using HPLC Gilson-Abimed Modell 231 (ABIMED Analysen-Technik GmbH, 45362 Düsseldorf, Germany) which consist the following:

Pump : Kontron 422 (programmable) ; Kontron 422S

Detector : Diode-arry Detector Kontron 540

Column: 250mm*4mm (ID), filled with Shandon ODS Hypersil 3µm

Solvent: A: 5% formic acid

B: Methanol (gradient grade Table 10)

Flow: 0.5 ml/min

Data processing: Chromatographic Data System Geminyx Version 1.91

After column derivatization:

Pump: Gynkotek Modell 300 C

Detector: Kontron 432, 640 nm

Reactor: knitted PTFE- capillary, length 13 m, ID 0.5 mm

Reaction time: 2.5 min

**Table (10) Gradient for HPLC-CRD and a diode array detector .**

| Time (min) | % B | Time (min) | % B |
|---|---|---|---|
| 0-5 | 5 | 95-125 | 25-30 |
| 5-10 | 5-10 | 125-145 | 30-40 |
| 10-15 | 10 | 145-160 | 40-50 |
| 15-35 | 10-15 | 160-175 | 50-90 |
| 35-55 | 15 | 175-195 | 90 |
| 55-70 | 15-20 | 195-210 | 90-5 |
| 70-80 | 20 | 210-235 | 5 |
| 80-95 | 20-25 | | |

#### 3.3.5.2.5.3 HPLC- Standards

Table (11) include the standards of flavonoid (flavan-3-ols, flavonols, anthocyanins) and non-flavonoid compounds (phenolic acids, stilbine) that were found in the skin berry of ‘Crimson Seedless’ grapes during the HPLC analysis for the two experiments (fertilization treatments and canopy management practises).

### 3.3.6 Leaf petioles mineral content:

Laves samples were taken at the harvest (the first week of October for both seasons from the most recent fully matured leaves (5-7$^{th}$ leaves from shoot tips). Leaf petiole samples were oven at 70º C for 72 hours (until a constant weight), then ground to a powder texture and 0.2 gram of this dried samples was stored in plastic vials and used in preparing the wet digested solution procedure by using sulphuric acid and hydrogen peroxide ($H_2O_2$) as described by Evenhuis and De-Waard (1980).

The digested solution was saved for analysis of nitrogen, phosphorus and potassium in all treated vines using the following procedures:-

#### 3.3.6.1 Nitrogen

Total nitrogen content was determined in digested solution by the modified Kjeldahl method as described by Pregl (1945).

#### 3.3.6.2 Phosphorus

Phosphorus content was determined by using speklo spectrophotomoter at 882 U.V. according to Murphy and Riely 1962.

#### 3.3.6.3 Potassium

Potassium content was determined in the digested solution by using Flame photometer as mentioned by the method of Brown and Lilleland (1946).

### 3.3.7 Statistical analysis

The data was analyzed using SAS statistical software (SAS Institute, Cary, N.C.). Analysis of variance (ANOVA) in a randomized complete block design (RCBD) and Duncan's multiple range test 5 % level were used to show the differences among all variables and treatments.

**Table (11): HPLC- standards.**

| Wavelength | Name | Retention Time [min] | Spectrum [nm] |
|---|---|---|---|
| 640 nm | B2 | 41.15 | 278 |
| | Epicatchin | 48.81 | 278 |
| 280 nm | *Cis*-piceid | 113.06 | 281 |
| 320 nm | Caffeoyltartaric acid | 18.63 | 328 |
| | *Trans*-piceid | 90.42 | 300/317 |
| | Resveratrol | 130.51 | 300/317 |
| 350 nm | Quercetin 3-glucoside | 41.15 | 259/353 |
| | Kaempferol-3-glycoside | 41.15 | 264/346 |
| 540 nm | Cyanidin 3-glucoside | 100.21 | 278/514 |
| | Peonidin 3-glucoside | 121.41 | 279/515 |
| | Malvidin 3-glucoside | 132.16 | 265/530 |

# 4 Results and discussions

## 4.1 Effect of N and K fertilization on the nutritional status

Data presented in Table 12 show the effect of N and K fertilization on the N, P and K concentrations in the petioles of 'Crimson Seedless' grapes during the two growing seasons of 2004 2005.

Concerning the content of nitrogen in the petioles, increasing N-supply from 24 to 48 kg N/ha enhanced N-concentrations in the petioles in both seasons. The highest value of N-concentrations and in the petioles was obtaind by high N supply (48 kg N/ha) and the lowest was recorded by low N supply (24 kg N/ha). However, there were not signaficant differences between the medium dose of N (36 kg N/ha) and the high N supply (48 kg N/ha) as well as between the medium dose of N (36 kg N/ha) and the low N supply (24 kg N/ha). Furthermore, the K fertilization had no clear effect on N-concentrations in the petiole.

The same trend has been observed in other experiments, Andrew and Kliewer (1977) on several grape cultivars, Aceituno *et al*. (1987), on 'Pedro Ximenez' cv; Ahlawat *et al*. (1988) on 'Perlette', Habeeb *et al.*, (1987) and Wafik *et al*. (1989) on 'Rommy Red', Maigre and Murisier (1991) and Jackson and Lombard (1993), James and John (1993) on 'Muscadine' grapes, Christensen *et al*. (1994) on 'Barbera', 'Grenache', 'French Colombard' and 'Chenin blanc', Nadia (1994) on 'Italia', 'Thompson seedless' and 'Roomy Red', Keller *et al*. (1995) on 'Riesling' grapevines, Yasuda *et al*. (1998) on 'Kyoho', Spayd *et al.* (2000) and Schreiber *et al.* (2002) on 'Riesling' vines, Abd-El-Mohsen (2003) on 'Flame Seedless' grapes, Yu and Cahoon (1990) and Gao and Cahoon (1991), Davenport *et al.* (2003) and Cheng *et al.* (2004) on 'Concord' grapes, El-Garhy (1990), Wasnik and Bharagava (1992) as well as Salem *et al*. (2004) on 'Thompson Seedless' grapevine, Delgado *et al.* (2004) and Martin *et al.* (2004) on 'Tempranillo' grapevines, who found that increasing N rates increased N concentration in the petioles.

In contrast, Licina (1999) found that N-application had no significant effect on leaf N-content on 'Cabernet Sauvignon' grapevines. Also, Gay-Eynard (2000) reported that there were no significant differences among treatments of N-fertilization; 0, 40, 80 and 160 kg N/ha. in the content of N in petioles of 'White Muscat' grapevines (0.66 , 0.92 , 0.98 and 0.97 % respectively) in 1996, but in 1997, the treatment of 80 kg N/ha. gave lowest value in the of N-content (1.17 %) than the control 0 kg N/ha. (1.35 %).

Table (12): Effect of N and K fertilization on the content of N, P and K in petioles of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | N % | | P % | | K % | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| **T1 = 24 240** | 1.12 c | 1.16 b | 0.16 b | 0.19 a | 1.66 c | 1.58 d |
| **T2 = 24 285** | 1.18 bc | 1.21 b | 0.16 b | 0.20 a | 1.74 bc | 1.67 bcd |
| **T3 = 24 330** | 1.20 bc | 1.28 b | 0.17 b | 0.19 a | 1.86 abc | 1.78 abcd |
| **T4 = 36 240** | 1.35 abc | 1.44 ab | 0.20 ab | 0.18 a | 1.70 c | 1.63 cd |
| **T5 = 36 285** | 1.39 abc | 1.50 ab | 0.21 ab | 0.21 a | 1.84 abc | 1.79 abcd |
| **T6 = 36 330** | 1.42 ab | 1.57 ab | 0.19 ab | 0.22 a | 1.91 abc | 1.84 abc |
| **T7 = 48 240** | 1.58 a | 1.74 a | 0.20 ab | 0.20 a | 2.02 ab | 1.89 ab |
| **T8 = 48 285** | 1.60 a | 1.72 a | 0.22 a | 0.19 a | 2.06 a | 1.94 a |
| **T9 = 48 330** | 1.63 a | 1.78 a | 0.22 a | 0.21 a | 2.09 a | 1.98 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In the presented work, the results show that the K fertilization had no clear effect on N-concentrations in the petiole. Thus, our result in agreement of those mentioned by Müller (1988) who concluded that no direct dependence was observed between soil K application and N-content of plant tissues.

On the other hand, our result are disagreement with those found by Casu (1980), Rabeh *et al.* (1994) and Omar (2000) who cleared that there are a gradual and significant increase in the leaf nitrogen content due to raising potassium application rates and suggest that this positive response can be explained on the basis of increasing the supply of a mobile ion sign can enhance the uptake of ions of the other sign. So, $K^+$ increases the uptake of $NO_3^-$. Another possibility was K function as a carrier for $NO_3^-$ during its absorption by plants. However, Brian and Mark (1983) reported that K fertilization reduced the level of nitrogen in petioles.

With regard to the effect of N and K-fertilization treatments on the P -leaf content, the obtained result did not show any significant differences among all treatments of combined N and $K_2O$ rates.

This result is in accordance to those reported by Girgis *et al.* (1998) who mentioned that P-content in the petioles was not influenced by N and K fertilization. In addition, Ghobrial *et al.* (1991) as well as James and John (1993) who recorded that there was no direct relation between different rates of applied nitrogen and leaf P-content. Moreover, Löhnertz (1988), Omar (1994) and Omar (2000) reported that there were no significant differences between leaf P-content and all of the K-fertilizer treatments.

However, Baveresco *et al.* (1986), Maatouk *et al.* (1988), Conradie and Saayman (1989), Wafik *et al.* (1989), Bell (1991), Gay-Eynard (2000) reported that increasing N fertilization decreased the P-concentration in the petioles since they explained that the reduction in leaf content of P with increasing the applied rate of N could be due to the antagonism existed between the two elements.

The obtaind results of this work indicate that increasing N fertilization from 24 to 48 kg N/ha also increased K-concentrations in the petioles during the two seasons of this research, however, K-fertilization variants themselves did not alter the K content in the petioles.

The results are in agreement with those mentioned by Delgado *et al.* (2004) and Martin *et al.* (2004) found that the higher nitrogen doses had the highest or potassium values in the leaves compared with the low and meduim N-fertilization. Meanwhile, Yasuda *et al.* (1998) cleared that K-content in was highest with the middle concentration of N.

On the other side, the result in opposite to those cleared by Habeeb *et al.* (1987) Maatouk *et al.* (1988) and Wafik *et al.* (1989) on 'Rommy Red' grapes who found that K-concentration was within the optimum range in the petioles of vines supplied with meduim and high doses of Nitrogen but was over the optimum range with the low rate of nitrogen. In contrast, Conradie and Saayman (1989) reported that increasing N fertilization did not effect on K-concentration.

This work investigated the nutritional status of 'Crimson Seedless' grapevine as influenced by N and K-fertilization as a permanent tool to evaluated the vines performance.

The relationship between the nutritional status and the vine performance was mentioned by Bell and Robson (1999) who explained that the vine growth, vigor, and productivity affected by petiole nitrate concentration.

Thus, these results explain the effect of N and K fertilization on the nutritional status of 'Crimson Seedless' grapevines which reflected on vines performance that include vine growth, vigor, and productivity, since, the leaf is the major metabolic organ on the grapevine, and thus foliar mineral analysis has been used as a diagnostic tool to evaluate vine performance and grape quality for several decades (Fallahi 2005).

### 4.2 Effect of N and K fertilization on productivity:

The results presented in Table (13) depict the effect of N and K-application on productivity of 'Crimson Seedless' grapevines, which included the number of cluster per vine and the yield (kg/vine).

It is obvious from the results that N-supply negatively affected yield per vine by reducing the number of fruit clusters per vine during the two seasons of this study. The vines were supplied by the high N-supply (48 kg/ha) gave the lowest cluster numbers compared with the meduim and low rates of N-supply (24 and 36 kg /ha).

This result is in accordance with Reynolds *et al.* (2005) who found that slight yield increases; about 10 % in 'Concord' and 29 % in 'Niagara' grapevines in fertigated treatments were attributable to increased cluster numbers, cluster weights and berry weight.

In contrast, Delgado *et al.* (2004) and Martin *et al.* (2004) studied the influence of combined application of different doses of N and K on 'Tempranillo' grapevine and reported that the rate of N and K-fertilization did not affect either the vigour or productivity of vines or the size of berries.

Moreover, Habeeb *et al.* (1987), Gay-Eynard (2000) found that the number of clusters per vine was not influenced by N-applications. Conversely, Badr (1990) and Celik *et al.* (1995) noticed that vines treated with N fertilizers produced a significantly lower yield than the control.

The result of this work exhibit that the K-fertilization had no effect on the number of cluster per vines. This result in parallel with those claimed by Kliewer *et al.* (1983) who found that K- fertilization had no significant effect on cluster number /vine.

In contrast, Valenzuela and Ruiz (1984), Morries *et al.* (1987), El-Sese *et al.* (1988) Conradie and Saayman (1989), Omar (1994) and Omar (2000) stated that the treatments with K-fertilizer increased the yield and /or the number of clusters per grapevine.

Table (13): Effect of N and K fertilization on productivity of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | No. of clusters / vine | | Yield / vine (kg) | |
|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 |
| **T1 = 24 240** | 25.34 b | 28.11 a | 9.32 bc | 10.76 bcd |
| **T2 = 24 285** | 27.17 ab | 28.69 a | 10.07 abc | 11.33 abc |
| **T3 = 24 330** | 27.83 ab | 29.83 a | 10.45 ab | 12.23 ab |
| **T4 = 36 240** | 25.75 b | 28.30 a | 10.00 abc | 11.95 ab |
| **T5 = 36 285** | 26.64 ab | 29.25 a | 10.46 ab | 12.60 a |
| **T6 = 36 330** | 28.83 a | 29.67 a | 11.50 a | 13.02 a |
| **T7 = 48 240** | 20.34 c | 21.16 b | 8.54 c | 9.37 d |
| **T8 = 48 285** | 20.65 c | 21.45 b | 8.81 bc | 9.58 d |
| **T9 = 48 330** | 21.29 c | 22.15 b | 9.24 bc | 9.94 cd |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

### 4.3 Effect of N and K fertilization on bud behavior

The effect of different N and K-fertilization treatments on the percentage of bud burst, bud fertility and fruitfulness during the two years of this study exhibited in Table (14).

The obtained results cleary show that the high N-fertilization (48 kg/ha) reduced the percentage of bud burst, bud fertility and fruitfulness. No further increases in the percentage of them were observed when the K-fertilization was applied more than (240 kg/ha).

Table (14): Effect of N and K fertilization on bud behavior of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Bud burst % | | Bud fertility % | | Fruitfulness % | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| T1 = 24 240 | 81.08 a | 84.98 a | 26.40 b | 29.28 a | 32.55 a | 34.46 a |
| T2 = 24 285 | 83.07 a | 84.03 a | 28.30 ab | 29.86 a | 34.07 a | 35.57 a |
| T3 = 24 330 | 82.81 a | 85.94 a | 29.00 ab | 31.07 a | 35.01 a | 36.16 a |
| T4 = 36 240 | 80.64 a | 84.29 a | 26.82 b | 29.48 a | 33.26 a | 34.96 a |
| T5 = 36 285 | 82.20 a | 83.25 a | 27.75 ab | 30.47 a | 33.79 a | 35.14 a |
| T6 = 36 330 | 82.55 a | 84.11 a | 30.03 a | 30.91 a | 36.38 a | 36.74 a |
| T7 = 48 240 | 75.09 b | 76.30 b | 21.19 c | 22.04 b | 28.21 b | 28.89 b |
| T8 = 48 285 | 75.52 b | 77.95 b | 21.51 c | 22.34 b | 28.50 b | 28.67 b |
| T9 = 48 330 | 74.84 b | 75.30 b | 22.18 c | 23.07 b | 29.63 b | 29.48 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

These results are in accordance with the sequences trend of Habeeb *et al.* (1987) on 'Romi Ahmar' grapevines who stated that the bearing shoot were larger at low N rate. Also, these results are agreement of those reported by Mostasugi and Lin (1990) who found that increasing nitrogen application decreased the percentage of bursted buds of 'Kyoho' grapevines. Girgis *et al.* (1998) observed that fertility coefficient of 'Thompson seedless' grapes was increased significantly with vine received moderate combined level of N and K fertilizer (supplied with N: K at 80:40 and 80:80 g/vine) compared with vines received low and high level of N and K fertilizer (supplied with 40:20, 40:40, 80:160, 160:80, 160:160 and 160:320 g/vine).

The same observation was found by Shaker (2001) who mentioned that bud burst percentage of 'Thompson Seedless' grapevines decreased gradually with increasing N-application from 150 to 200 Kg N/ha.

However, these results are disagreement with those of Peacock *et al.* (1991) who found that N fertilization applications did not affect cane fruitfulness of ‘Thompson Seedless’ and ‘Flame Seedless’ grapevines. Moreover, Giorgessi *et al.* (2000) who ensured that bud burst percentage as well as numbers of inflorescence per shoot were not significantly influenced by increasing N application.

## 4.4 Effect of N and K fertilization on growth

Data presented in Table (15) explain the effect of N and K-applications on the growth vigorous of ‘Crimson Seedless’ grapevines during the two seasons of this research. It is appeared from results that high N-fertilization improved vegetative growth (leaf area, cane diameter).

Concerning the leaf area, the meduim and high rates of N-fertilization (36, 48 kg/ha) produced the largest leaf area compared with the low rate of N-fertilization (24 kg/ha) during the two concessive seasons. Furthermore, the K- fertilization over (240 kg) had no clear effect on leaf area.

These results are in agreement with those mentioned by many authors who found that N-supply was responsible for raising the leaf area in different grape varieties, since they revealed that leaf area expansion progressively increased with the amount of N fertilized applied (Krusteva-Kastova 1977, Maatouk *et al.* 1988 and El-Garhy 1990, Gay-Eynrd, 2000, Keller *et al.* 2001, Salem *et al.* 2004, Grechi *et al.* 2007).

On the other hand, no significant differences in the leaf area where shown between the K-variant in our result. Our result suggest that K-supply had no clear effect on leaf area over 240 kg/ha due to this level achieved the maximum leaf area of ‘Crimson Seedless’ grapevine. A similar trend was reported by Tisdale *et al.* (1985) who found that a linear relationship between leaf area and N application especially when combine with K, this may reflect the role of N as constituent of amino acids and protein as well as the important role of K in encouraging cell division and development of meristimatic tissue. Furthermore, Ahmed (1991) mentioned that the high application of N and $K_2O$ achieved the maximum leaf area of ‘Thompson Seedless’ vines.

Regarding the cane thickness, increasing N-supply from 24 to 48 kg N/ha improved the cane thickness. The high N-application (48 kg N/ha) gave high value of cane thickness as compared with those treated with lower N-level application (24 kg/ha) and without significant differences compared to Meduim N doses (36 kg/ha). Moreover, the K fertilization had no clear effect on the cane thickness of ‘Crimson Seedless’ grapevine.

The obtained results are in accordance with the trend of several investigators were interested in evaluating the efficiency of nitrogen on thickness of canes in various grapevine cvs. (Ismail *et al.* 1963, Chadha and Singh 1971, Maatouk *et al.* 1988, Abdel-Hady 1990, El-Garhy 1990; Ahmed *et al.* 1993, Zonathy *et al.* 1996, Shaker, 2001).

Table (15): Effect of N and K fertilization on growth vigor of ‘Crimson Seedless’ grape in 2004 and 2005.

| **Treatments** | Leaf area ($cm^2$) | | Cane thickness (cm) | |
|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 |
| **T1 = 24 240** | 76.05 c | 78.01 b | 1.29 c | 1.26 b |
| **T2 = 24 285** | 79.18 bc | 81.27 b | 1.33 bc | 1.29 b |
| **T3 = 24 330** | 81.46 b | 82.04 b | 1.34 bc | 1.30 b |
| **T4 = 36 240** | 85.96 a | 86.51 a | 1.41 ab | 1.37 ab |
| **T5 = 36 285** | 85.74 a | 87.72 a | 1.43 ab | 1.34 ab |
| **T6 = 36 330** | 86.55 a | 88.70 a | 1.40 ab | 1.38 ab |
| **T7 = 48 240** | 86.95 a | 87.04 a | 1.48 a | 1.44 a |
| **T8 = 48 285** | 87.17 a | 88.27 a | 1.51 a | 1.48 a |
| **T9 = 48 330** | 88.46 a | 90.14 a | 1.50 a | 1.47 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan’s multiple range test.

The results are in agreement with Nijjar (1985) who mentioned that the action of N and K increased the thickness of canes, this could be attributed to their effect on carbohydrates and protein synthesis and accumulation, as well as on their role in the formation of cellulose and lignin which are playing an important role in encouraging cell division and building new tissues in the plants.

Our result explain that the K-fertilization had no effect on the cane thickness over 240 Kg/ha due to this level achieved the maximum cane thickness of ‘Crimson Seedless’ grapevine.

These results explain the difference between the vine nutritional status, growth vigor and yield among all treatments due to the effect of N-fertilization on the leaf area of ‘Crimson Seedless’ grapevine.

This previous study of Bell and Robson (1999) support our investigation, since they found that the vine petiole nitrate concentration, growth and vigor, as well as productivity are affected by leaf area. They applied five rates of nitrogen fertilizer (0, 50, 100, 200, and 400 g N/vine) to irrigated- 12-year-‘Cabernet Sauvignon’ vines over three seasons. They found that moderate rates of nitrogen fertilization (100 g/vine) stimulated vine growth and vigor resulting in increase in canopy density. The petiole nitrate concentration, total leaf area and canopy density of vines supplied with 200 to 400 g N/vine were no different to those vines supplemented with 100 g N/vine. The highest yield came from vines receiving 100 g N/vine. They pointed out that moderate rates of nitrogen fertilization could have a beneficial effect on vine productivity in situations where vine nitrogen status is low. In contrast, excessive nitrogen fertilization was an unprofitable exercise as it provided no further benefits in terms of vine productivity.

This research investigates improving the productivity of ‘Crimson Seedless’ grapes as affected by N and K-fertilization. The results indicate that improving yield related to the increasing in vine nutritional status, bud behavior, and growth as influenced by N fertilization.

### 4.5 Effect of N and K fertilization on cluster characteristics

Increasing N-nutrition increased cluster weight and size (Table 16). Cluster size (cluster length and width), however, was improved with increasing N-nutrition whereas the number of berries per cluster and cluster compactness remained unchanged (Table 17).

It is clear from Table 16 that the high N-level supply (48 kg/ha) produced the heaviest cluster compared to those that treated with the lowest N-level supply (24 kg/ha) except T3 in the second season. There are no significant differences in the cluster weight between the high N-level supply (48 kg/ha) and the meduim N-doses (36 kg/ha) except between T8 and both of T4 and T5 in the first season.

This result is in parallel with those claimed by many researchers who have shown that increasing the applied rate of nitrogen was responsible for the highest cluster weight. In this respect, Kozma and Polyak (1975), Wassel *et al.* (1985), Habeeb *et al.* (1987), Neilsen *et al.* (1987), Ahlawat and Yamdagni (1988), Ahmed *et al.* (1988), Abdel-Hady (1990), Badr (1990), El-Garhy (1990), Saayman and Lambrechts (1995), Gay-Eynrad (2000), Giorgessi *et al.* (2000), Schaller (2000), Abd-El-Mohsen (2003), Salem *et al.* (2004) and Reynolds *et al.* (2005).

Table (16): Effect of N and K fertilization on cluster weight and dimensions of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Cluster weight (g)** | | **Cluster length (cm)** | | **Cluster width (cm)** | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| **T1 = 24 240** | 368 d | 383 d | 18.33 b | 18.60 b | 14.15 c | 14.35 b |
| **T2 = 24 285** | 370 d | 395 cd | 19.18 b | 19.65 b | 14.53 c | 14.70 b |
| **T3 = 24 330** | 376 d | 410 bcd | 19.90 b | 20.20 b | 14.90 bc | 15.13 b |
| **T4 = 36 240** | 389 cd | 422 abc | 21.95 a | 22.15 a | 16.50 ab | 16.85 a |
| **T5 = 36 285** | 393 cd | 431 ab | 22.05 a | 22.23 a | 16.88 a | 16.98 a |
| **T6 = 36 330** | 399 bcd | 439 ab | 22.23 a | 22.45 a | 16.93 a | 17.05 a |
| **T7 = 48 240** | 420 abc | 441 ab | 22.30 a | 22.65 a | 16.95 a | 17.15 a |
| **T8 = 48 285** | 427 ab | 447 a | 23.43 a | 22.70 a | 16.98 a | 17.23 a |
| **T9 = 48 330** | 434 bc | 449 a | 22.45 a | 22.73 a | 17.03 a | 17.40 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In contrast, Gao and Cahoon (1991) proved that N application was not affect on cluster weight of 'Concord' grapes. Celik *et al.* (1995) found that cluster weight of 'Narince' grapes was lower with N-application than without N-application.

The K-fertilization variant in this study did not affect on cluster weight of 'Crimson Seedless' grapes. However, Shardakova and Shardakova (1984), El-Sese *et al.* (1988), Dhillon *et al.* (1999) and Omar (2000) ensured that K-fertilization increased cluster weight.

Regarding the cluster size, the result in Table 17 show that increasing N- nutrition from 24 kg N/ha to 36 kg N/ha increased the dimension of cluster (culster length and width).

The cluster size of vines supplied with 48 kg N/ha do not different from those supplemented with 36 kg N/ha.

This result is in accordance to those reported by Habeeb *et al.* (1987) who found that cluster length of 'Roomy Red' significantly increased at 40 g N/vine than compared to 10 or 20 g N/vine and there was no significantly increase from 40 g N/vine to N-application of 80, 160, and 320 g N/vine.

Ghobrial *et al.* (1991) suggested that medium level of N application (80 g N/vine) had the highest cluster length and width of 'Thomposon Seedless' grapes than 40 and 160 g N / vine .

Moreover, Salem *et al.* (2004) demonstrated that the vines of 'Thomposon Seedless' produced the heaviest clusters with N fertilization of 200 kg/ha.

On the other side, Girgis *et al.* (1998) mentioned that cluster length and width of 'Thompson Seedless' grapes appeared to have insignificant response to moderate combined level of N and K fertilizer.

The number of berries per cluster and cluster compactness remained unchanged (Table 18). However, there is an increment in the number of berries from 118.10 to 127.24 in the frist year and from 120.32 to 127.28 in the second year, but this increment is non-significant. A similar increment appears when we compare these results with those shown by El-Baz *et al.* (2002) who reported that the number of berries per cluster of 'Crimson Seedless' grapes was found between 98-107,5.

The cluster compactness coefficient (number of berries/cluster length) also remained unchanged, however, there was significantlly increment in the cluster length due to the number of the berries increased but this increment was non-significant (118.10 to 127.24 in 2004 and 120.32 to 127.28 in 2005).

The results gave a high value of cluster compactness coefficient compared to the result that found by El-Baz *et al.* (2002) who stated that cluster compactness coefficient was 4.6-5.1 %, but it is in the same trend of those indicated by Ramming *et al.* (1995) and Pommer *et al.* (1999) who demonstreated that cluster of 'Crimson Seedless' grapes are medium in length and therefore are slightly compact.

Table (17): Effect of N and K fertilization on fruit set of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **No. of berries / cluster** | | **Cluster compactness** | |
|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 |
| **T1 = 24 240** | 118.10 a | 120.32 a | 5.70 a | 5.72 a |
| **T2 = 24 285** | 118.51 a | 120.85 a | 5.46 a | 5.69 a |
| **T3 = 24 330** | 118.72 a | 121.22 a | 5.57 a | 5.68 a |
| **T4 = 36 240** | 119.09 a | 126.63 a | 5.42 a | 5.71 a |
| **T5 = 36 285** | 119.22 a | 127.38 a | 5.43 a | 5.74 a |
| **T6 = 36 330** | 120.37 a | 127.70 a | 5.30 a | 5.69 a |
| **T7 = 48 240** | 124.60 a | 127.65 a | 5.59 a | 5.66 a |
| **T8 = 48 285** | 125.85 a | 127.83 a | 5.62 a | 5.64 a |
| **T9 = 48 330** | 127.24 a | 127.98 a | 5.66 a | 5.65 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Many authors reported an increasing number of berries as affected by N-application (Habeeb *et al.* (1987), Ahlawat and Yamadani (1988), Srivastava and Soni (1988), Spayd *et al.* (1993), Bell and Robson (1999), Salem *et al.* (2004), Reynolds *et al.* (2005).

The K-fertilization variant had not influence on the number of berries per cluster and on the cluster compactness coefficient. On the other hand, El-Sese *et al.* (1988) indicated that increasing the potassium fertilization up to 100-150 g/vine increased the number of clusters, and their flowers, as well as the percentage of fruit set and, consequently, the number of berries per cluster.

### 4.6 Effect of N and K fertilization on fruit quality

#### 4.6.1 Fruit physical properties

The data presented in Tables 18, 19 and 20 exhibit the effect of N and K-fertilization on 'Crimson Seedless' berry length, diameter, weight and volume as well as berry juice weight, volume and juice percentage.

The single berries of 'Crimson Seedless' grapes were bigger (size, weight) by increasing N-level fertilization and their shape remained typically for the cultivar. The berry juice weight, volume and juice percentage increased as N-application increased.

Table (18): Effect of N and K fertilization on berry dimension of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Berry length (cm) | | Berry diameter (cm) | |
|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 |
| **T1 = 24 240** | 1.98 d | 2.02 b | 1.60 b | 1.63 d |
| **T2 = 24 285** | 2.10 cd | 2.13 ab | 1.64 ab | 1.67 cd |
| **T3 = 24 330** | 2.12 bcd | 2.16 ab | 1.68 ab | 1.71 cd |
| **T4 = 36 240** | 2.14 abcd | 2.18 ab | 1.71 ab | 1.74 abcd |
| **T5 = 36 285** | 2.18 abc | 2.21 a | 1.73 ab | 1.78 abcd |
| **T6 = 36 330** | 2.26 abc | 2.23 a | 1.77 ab | 1.80 abcd |
| **T7 = 48 240** | 2.26 abc | 2.28 a | 1.79 ab | 1.83 abc |
| **T8 = 48 285** | 2.30 ab | 2.31 a | 1.82 ab | 1.86 ab |
| **T9 = 48 330** | 2.32 a | 2.33 a | 1.84 a | 1.90 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

This increase in the average of berry length, width, weight, volume as well as berry juice weight, volume and juice percentage as a result of increasing nitrogen could be attributed to the effect of nitrogen in producing new cells and tissues as well as its effect in increasing cell enlargement. The same result have been explaind by Follet *et al.* 1981.

The values resemble those found by Badr and Ramming (1994), Ramming *et al.* (1995), Badr (1997), Dokoozlian *et al.* (2000) who described the berries of ‘Crimson Seedless’ being medium in weight with about 4.0 g and 16.6 mm in diameter.

Table (19): Effect of N and K fertilization on berry size of ‘Crimson Seedless’ grape in 2004 and 2005.

| **Treatments** N K | **Weight of 100 berries (g)** | | **Volume of 100 berries (cm$^3$)** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **T1 24 240** | 312 c | 319 b | 305 c | 310 d |
| **T2 24 285** | 313 c | 328 ab | 313 bc | 318 cd |
| **T3 24 330** | 316 bc | 332 ab | 318 abc | 324 bcd |
| **T4 36 240** | 327 abc | 335 ab | 321 abc | 329 abc |
| **T5 36 285** | 330 abc | 340 ab | 322 abc | 334 abc |
| **T6 36 330** | 332 abc | 344 ab | 326 ab | 339 ab |
| **T7 48 240** | 338 ab | 346 ab | 328 ab | 340 ab |
| **T8 48 285** | 340 a | 349 a | 331 ab | 341 a |
| **T9 48 330** | 342 a | 351 a | 332 a | 343 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan’s multiple range test.

The same result was described by Peacock and Simpson (1995) who reported that berry weight of ‘Crimson Seedless’ vines was 2.4 - 7.4 g, berry diameter was 14 to 20 mm and berry length was 20.0 to 27.0 mm.

Dokoozlian (1998) stated that berry weight of untreated vines ranged from 4.4 to 4.7 g. and berry diameter ranged 17.4 to 18.1 mm.

El-Baz *et al.* (2002) found that the berry weight ranged 3.31 to 3.70 g and berry diameter ranged 16.3 to 17.6 mm as effect by pruning levels.

The results are agreement with those of many researchers that found an increasing of berry dimensions, weight and size as well as berry juice weight, volume and juice percentage as a result of N-nutrition (Eid 1978, El-Sayed 1980, Ahmed *et al*. 1988, Abdel-Hady 1990, El-Garhy 1990, Dhillon *et al.* 1992, Spayd *et al.* (1993), Yasuda *et al.* 1998, Salem *et al.* 2004, and Reynolds et al. 2005).

Table (20): Effect of N and K fertilization on berry softing of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Juice weight of 100 berries (g)** | | **Juice volume of 100 berries (cm$^3$)** | | **Berry Juice (%)** | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| **T1 24 240** | 220 c | 228 g | 218 e | 224 h | 67.80 d | 68.20 c |
| **T2 24 285** | 223 c | 237 fg | 222 e | 233 g | 68.73 cd | 69.15 c |
| **T3 24 330** | 229 c | 243 ef | 225 e | 239 fg | 69.52 bcd | 70.46 bc |
| **T4 36 240** | 243 b | 248 de | 238 d | 244 ef | 74.28 bcd | 74.17 abc |
| **T5 36 285** | 245 b | 253 de | 241 cd | 249 de | 74.52abcd | 74.49 abc |
| **T6 36 330** | 249 b | 258 cd | 244 bcd | 254 dc | 75.17 abc | 74.94 abc |
| **T7 48 240** | 253 ab | 265 bc | 249 bc | 261 bc | 74.89 abc | 76.84 ab |
| **T8 48 285** | 258 ab | 270 ab | 253 ab | 267 ab | 75.84 ab | 77.37 ab |
| **T9 = 48 330** | 264 a | 277 a | 260 a | 273 a | 77.23 a | 78.75 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In contrast, Morris *et al.* (1983), Gao and cahoon (1991) and Ghobrial *et al.* (1991), Khattari and Shata (1993), Keller *et al.* (1999), Gay-Eynrad (2000) found that N fertilization did not affect berry weight in their experiments.Saayman and Lambrechts (1995) on 'Barlinka' table grapes found that berry mass seems to be negatively affected by high N level.

The result also is in the same trend of those found by Srivastava and Soni (1988) who cleared that berry size of 'Perlette' grape increased by N-application, but K had no effect.

El-Sese *et al.* (1988), Srivastava and Soni (1988) mentioned that berry weight was not significantly affected with K treatments.

However, Conradie and Saayman (1989) found that an increase in the yield of about 6.1 % due to larger berries after K-application.

Table 21 shows the effect of N and K-supply on the berry firmness and adherence that considered as the parameters for the berry softing and berry separation from the cluster.

It is obvious from the results that increasing N-supply from 24 to 48 kg/ha. negatively affected berry firmness and adherence. Increasing N-fertilizer reduced berry firmness and the berries are more easily separated from the cluster. Increasing K-feritlization from 240 to 330 kg/ha enhance berry adherence but had no effect on berry firmness. The values of firmness and adherence of 'Crimson Seedless' grapes which are recorded in the results, mean that all treatments of this study gave good quality for the marketing as well as for export.

Table (21): Effect of N and K fertilization on berry firmness and adherence of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** N K | **Berry firmness (g/berry)** | | **Berry adherence (g)** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **T1 24 240** | 4340 a | 4234 a | 763 a | 682 a |
| **T2 24 285** | 4184 ab | 4161 ab | 735 b | 660 ab |
| **T3 24 330** | 4150 ab | 4080 abc | 718 b | 641 bc |
| **T4 36 240** | 4088 abc | 4020 abcd | 690 c | 622 cd |
| **T5 36 285** | 3995 bcd | 3914 bcd | 673 cd | 610 de |
| **T6 36 330** | 3898 bcd | 3811 cde | 658 de | 584 ef |
| **T7 48 240** | 3787 cde | 3734 def | 647 ef | 577 fg |
| **T8 48 285** | 3706 de | 3601 ef | 627 fg | 563 fg |
| **T9 48 330** | 3566 e | 3497 f | 618 g | 550 g |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Generally, these results supported those claimed by Dokoozlian *et al.* (2000) who concluded that berries of 'Crimson Seedless' are more crisp and firm. Morover, El-Baz *et al.* (2002) mentioned that berry adherence was 681 to 724 g as affected by pruning severity treatments.

Furthermore, Ramming *et al.* (1995) reported that the pedicel of berries in 'Crimson Seedless' grape is medium in length and thickness. The brush is medium in length and is yellow-green. The berries are bright red and the flesh is light yellow, translucent, meaty, and firm. The skin is thick, medium tough, and does not separate from the flesh.

### 4.6.2 Fruit chemical properties

#### 4.6.2.1 T.S.S %, acidity and T.S.S/acid ratio

It is apparent from the data in Table 22 that there is an effect of N and K-fertilization on total soluble solids (T.S.S), acidity and T.S.S/acidity ratio of 'Crimson seedless' grape in 2004 and 2005. Increasing the K-fertilization from 240 to 330 kg/ha increased the percentage of total soluble solids (T.S.S %) and decreased the acid concentration. Increasing the amount of K-fertilization also caused a significant increase in the T.S.S./ acid ratio.

Regarding the effect of K-fertilization on the total soluble solids (T.S.S), the results show that T.S.S % increased as the potassium fertilization increased because it promotes the translocation of products of photosynthesis in the plant.

The obtained data go in line with those of Ahlawat and Yamadagni (1988), El-Sese *et al.* (1988), Omar (2000), Delgardo *et al.* (2004) and Martin *et al.* (2004) who reported that berry total soluble solids increased significantly as potassium level increased.

In contrast, Cline and Bradt (1980) as well as Kliewer and Freeman (1983) pointed out that K-fertilization had no significant effect on the berry total soluble solids concentration (T.S.S %).

Concerning the effect of N-fertilization on the total soluble solids (T.S.S), the results show that the total soluble solids (T.S.S) were influenced by the combination of N and K-fertilization. The data in Table 22 reported that the medium dose of N-fertilizer combined with the high dose of K-fertilizer T6 (36 kg N/ha + 330 kg $K_2O$/ha) gave the highest T.S.S % in 2004, however, there is no different in T.S.S % affected by T6 and those affected by the high dose of N-fertilizer combined with the high level of K-fertilizer T9 (48 kg N/ha+ 330 kg $K_2O$/ha). This mean the T.S.S % not affected when the nitrogen fertilizer raised over 36 kg N/ha when combined with the high level of K-fertilization (330 kg $K_2O$/ha) in 2004.

Table (22): Effect of N and K fertilization on total soluble solids (T.S.S), acidity and T.S.S/acidity ratio of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **T.S.S (%)** | | **Acidity (g / 100 ml juice)** | | **T.S.S /acid ratio** | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| **T1 24 240** | 21.2 cd | 21.4 bc | 0.668 bc | 0.723 bc | 31.73 cde | 29.60 cd |
| **T2 24 285** | 22.4 bcd | 21.8 bc | 0.654 bc | 0.694 cd | 34.29 abcd | 31.38 abc |
| **T3 24 330** | 22.5 bc | 23.0 abc | 0.643 c | 0.671 d | 35.12 abc | 34.40 ab |
| **T4 36 240** | 22.0 bcd | 22.2 abc | 0.711 a | 0.752 ab | 30.96 de | 29.49 cd |
| **T5 36 285** | 22.8 bc | 22.5 abc | 0.687 ab | 0.728 abc | 33.19 bcd | 30.93 bcd |
| **T6 36 330** | 24.7 a | 24.6 a | 0.656 bc | 0.697 cd | 37.66 a | 35.34 a |
| **T7 48 240** | 20.7 d | 20.5 c | 0.723 a | 0.763 a | 28.66 e | 26.80 d |
| T8 48 285 | 21.4 cd | 21.6 bc | 0.693 ab | 0.721 bc | 30.91 de | 29.89 cd |
| T9 48 330 | 23.6 ab | 23.5 ab | 0.664 bc | 0.683 d | 35.50 ab | 34.45 ab |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In 2005, the medium rate of N-fertilizer combined with the high level of K-fertilizer T6 (36 kg N/ha + 330 kg $K_2O$/ha) produced the highest T.S.S % compared with low rate of N-fertilization combined with low and medium levels of K-fertilizer (T1 and T2) (24 kg N/ha + 240 or 285 kg $K_2O$/ha) as well as compared with the high rate of N-fertilization combined with low and medium levels of K-fertilizer (T7 and T8) (48 kg N/ha + 240 or 285 kg $K_2O$/ha). On the other hand, there were no differences between the medium application of N-fertilizer combined with the high rate of K-fertilizer T6 and T3, T4, T5, T9 (low N-application combined with high K-application; the medium N-application with low & medium K-application; high application of N combined with high application of K).

The results go in line with those reported by many authors who found that total soluble solids in the juice of grapes increased as NK-application increased [Adel-Malik (1970); Krsteva and Kantarev (1979), Colapietra (1987), Srivastava and Soni (1988), Monga *et al.* (1990), Papric (1991), Apostolova (1998)], but the results stated that the increase in T.S.S % obtained from medium dose (36 kgN/ha) combined with the high level of potassium fertilization (330 kg K2O/ha) and the excessive dose of nitrogen (48 kg N/ha) when combined with the high level of K- fertilization (330 kg K2O/ha) had the same result.

On the other hand, Neilsen *et al.* (1987) on 'Foch' grapes, Girgis *et al.* (1998) on 'Thompson Seedless' grapevines found that total soluble solids appeared to have insignificant response to N and K fertilization.

The obtained data go in line with those reported by Morris *et al.* (1983) and Badr (1990) Spayd *et al.* (2000) indicated that accumulation of soluble solids enhanced by N-supply.

On the other side, Roubelakis and Kilewer (1981), Gao and Choon (1991), Maigre and Murisier (1991), Khattari and Shatat (1993), Keller *et al.* (1999), and Gay-Eynard (2000) found that soil N-fertilization did not affecte T.S.S %.

From Table (22), it is obvious that raising the K-supply from 240 to 330 kg/ha decreased the acidity of 'Crimson Seedless' grapes during the two years in this study.

The results appear that the acidity of 'Crimson Seedless' grapes was influenced by the combination of N and K-fertilization. In this respect, the result shows that increasing N-supply increased acidity but when combined with the high dose of K-fertilizer the acidity decreased.

Also, the highest acidity was obtaind from raising the N-fertilization combined with low level of K-fertilization.

The same trend was reported by many authors, who found that the increase in juice acidity was in relation to nitrogen (Abdel-Al 1967, Eid 1978, Ahmed 1987, El-Garhy 1990, Abdel-Hady 1990, Ahmed *et al.* 1990, Dhillon *et al.* 1992, Lovisolo *et al.* 2000, Gay-Eynard 2000, Keller *et al.* 2001, Salem *et al.* 2004, Reynolds *et al.*2005).

However, the findings of Morris *et al.* (1983), Keller *et al.* (1998), and Delgardo *et al.* (2004) observed that N fertilization tended to reduce the acidity in berries.

Nevertheless, Stevenson (1981), Gao and Cahoon (1991), Spayed *et al.* (1994), Saayman and Lamberchts (1995), Treeby *et al.* (2000), Spayd *et al.* (2000) noticed that juice acid levels were not affected by N fertilization.

In the experiment described here the acidity was affected by K-fertilization with the same trend of Sommers (1977) who explained that potassium reduces acid levels in berries and interacts with tartaric acid to form potassium tartrate, which has limited solubility.

This result also have been recorded by many authors who mentioned the role of potassium fertilization in reducing the acid levels in berries (Morris *et al.* (1983), Ahlawat and Yamadagni (1988), Balasubrahmanyam *et al.* (1988), El-Sese *et al.* (1988), Omar (2000) Rühl (2000), Martin *et al.* (2004), Salem *et al.* (2004).

On the other hand, these results are in disagreement of those recorded by Conradie and Saayman (1989) and Dhillon *et al.* (1999) who reported that acid content increased with increasing K application.

In contrast, Cline and Bradt (1980), Morris and Cawthon (1982) and Jackson and Lombard (1993) showed that acidity is not affected by K-fertilization.

Concerning the effect of combined N and K fertilization, the result of this study is in contrast with those stated by Pire and Rivas (1987), Apstolova (1998) and Salem *et al.* (2004) who reported that high levels of N and K application decreased acidity in the fruit.

However, Colapietra (1987), Neilson *et al.,* (1987) and Girgis *et al.* (1998) concluded that titratable acidity in fruit was not consistently affected by NK-fertilization.

In contrast, Bavha (1997) proved that acidity of 'Lastki Rizling' grapes was higher with increasing NK application whereas T.S.S content was lower.

With regard to the effect of N and K-supply on the T.S.S/acid ratio, there was an obvious increase with increasing the K-supply. N-supply has no effect on the T.S.S/acid ratio.

The obtained data are in accordance with the observation of El-Sese *et al.* (1988) and Omar (2000) who found that increasing $K_2O$ significantly increased TSS/acidity. Also, the same result was reported by Dhillon *et al.* (1999) as well as Salem *et al.* (2004).

Furthermore, Badr (1990) found that TSS/acid ratio was not significantly affected by any treatments of N-fertilization.

### 4.6.2.2 Sugars fraction

The study identified and determined all fractions of sugars in the berries of 'Crimson Seedless'. 4 fractions of sugar were found that are glucose, fructose, sorbitol and unknown sugar.

The results given in Table 23 and 24 exhibit the effect of N and K fertilization treatments on the sugars fraction of 'Crimson Seedless' grapes in 2004 and 2005.

The results show that glucose was influenced by the combined N and K fertilization in the first year. The high nitrogen rate combined with the level of potassium (T9) gave the highest value of glucose (110.31 mg/g fresh weight) compared with the low nitrogen rate combined with the medium potassium level (T2), which had (69.67 mg/g fresh weight).

There were no clear differences between (T9) and the other treatments. In the second season, no difference in glucose contents between the combined N and K fertilization treatments have been noticed. The values of the glucose content in the berries of 'Crimson Seedless grape ranged between 99.46 (T7) to 77.96 mg/g fresh weight (T2).

With regard to the fructose content in the berries of 'Crimson Seedless' grape (Table 23), there was a significant difference in the first year between T7 (the high application of N combined with low potassium level) and T2 (the low nitrogen rate combined with the medium potassium level) whereas T7 had a large content of the fructose (124.13 mg/g fresh weight) than T2 (75.09 mg/g fresh weight).

The second year did not show any significant variation between the combined N and K fertilization in the berry content of fructose. The values varied from 97.73 (T2) to 126.29 mg/g fresh weight (T7).

Concerning the effect of N and K fertilization on the content of sorbitol as well as on the unknown sugar that has been found in the berries of 'Crimson Seedless' grape (Table 24), the results exhibit that the sorbitol and the unknown sugar were not affected by N and K fertilization during two growing seasons.

Table (23): Effect of N and K fertilization on sugars fraction (glucose and fructose) of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Glucose (mg/g fresh weight )** | | **Fructose (mg/g fresh weight )** | |
|---|---|---|---|---|
| N K | 2004 | 2005 | 2004 | 2005 |
| **T1 24 240** | 93.89 ab | 97.36 a | 107.65 ab | 118.87 a |
| **T2 24 285** | 69.67 b | 77.96 a | 75.09 b | 97.73 a |
| **T3 24 330** | 92.89 ab | 85.82 a | 115.59 ab | 109.12 a |
| **T4 36 240** | 86.53 ab | 87.95 a | 107.15 ab | 117.54 a |
| **T5 36 285** | 97.73 ab | 99.30 a | 116.14 ab | 125.19 a |
| **T6 36 330** | 99.99 ab | 93.57 a | 119.99 ab | 121.05 a |
| **T7 48 240** | 101.31 ab | 99.46 a | 124.13 a | 126.29 a |
| **T8 48 285** | 99.68 ab | 93.41 a | 115.09 ab | 120.92 a |
| **T9 48 330** | 110.31 a | 91.29 a | 115.90 ab | 117.17 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

This aim has been reported before by Swanson and Elshishiny (1958) who mentioned that the accumulation of sugar in the form of glucose and fructose within the vacuole is one of the main features of the ripening process in grape berries and is a major commercial consideration for the grape grower and dried fruit producer. Sugar accumulation in climacteric fruit has received considerable attention, but little is known about the process in non-climacteric fruit such as grape. In grapevines, sucrose produced as a result of photosynthesis in the leaf is transported via the phloem to the berry. So, the result suggest that T9 as well as T7 are better than T2 in the content of glucose and fructose, respectively, since T7 and T9 produced a large amount of glucose and fructose than T2.

This result was supported by the findings of Davies and Robinson (1996) who stated that during grape berry ripening, sucrose transported from the leaves is accumulated in the berry vacuoles as glucose and fructose. In grape berries, hexose accumulation begins 8 weeks after flowering and continued until the fruit was ripe at 16 weeks. Invertase activity increased from flowering, is maximal 8 weeks after flowering and remains constant on a per berry basis throughout ripening. Although vacuolar invertases are involved in hexose accumulation in grape berries, the expression of the genes and the synthesis of the enzymes produce the onset of hexose accumulation by some weeks, so other mechanisms must be involved in regulating this process

Table (24): Effect of N & K fertilization on sugars fraction (sorbitol and unkown sugar) of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** N K | **Sorbitol (mg/g fresh weight )** | | **Unknown Sugar (mg/g fresh weight)** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **T1 24 240** | 19.72 a | 22.47 a | 4.65 a | 9.42 a |
| **T2 24 285** | 14.82 a | 16.03 a | 1.29 a | 3.02 a |
| **T3 24 330** | 19.87 a | 19.40 a | 10.31 a | 7.92 a |
| **T4 36 240** | 15.76 a | 17.31 a | 9.02 a | 4.91 a |
| **T5 36 285** | 15.78 a | 28.85 a | 8.37 a | 6.89 a |
| **T6 36 330** | 17.85 a | 21.34 a | 8.45 a | 6.35 a |
| **T7 48 240** | 22.78 a | 25.40 a | 8.66 a | 7.63 a |
| **T8 48 285** | 17.54 a | 22.98 a | 9.41 a | 8.65 a |
| **T9 48 330** | 20.52 a | 20.38 a | 5.11 a | 8.22 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

This result is in contrast with those of Martin *et al.* (2004) who found that the higher nitrogen doses delayed the accumulation of sugars during ripening, compared to the other treatments (low and medium rate of nitrogen application). Our results show that the difference between the rates of nitrogen (24, 34 and 48 kg/ha) in our fertilization experiment were not the same as those of Martin *et al.,* (2004) that are 0, 50 and 200 g/vine.

#### 4.6.2.3 Phenolic compounds

The concentration of phenolic compounds in grape berries depends on the variety of grapevine and is influenced by viticulture and environmental factors. This study determined the phenolics in 'Crimson Seedless' grapes as affected by N and K-fertilization during two seasons, since flavonoids play an important role in the quality of grape berries by contributing to color and sensory properties such as bitterness, astringency and flavor. Also, phenolic are considered as antioxidant compounds, biologically active dietary components (bioactive compound) and are generally accepted to be relevant for human health.

These compounds are an integral part of the human diet, and could be helpful against human cancers, arteriosclerosis, ischaemia and inflammatory disease, which are partially caused by exposure to oxidative stress (Namiki, 1990; Halliwell, 1996).

Flavonoid antioxidant compounds present in 'Crimson Seedless' grapes have been identified in this study as derivatives of phenolic acids, stilbenes, flavan 3-ols, flavonols and anthocyanins.

Each group of phenolics in 'Crimson Seedless' grapes have been determined and the individual compounds in the group have been studied. The study detected further the phenolic compounds which could not be identified.

##### 4.6.2.3.1 Phenolic acids

Table 25 and 26 show the effect of N and K fertilization on the phenolics acids of 'Crimson Seedless' grape in 2004 and 2005.

3 hydroxycinnamic acids have been detected in the berry skin of 'Crimson Seedless'; caffeoyltartaric acid, hydroxycinnamic acid (1) and hydroxycinnamic acid (2).

Concerning the determintion of caffeoyetartaric acid, it is obvious from Table 25 that the N and K fertilization did not affect on the caffeoyltartaric acid in the berry skin of 'Crimson Seedless' grapes during the first season. In the second season of this study, caffeoyltartaric acid in the berry skin of 'Crimson Seedless' grapes have been affected by the combined N and K fertilization. There were significant differences between the combined N and K ferilization treatment, T3 produced higher amount of caffeoyltartaric acid in the berry skin than T5, T8 and T9. There were no significant differences between T3 and the other combined N and K fertilization treatments.

Table (25): Effect of N and K fertilization on caffeoyltartaric acid and hydroxycinnamic acid (1) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Caffeoyltartaric acid (mg/kg) | | | Hydroxycinnamic acid (1) (mg/kg) | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 1.32 a | 2.67 ab | 1.95 ab | 0.99 ab | 1.56 ab | 1.27 bc |
| **T2 24 285** | 2.51 a | 2.84 ab | 2.68 ab | 0.08 b | 0.69 ab | 0.38 c |
| **T3 24 330** | 2.90 a | 6.19 a | 4.55 a | 0.60 ab | 1.35 ab | 0.98 c |
| **T4 36 240** | 3.26 a | 4.24 ab | 3.75 ab | 3.14 ab | 3.19 a | 3.17 a |
| **T5 36 285** | 4.46 a | 2.16 b | 3.31 ab | 3.73 a | 2.25 ab | 2.99 a |
| **T6 36 330** | 3.22 a | 3.30 ab | 3.26 ab | 2.63 ab | 2.91 a | 2.77 ab |
| **T7 48 240** | 1.35 a | 3.77 ab | 2.56 ab | 0.73 ab | 3.00 a | 1.86 abc |
| **T8 48 285** | 1.04 a | 2.42 b | 1.73 b | 0.20 b | 0.97 ab | 0.58 c |
| **T9 48 330** | 3.43 a | 1.76 b | 2.59 ab | 1.54 ab | 0.09 b | 0.82 c |
| **N 24** | 2.21 a | 3.90 a | 3.06 a | 0.56 b | 1.20 b | 0.88 b |
| **N 36** | 3.65 a | 3.23 a | 3.44 a | 3.17 a | 2.78 a | 2.98 a |
| **N 48** | 1.94 a | 2.65 a | 2.30 a | 0.82 b | 1.35 b | 1.09 b |
| **K 240** | 1.95 a | 3.56 a | 2.76 a | 1.62 a | 2.59 a | 2.11 a |
| **K 285** | 2.67 a | 2.48 a | 2.58 a | 1.33 a | 1.30 b | 1.32 a |
| **K 330** | 3.19 a | 3.75 a | 3.47 a | 1.59 a | 1.45 b | 1.52 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The mean of the two years of this study indicated that T3 (24 kg N/ha + 330 kg $K_2O$/ha) had greater amount of the caffeoyltartaric acid than T8 (48 kg N/ha + 285 kg $K_2O$/ha). No significant differences have been found between T3 and the other combined N and K fertilization treatments.

With regard to the effect of N and K fertilization on hydroxycinnamic acid (1) which have been detected by HPLC at 320 nm, the results claimed that in 2004, T5 had bigger amount than T2 and T8. There was no difference between T5 and the other treatments. This effect as the result of nitrogen fertilization. The middle dose of nitrogen fertilization produced higher amount of this compound than the low and high level of nitrogen fertilization, whereas the K-application had no effect.

In 2005, T4 , T6 and T7 enhanced hydroxycinnamic acid (1) in the skin compared to T9. Both of the N and K fertilization variants affected the concentration of hydroxycinnamic acid (1). The medium application of N had more effect than the low and the high N-applications. The low level of potassium fertilizer also had more effect than the medium and high K-application.

The mean of 2-years showed that the medium N-application influenced the concentration of hydroxycinnamic acid (1) in the berry skin compared with the low and high N-applications, however, there were no significant differences between the medium N-application combined with all K-fertilization levels and T7 (high N-application combined with low potassium level).

Table 26 shows the effect of N and K-fertilization on hydroxycinnamic acid (2) and total hydroxycinnamic acids in 2004 and 2005. It is clear that hydroxycinnamic acid (2) was not affected by the N and K-supply treatments in 2004, but in 2005, the N and K-applications: T2, T3, T6 and T7 had a higher value of hydroxycinnamic acid (2) than T9. The mean during 2 seasons proved that the low N-supply had more effect on hydroxycinnamic acid (2) than the high N-supply.

Regarding the total hydroxycinnamic acids, there were no differences between the combined N and K fertilization treatments during the first season, but the N fertilizer variant indicated that the medium N dose had a high value of total hydrxycinnamic acids compared to high N dose.

In 2005, total hydroxycinnamic acids were affected by the combined N and K fertilization, whereas T3, T4, T7 had a higher value of total hydroxycinnamic acids than T9.

The mean of the two years showed that T4 had a higher value of total hydroxycinnamic acids than T8 and the N fertilizer variant indicated that the medium N dose had a high value of total hydroxycinnamic acids compared to high N dose.

Table (26): Effect of N and K fertilization on hydroxycinnamic acid (2) and total hydroxycinnamic acids in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments N K | Hydroxycinnamic acid (2) (mg/kg) | | | Total hydroxycinnamic acids (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 3.40 a | 1.94 ab | 2.67 a | 5.63 a | 6.17 ab | 5.90 ab |
| **T2 24 285** | 2.06 a | 2.67 a | 2.37 a | 4.65 a | 6.20 ab | 5.43 ab |
| **T3 24 330** | 2.06 a | 2.75 a | 2.40 a | 5.55 a | 10.30 a | 7.92 ab |
| **T4 36 240** | 1.93 a | 2.06 ab | 2.00 a | 8.34 a | 9.49 a | 8.91 a |
| **T5 36 285** | 2.21 a | 1.79 ab | 2.00 a | 10.40 a | 6.20 ab | 8.30 ab |
| **T6 36 330** | 2.41 a | 2.39 a | 2.40 a | 8.27 a | 8.59 ab | 8.43 ab |
| **T7 48 240** | 0.63 a | 2.54 a | 1.58 a | 2.70 a | 9.31 a | 6.00 ab |
| **T8 48 285** | 1.40 a | 1.69 ab | 1.55 a | 2.64 a | 5.08 ab | 3.86 b |
| **T9 48 330** | 2.52 a | 0.75 b | 1.63 a | 7.49 a | 2.60 b | 5.04 ab |
| **N 24** | 2.51 a | 2.45 a | 2.48 a | 5.28 ab | 7.56 a | 6.42 ab |
| **N 36** | 2.19 a | 2.08 a | 2.14 ab | 9.00 a | 8.10 a | 8.55 a |
| **N 48** | 1.51 a | 1.66 a | 1.59 b | 4.28 b | 5.66 a | 4.97 b |
| **K 240** | 1.99 a | 2.18 a | 2.09 a | 5.55 a | 8.32 a | 6.94 a |
| **K 285** | 1.89 a | 2.05 a | 1.97 a | 5.89 a | 5.83 a | 5.86 a |
| **K 330** | 2.33 a | 1.96 a | 2.15 a | 7.10 a | 7.16 a | 7.13 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The results identified the phenolic acids in 'Crimson Seedless' grape as hydroxycinnamic acids and are in agreement with those mentioned by Ribereau-Gayon (1965) who confirmed that the phenolic acids of grape are hydroxycinnamic acids, which are in the form of esters of the tartaric acid in the skin and pulp.

Also, the results of Cantos *et al.* (2002) on ‘Crimson Seedless’ grapes confirmed our result, since they identified two hydrxycinnamic acids; Caffeoyltartaric acid (5.7 mg/kg berries) and *p*-coumaroyltartaric acid (5.7 mg/kg). In addition, they determined unkown hydroxycinnamic acid (1.1 mg/kg) and total hydroxycinnamic acid derivatives (9.5 mg/kg).

Montealegre *et al.* (2006) found *cis*-caftaric, *trans*-caftaric, *cis*-coutaric, *trans*-coutaric, *trans*-fertaric and protocatechuic acids in four grape cvs, ‘Cencible’, ‘Caberenet Sauvignon’, ‘Merlot’ and ‘Shiraz’. Moreover, the same acids except protocatechnuic acid were found in 6 white grapes ‘Chardonnay’, ‘Sauvignon’, ‘Moscatel’, ‘Gewürztraminer’, ‘Riesling’ and ‘Viogner’.

However, the results are in partial agreement with Miller *et al.* (1995), Vinson and Hontz (1995), Ghiselli *et al.* (1998) who mentiond that the phenolic acids in the grapes are hydroxybenzoic and hydroxycinnamic acids.

#### 4.6.2.3.2 Stilbene derivatives

Table 27 and 28 claimed the effect of N and K fertilization on the stilbene derivatives of ‘Crimson Seedless’ grape in 2004 and 2005. Stilbene derivatives, which have been found in the ‘Crimson Seedless’ grapes, are *cis*-piceid, *trans*-piceid and resveratrol.

It is obvious from Table 27 that *cis*-piceid was not affected by N and K applications in the first season, but it was affected in the second season, while T2 gave a higher amount of *cis*-piceid than the other treatments. The N-supply variants showed that the low nitrogen supply improved the *cis*-piceid compared to the medium and high levels of N-supply.

The mean of the two seasons concluded that the low dose of nitrogen fertilizer combined with medium level of potassium (T2) increased the amount of *cis*-piceid compared to the high dose of nitrogen combined with low level of potassium (T7).

Concerning the *trans*-piceid in the skin berry of ‘Crimson Seedless grapes, the data in Table 27 stated that *trans*-piceid was affected by the nitrogen variant in the first year, since the low nitrogen fertilization produced the higher concentration of this compound (1.24 mg/kg berry skin) compared to the high N-application (0.30 mg/kg berry skin).

In the second year, the concentration of the *trans*-piceid was influenced by the combined N and K-fertilization. T2 produced higher concentration.

Table (27): Effect of N and K fertilization on *cis*-piceid and *trans*-piceid in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | *cis*-Piceid (mg/kg) | | | *trans*-Piceid (mg/kg) | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 1.98 a | 0.88 b | 1.43 ab | 1.29 a | 0.04 b | 0.67 b |
| **T2 24 285** | 2.30 a | 2.33 a | 2.32 a | 0.96 a | 3.54 a | 2.25 a |
| **T3 24 330** | 0.61 a | 0.83 b | 0.72 ab | 1.46 a | 1.91 ab | 1.69 ab |
| **T4 36 240** | 0.79 a | 0.84 b | 0.81 ab | 0.61 a | 0.29 b | 0.45 b |
| **T5 36 285** | 3.06 a | 0.55 b | 1.80 ab | 0.70 a | 0.13 b | 0.41 b |
| **T6 36 330** | 1.13 a | 0.83 b | 0.98 ab | 0.19 a | 1.66 ab | 0.92 ab |
| **T7 48 240** | 0.50 a | 0.42 b | 0.46 b | 0.20 a | 0.49 b | 0.35 b |
| **T8 48 285** | 1.29 a | 0.51 b | 0.90 ab | 0.40 a | 0.54 b | 0.47 b |
| **T9 48 330** | 2.83 a | 0.94 b | 1.89 ab | 0.30 a | 0.15 b | 0.23 b |
| **N 24** | 1.63 a | 1.35 a | 1.49 a | 1.24 a | 1.83 a | 1.54 a |
| **N 36** | 1.66 a | 0.74 b | 1.20 a | 0.50 ab | 0.69 a | 0.60 b |
| **N 48** | 1.54 a | 0.62 b | 1.08 a | 0.30 b | 0.39 a | 0.35 b |
| **K 240** | 1.09 a | 0.72 a | 0.91 a | 0.70 a | 0.28 a | 0.49 a |
| **K 285** | 2.22 a | 1.13 a | 1.68 a | 0.69 a | 1.40 a | 1.05 a |
| **K 330** | 1.53 a | 0.87 a | 1.20 a | 0.65 a | 1.24 a | 0.95 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The mean of the two periods showed that there were significant differences between the low N-fertilization variant (24 kg/ha.) and both of the medium and high N-fertilization (36 and 48 kg/ha.). The *trans*-piceid concentration was higher in T2.

The results presented in Table (28) show that no resveratrol was found in the skin during the first period of this study, but in the second year 2005, the medium application of N-fertilization combined with low potassium level T4 (36 kg N/ha + 240 kg $K_2O$/ha) gave 1.45 mg resveratrol, however in the other treatments no resveratrol was found.

Table 28 shows the impact of N and K-fertilization during 2 years on total stilbenes content in the skin berry of ‘Crimson Seedless’ grapes. The treatments did not affect total stilbenes concentration in 2004. In 2005, T2 gave a higher concentration of total stilben than T1, T5, T7, T8 and T9. The N-supply variant affected total stilbenes concentration in the skin berry. The low rate of N-supply produced higher concentration of total stilbenes than the high rate of N-supply.

The mean of 2 years shows that T2 (24 kg N/ha + 285 kg $K_2O$/ha) had the highest total stilbenes compared to the other N and K-fertilization treatments as a result to N-fertilization that produced the highest total stilbenes under the low nitrogen supply level.

The study detected stilbene derivatives in ‘Crimson Seedless’ grapes, which are *cis*-piceid, *trans*-piceid and resveratrol (the retention time of HPLC to detect stilbene derivatives are: 113.06, 90.42 and 130.51 respectively). However, the resveratrol compound was found only in one treatment of N and K fertilization (T4) in the second season of this study, but its quantity was non-significant with the other treatments.

Moreover, the study states that stilbene derivatives (resveratrol) are only located in the skin of the grapes and this result in parallel with those of Jeandet *et al.* (1991) and Lamuela-Raventos *et al.* (1995).

On the other side, Cantos *et al.* (2002) studied the varietal differences among the polyphenol profiles of seven table grape cultivars including ‘Crimson Seedless’ and identified *trans*-piceid in ‘Napoleon’ red grapes but not in ‘Crimson Seedless’ grapes and the other varieties.

On another grape varieties, Okuda and Yokotsuka (1996) determined *trans*-resveratrol concentration in berry skins from 16 white-, 20 pink or red grape varieties grown in Japan.

Also Pineiro *et al.* (2006) mentiond that the mean of *trans*-resveratrol in ‘Viura’ grapes was 2.18 mg /kg.

Table (28): Effect of N and K fertilization on resveratrol and total stilbenes in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | | | **Resveratrol (mg/kg)** | | | **Total stilbenes (mg/kg)** | | |
|---|---|---|---|---|---|---|---|---|
| | **N** | **K** | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1** | **24** | **240** | 0.00 a | 0.00 a | 0.00 a | 3.27 a | 0.93 b | 2.10 b |
| **T2** | **24** | **285** | 0.00 a | 0.00 a | 0.00 a | 3.26 a | 5.87 a | 4.57 a |
| **T3** | **24** | **330** | 0.00 a | 0.00 a | 0.00 a | 2.08 a | 2.74 ab | 2.41 b |
| **T4** | **36** | **240** | 0.00 a | 1.45 a | 0.73 a | 1.40 a | 5.58 ab | 1.99 b |
| **T5** | **36** | **285** | 0.00 a | 0.00 a | 0.00 a | 3.76 a | 0.67 b | 2.22 b |
| **T6** | **36** | **330** | 0.00 a | 0.00 a | 0.00 a | 1.31 a | 2.49 ab | 1.90 b |
| **T7** | **48** | **240** | 0.00 a | 0.00 a | 0.00 a | 0.71 a | 0.91 b | 0.81 b |
| **T8** | **48** | **285** | 0.00 a | 0.00 a | 0.00 a | 1.69 a | 1.04 b | 1.37 b |
| **T9** | **48** | **330** | 0.00 a | 0.00 a | 0.00 a | 3.14 a | 1.09 b | 2.11 b |
| **N** | **24** | | 0.00 a | 0.00 a | 0.00 a | 2.87 a | 3.17 a | 3.02 a |
| **N** | **36** | | 0.00 a | 0.48 a | 0.24 a | 2.16 a | 1.91 ab | 2.04 ab |
| **N** | **48** | | 0.00 a | 0.00 a | 0.00 a | 1.85 a | 1.01 b | 1.43 b |
| **K** | | **240** | 0.00 a | 0.48 a | 0.24 a | 1.79 a | 1.47 a | 1.63 a |
| **K** | | **285** | 0.00 a | 0.00 a | 0.00 a | 2.90 a | 2.53 a | 2.72 a |
| **K** | | **330** | 0.00 a | 0.00 a | 0.00 a | 2.18 a | 2.10 a | 2.14 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

### 4.6.2.3.3 Flavonol derivatives

The flavonol derivatives in the berry skin of 'crimson Seedless' grapes have been identified quercetin 3-glucoside, kaempferol 3-glucoside, and further flavonols (1, 2, 3, 4 and 5). Table 29 - 32 show the effect of N and K fertilization on the flavonols in the berry skin of 'Crimson Seedless' grapes during 2004 and 2005.

It is clear from Table 29-32 that quercetin 3-glucoside, kaempferol 3-glycoside, flavonols (1, 2, 3, 4), and total flavonols were not affected by the treatments in 2004, but in 2005, T2 (the low nitrogen dose combined with meduim potassium level) gave the highest concentration of them in the berry skin of 'Crimson Seedless' grapes (350.87, 50.49, 7.80, 49.16, 94.24, 13.27 and 567.96 mg /kg, respectively) compared with the other N and K-fertilization. Also, the mean of the 2 years show the same result.

Table (29): Effect of N and K fertilization on quercetin 3-glucoside and kaempferol 3-glucoside in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Quercetin 3 glucoside (mg/kg)** | | | **Kaempferol 3-glucoside (mg/kg)** | | |
|---|---|---|---|---|---|---|
| **N K** | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 99.07 a | 55.82 b | 77.45 b | 7.40 a | 4.71 b | 6.06 b |
| **T2 24 285** | 190.40 a | 350.87 a | 270.63 a | 25.87 a | 50.49 a | 38.18 a |
| **T3 24 330** | 133.59 a | 100.87 b | 117.23 b | 15.00 a | 9.18 b | 12.09 b |
| **T4 36 240** | 72.49 a | 75.15 b | 73.82 b | 6.46 a | 5.85 b | 6.15 b |
| **T5 36 285** | 111.57 a | 56.92 b | 84.24 b | 15.26 a | 5.66 b | 10.46 b |
| **T6 36 330** | 88.59 a | 107.59 b | 98.09 b | 7.66 a | 12.59 b | 10.12 b |
| **T7 48 240** | 14.51 a | 135.82 b | 75.17 b | 1.06 a | 13.43 b | 7.24 b |
| **T8 48 285** | 180.70 a | 77.70 b | 129.20 b | 25.06 a | 8.16 b | 16.61 b |
| **T9 48 330** | 138.73 a | 30.83 b | 84.78 b | 16.27 a | 3.37 b | 9.82 b |
| **N 24** | 141.02 a | 169.16 a | 155.09 a | 16.09 a | 21.46 a | 18.78 a |
| **N 36** | 90.88 a | 79.89 a | 85.39 a | 9.79 a | 8.03 a | 8.91 a |
| **N 48** | 111.32 a | 81.45 a | 96.39 a | 14.13 a | 8.32 a | 11.23 a |
| **K 240** | 62 03 a | 88.93 a | 75.48 b | 4.97 b | 7.99 a | 6.48 b |
| **K 285** | 160.89 a | 161.83 a | 161.36 a | 22.07 a | 21.44 a | 21.76 a |
| **K 330** | 120.30 a | 79.77 a | 100.04 ab | 12.97 ab | 8.38 a | 10.68 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

On the other hand, it is obvious from Table 32 that in 2004, flavonol (5) was raised to 11.49 mg/kg by T1 (the low nitrogen rate combined with the low potassium level) compared with T2, T4, T5, T7, T8 and T9. However in 2005, T3 (the low nitrogen rate combined with the high potassium level) had the highest content of flavonol (5) with 12.43 mg/kg. The mean of the two years in this study indicated that T3 gave the highest concentration of flavonol (5) with 10.13 mg/kg.

Table (30): Effect of N and K fertilization on flavonol (1) and flavonol (2) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** N K | **Flavonol (1) (mg/kg)** | | | **Flavonol (2) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 1.70 a | 0.30 b | 1.00 b | 11.15 a | 7.81 b | 9.48 b |
| **T2 24 285** | 2.52 a | 7.80 a | 5.16 a | 28.04 a | 49.16 a | 38.60 a |
| **T3 24 330** | 2.31 a | 0.80 b | 1.55 b | 16.46 a | 11.43 b | 13.95 b |
| **T4 36 240** | 0.65 a | 0.67 b | 0.66 b | 8.72 a | 6.93 b | 7.82 b |
| **T5 36 285** | 0.83 a | 0.72 b | 0.77 b | 17.26 a | 6.04 b | 11.65 b |
| **T6 36 330** | 0.39 a | 2.58 b | 1.48 b | 8.57 a | 14.30 b | 11.43 b |
| **T7 48 240** | 0.27 a | 1.21 b | 0.74 b | 1.28 a | 14.14 b | 7.71 b |
| **T8 48 285** | 2.41 a | 0.62 b | 1.52 b | 28.41 a | 9.16 b | 18.78 b |
| **T9 48 330** | 1.51 a | 0.40 b | 0.96 b | 23.27 a | 3.47 b | 13.37 b |
| **N 24** | 2.17 a | 2.96 a | 2.57 a | 18.55 a | 22.82 a | 20.69 a |
| **N 36** | 0.62 b | 1.32 a | 0.97 b | 11.52 a | 9.09 a | 10.31 a |
| **N 48** | 1.40 ab | 0.74 a | 1.07 b | 17.65 a | 8.92 a | 13.29 a |
| **K 240** | 0.87 a | 0.73 a | 0.80 b | 7.05 b | 9.65 a | 8.35 b |
| **K 285** | 1.91 a | 3.05 a | 2.48 a | 24.57 a | 21.45 a | 23.01 a |
| **K 330** | 1.40 a | 1.26 a | 1.33 ab | 16.10 ab | 9.73 a | 12.92 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

This increment in the concentration of flavonol (5) was related to N-fertilization variant. In 2004, the low rate of N-supply gave a larger amount of flavonol (5) (7.93 mg/kg) than the high rate of nitrogen fertilization (1.69 mg/kg). There was no significant difference between the effect of low and medium dose of nitrogen on the concentration of flavonol (5).

Table (31): Effect of N and K fertilization on flavonol (3) and flavonol (4) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Flavonol (3) (mg/kg)** | | | **Flavonol (4) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| **N K** | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 21.58 a | 24.42 b | 23.00 b | 1.68 a | 1.40 b | 1.54 b |
| **T2 24 285** | 73.96 a | 94.24 a | 84.10 a | 6.95 a | 13.27 a | 10.11 a |
| **T3 24 330** | 22.53 a | 18.74 b | 20.63 b | 4.18 a | 2.93 b | 3.56 b |
| **T4 36 240** | 26.02 a | 19.64 b | 22.83 b | 2.31 a | 2.04 b | 2.18 b |
| **T5 36 285** | 57.15 a | 16.71 b | 36.93 ab | 5.33 a | 1.39 b | 3.36 b |
| **T6 36 330** | 24.64 a | 40.67 b | 32.66 ab | 2.97 a | 3.49 b | 3.23 b |
| **T7 48 240** | 5.07 a | 23.94 b | 14.51 b | 0.32 a | 4.05 b | 2.18 b |
| **T8 48 285** | 41.02 a | 25.04 b | 33.03 ab | 8.37 a | 2.55 b | 5.46 b |
| **T9 48 330** | 85.67 a | 12.64 b | 49.16 ab | 5.98 a | 0.99 b | 3.48 b |
| **N 24** | 39.36 a | 45.80 a | 42.58 a | 4.27 a | 5.87 a | 5.07 a |
| **N 36** | 35.94 a | 25.68 a | 30.81 a | 3.54 a | 2.31 a | 2.93 a |
| **N 48** | 43.92 a | 20.54 a | 32.23 a | 4.89 a | 2.53 a | 3.71 a |
| **K 240** | 17.56 a | 22.67 a | 20.12 a | 1.44 b | 2.50 a | 1.97 b |
| **K 285** | 57.38 a | 45.33 a | 51.36 a | 6.88 a | 5.74 a | 6.31 a |
| **K 330** | 44.28 a | 24.02 a | 34.15 a | 4.38 ab | 2.47 a | 3.43 ab |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In contrast, the result show that the increase of other flavonols (quercetin 3-glucoside, kaempferol 3-glucoside, flavonols (1, 2, 3, 4) that were detected in the skin of 'Crimson Seedless' grapes was related to K-application. Generally, total flavonols increased as the K-fertilization increased from 240 to 285 kg $K_2O$/ha (Table 29-32).

Table (32): Effect of N and K fertilization on flavonol (5) and total flavonols in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Flavonol (5) (mg/kg)** | | | **Total flavonols (mg/kg)** | | |
|---|---|---|---|---|---|---|
| **N K** | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 11.94 a | 1.34 b | 6.64 ab | 154.51 a | 95.81 b | 125.16 b |
| **T2 24 285** | 4.02 b | 2.14 b | 3.08 b | 331.67 a | 567.96 a | 449.86 a |
| **T3 24 330** | 7.84 ab | 12.43 a | 10.13 a | 201.90 a | 156.39 b | 179.14 b |
| **T4 36 240** | 4.10 b | 4.39 b | 4.24 b | 120.75 a | 114.67 b | 117.71 b |
| **T5 36 285** | 3.41 b | 3.84 b | 3.63 b | 210.81 a | 91.28 b | 151.04 b |
| **T6 36 330** | 6.58 ab | 6.85 ab | 6.72 ab | 139.39 a | 188.06 b | 163.73 b |
| **T7 48 240** | 0.42 b | 7.69 ab | 4.05 b | 22.93 a | 200.28 b | 111.61 b |
| **T8 48 285** | 1.90 b | 2.61 b | 2.26 b | 287.87 a | 125.85 b | 206.86 b |
| **T9 48 330** | 2.76 b | 0.55 b | 1.66 b | 274.21 a | 52.24 b | 163.23 b |
| **N 24** | 7.93 a | 5.30 a | 6.62 a | 229.39 a | 273.39 a | 251.39 a |
| **N 36** | 4.70 ab | 5.03 a | 4.87 ab | 156.99 a | 131.34 a | 144.17 a |
| **N 48** | 1.69 b | 3.62 a | 2.66 b | 195.00 a | 126.12 a | 160.56 a |
| **K 240** | 5.49 a | 4.47 a | 4.98 ab | 99.40 a | 136.92 a | 118.16 b |
| **K 285** | 3.11 a | 2.87 a | 2.99 b | 276.82 a | 261.70 a | 269.26 a |
| **K 330** | 5.73 a | 6.61 a | 6.17 a | 205.17 a | 132.23 a | 168.70 ab |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The mean of quercetin 3-glucoside was affected by K-fertilization (Table 29). The medium level of K-fertilization enhanced the amount of quercetin 3-glucoside (161 mg/kg) compared to the low K-fertilization (75.48 mg/kg), however, there was no significant difference between the effect of medium level of K-fertilization and the high K-fertilization level (100.04 mg/kg) on the concentration of quercetin 3-glucoside.

Kaempferol 3-glucoside was also influenced also K-fertilization (Table 29). In the first year 2004, medium level of K-fertilization (285 kg) increased the amount of kaempferol 3-glucoside from 4.97 to 22.07 mg/kg but there was no significant difference between the effect of medium level of K-fertilization and the high K-fertilization level (12.97 mg/kg).

The mean of kaempferol 3-glucoside in the berry skin of 'Crimson Seedless' grapes has been affected by K-fertilization (Table 29). The medium level of K-fertilization had the highest amount of kaempferol 3-glucoside (21.76 mg/kg) as compared to the low and high K-fertilization level (6.48 and 10.68 mg/kg, respectively).

Concerning the unknown (1), it was also influenced by K-fertilization (Table 30). The mean of two seasons indicated that the middle dose of potassium fertilization raised the concentration of flavonol (1) from 0.80 to 2.48 mg/kg. There was no significant difference between the effect of middle and high dose of potassium fertilization on the berry skin of 'Crimson Seedless' grapes (2.48 & 1.33 mg/kg, respectively).

In 2004, the middle level of K-application showed the highest value of flavonol (2) with 24.57 mg/kg compared to the low level of K-application which had 7.05 mg/kg. There were no differences between the effect of middle and high level of K-application which had 16.10 mg/kg (Table 30). In the second season, there were no significant differences between the treatments, but the mean of the two season concluded that the medium level of potassium fertilization had the highest concentration of flavonol (2) (23.01 mg/kg) compared with low and high level of potassium fertilization (8.35 and 12.95 mg/kg, respectively).

Table 31 shows the relationship between flavonol (4) and the K-supply. The first year (2004) as well as the mean of the two years in this study showed that the medium K-application exhibited a large amount of flavonols (4) [6.88 mg/kg in 2004 and the mean had 6.31 mg/kg] compared to the low level of K-application, which had 1.44 mg/kg in

2004, and 1.97 as mean. The medium and high level of K-application had no significant differences.

Total flavonols were affected by the K-supply (Table 32). The mean of the two seasons in this study claimed that the medium K-application (285 kg $K_2O$/ha) had a larger amount of the total flavonols (269.26 mg/kg) than the low level of K-application (240 kg $K_2O$/ha), which had 118.16 mg/kg. No significant difference has been found between the amounts of high level of total flavonols as affected by the high K-application (168.70 mg/kg) compared with those affected by the medium level of K-application.

The study claimed that the flavonols present in 'Crimson Seedless' red grapes are localized only in the skin and these results are in agreement with Wulf and Nagel (1980) and Cheynier and Rigaud (1986).

The results are also in the same trend of Cantos *et al.* (2002) who determined the flavonols derivatives of seven table grape cultivars (4 red vareities: 'Red Globe', 'Flame Seedless', 'Crimson Seedless' and 'Napoleon' and 3 white vareities: 'Superior Seedless', 'Dominga' and 'Moscatel Italica'. They found that the main flavonols found in all the table grape varieties were quercetin 3-glucuronide, quercetin 3-glucoside and quercetin 3-rutinoside. Quercetin 3-glucuronide was the dominant flavonol in 'Flame Seedless' and 'Napoleon' varieties, wherease it was in the same concentration as the other two quercetin derivatives in 'Crimson Seedless' and 'Moscatel Italica' varieties. 'Red Globe', 'Superior Seedless', and 'Dominga' grapes contained quercetin 3-glucuronide in smaller amounts than quercetin 3-glucoside plus quercetin 3-rutinoside. They were identified and determined as kaempferol 3-galactoside and kaempferol 3-glucoside in the 'Crimson Seedless' and the other varieties but in trace amounts except 'Moscatel Italica' white grapesv cv (0.5 , 4.7 mg/kg, respectively).

On the other hand, the results of our study are in partial with those of Montealegre *et al.* (2006) who studied the polyphenolic compounds content in the skins of six white grape varieties: 'Chardonnay', 'Sauvignon', 'Moscatel', 'Gewürztraminer', 'Riesling' and 'Viogner' and in the skins of 4 red grapes cv: 'Cencibel', 'Cabernet Sauvignon', 'Merlot' and 'Shiraz'. They reported that there were four flavonol compounds in white grapes, which were quercetin 3-glucuronide, quercetin 3-glucoside, kaempferol 3-glucoside and isorhamnetin 3-glucoside. In the red grape varieties, they found 6 flavonols, that were myricetin 3-glucuronide, myricetin 3-glucoside, quercetin 3-glucuronide, quercetin 3-glucoside, quercetin-glucosylxyloside and kaempferol 3-glucoside. They noticed that the total content of polyphenolic compounds in the skins of white grapes was lower than in red grape skins because myricetin 3-glucuronide, myricetin 3-glucoside and quercetin-glucosylxyloside appear in red grape skins but were not present in white grape skins.

Makris *et al.* (2006) reported a critical review about flavonols in red and white grapes as well as in white and red grape juices. Concerning the red grapes, they observed that flavonols were quercetin 3-*O*-galactoside, quercetin 3-*O*-glucoside, quercetin 3-*O*-glucuronide, as well as quercetin, myricetin, kaempferol, isorhamnetin. As regarding to red juice, they noted quercetin, myricetin, and kaempferol.

With Regard to the effect of N fertilization treatment on the flavonols in the berry grapes. Keller *et al.* (1999) studied 4 rates of N-supply (0, 30, 60, 90 kg/ha) on phenolic compounds in the berries of 'Pinot Noir' grapevines. They found that high rate of N fertilization (90 kg/ha) reduced flavonols. The same observation have been found in our study on the falvonol (5), but between the low and the medium rate of nitrogen (24 and 36 kg/ha). however, there was no significant difference between the medium and high rate of nitrogen fertilization (36 and 48 kg/ha). This result means that increasing the N fertilization up to 36 kg/ha decreased flavonol (5) which follows the trend noticed by Keller *et al.* (1999). There were no differences in the contents of other flavonols and of total flavonols when comparing the N variants in our study.

#### 4.6.2.3.4 Flavan 3 -ols

The flavan 3- ols group include a range of polyphenolic compounds ranging from small oligomeric forms to large proanthocyanidin polymers (condensed tannins). These oligomers and polymers are composed of monomeric subunits analogous to flavan 3-ol monomers such as catechin and epicatechin (Downey *et al.* 2006).

This study detected 11 compounds of the flavan 3-ols group in the berry skin of 'Crimson Seedless' grapes. 2 compounds have been identified and determined in this group (procyanidin B2 as a condensed tannin and epicatechin as a flavan 3-ol monomer); beside these, further 9 proanthocyanidins were found.

Table (33) presented the effect of N and K fertilization on the procyanidin B2 content in the skin. In 2004, the treatments did not affect the procyanidin B2 content. In 2005, T3 and T7 had a higher content of procyanidin B2 (2.34 and 2.32) than T9 (0.51 mg/kg). No significant differences have been observed between T3 , T7 and the other treatments. The mean of two years in this study did not show any significant differences in the procyanidin B2 content between the treatments.

Table (33): Effect of N and K fertilization on B2 and epicatchen in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Procyanidin B2 (mg/kg) | | | Epicatchin (mg/kg) | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.84 a | 1.64 ab | 1.24 a | 0.76 a | 0.77 a | 0.77 a |
| **T2 24 285** | 1.73 a | 1.24 ab | 1.48 a | 0.65 a | 0.79 a | 0.72 a |
| **T3 24 330** | 0.97 a | 2.34 a | 1.65 a | 0.73 a | 1.16 a | 0.94 a |
| **T4 36 240** | 1.23 a | 1.22 ab | 1.22 a | 0.57 a | 0.67 a | 0.62 a |
| **T5 36 285** | 2.01 a | 1.25 ab | 1.63 a | 1.25 a | 0.55 a | 0.90 a |
| **T6 36 330** | 1.19 a | 1.88 ab | 1.54 a | 1.38 a | 0.66 a | 1.02 a |
| **T7 48 240** | 0.34 a | 2.32 a | 1.33 a | 0.36 a | 1.29 a | 0.83 a |
| **T8 48 285** | 1.78 a | 1.46 ab | 1.62 a | 1.52 a | 0.88 a | 1.20 a |
| **T9 48 330** | 0.91 a | 0.51 b | 0.71 a | 0.61 a | 0.43 a | 0.52 a |
| **N 24** | 1.18 a | 1.74 a | 1.46 a | 0.71 a | 0.91 a | 0.81 a |
| **N 36** | 1.48 a | 1.45 a | 1.47 a | 1.07 a | 0.62 a | 0.85 a |
| **N 48** | 1.01 a | 1.42 a | 1.22 a | 0.83 a | 0.87 a | 0.85 a |
| **K 240** | 0.81 a | 1.73 a | 1.27 a | 0.56 a | 0.91 a | 0.74 a |
| **K 285** | 1.84 a | 1.31 a | 1.58 a | 1.14 a | 0.74 a | 0.94 a |
| **K 330** | 1.02 a | 1.58 a | 1.30 a | 0.90 a | 0.75 a | 0.83 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

It becomes visible from Table 34 that proanthocyanidin (1) was influenced by the N and K fertilizers treatments. In the first season, T4 resulted in the highest content of proanthocyanidin (1) compared to T2, T4, T7 and T8. The second season as well as the mean of 2004 and 2005 did not show significant variations.

Table (34): Effect of N and K fertilization on proanthocyanidin (1) and proanthocyanidin (2) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Proanthocyanidin (1) (mg/kg)** | | | **Proanthocyanidin (2) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.13 ab | 0.00 a | 0.07 a | 0.43 b | 0.00 b | 0.22 ab |
| **T2 24 285** | 0.00 b | 0.00 a | 0.00 a | 0.01 b | 0.00 b | 0.01 b |
| **T3 24 330** | 0.20 ab | 0.34 a | 0.27 a | 0.33 b | 2.06 a | 1.20 a |
| **T4 36 240** | 0.11 b | 0.02 a | 0.06 a | 0.45 b | 0.67 ab | 0.56 ab |
| **T5 36 285** | 0.56 a | 0.00 a | 0.28 a | 1.65 a | 0.00 b | 0.83 ab |
| **T6 36 330** | 0.14 ab | 0.29 a | 0.22 a | 0.41 b | 0.84 ab | 0.63 ab |
| **T7 48 240** | 0.00 b | 0.55 a | 0.28 a | 0.00 b | 1.55 ab | 0.77 ab |
| **T8 48 285** | 0.00 b | 0.16 a | 0.08 a | 0.00 b | 0.77 ab | 0.39 ab |
| **T9 48 330** | 0.19 ab | 0.00 a | 0.10 a | 0.48 b | 0.00 b | 0.24 ab |
| **N 24** | 0.11 a | 0.11 a | 0.11 a | 0.26 a | 0.69 a | 0.48 a |
| **N 36** | 0.27 a | 0.10 a | 0.19 a | 0.84 a | 0.50 a | 0.67 a |
| **N 48** | 0.07 a | 0.24 a | 0.16 a | 0.16 a | 0.77 a | 0.47 a |
| **K 240** | 0.08 a | 0.19 a | 0.14 a | 0.30 a | 0.74 a | 0.52 a |
| **K 285** | 0.19 a | 0.06 a | 0.13 a | 0.55 a | 0.29 a | 0.42 a |
| **K 330** | 0.18 a | 0.21 a | 0.20 a | 0.41 a | 0.97 a | 0.69 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Data presented in Table 34 exhibit the effect of N and K fertilization on proanthocyanidin (2) during two growing seasons.

In 2004, T5 (the medium nitrogen application combined with the middle level of potassium fertilization) gave the highest value of proanthocyanidin (2).

Table (35): Effect of N and K fertilization on proanthocyanidin (3) and proanthocyanidin (4) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Proanthocyanidin (3) (mg/kg) | | | Proanthocyanidin (4) (mg/kg) | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.48 a | 2.00 ab | 1.24 a | 0.58 a | 2.06 a | 1.32 a |
| **T2 24 285** | 0.78 a | 0.00 b | 0.39 a | 1.92 a | 1.86 a | 1.89 a |
| **T3 24 330** | 1.81 a | 2.36 ab | 2.08 a | 1.28 a | 1.94 a | 1.61 a |
| **T4 36 240** | 1.82 a | 1.50 ab | 1.66 a | 1.46 a | 1.23 a | 1.34 a |
| **T5 36 285** | 5.00 a | 1.90 ab | 3.45 a | 3.56 a | 1.22 a | 2.39 a |
| **T6 36 330** | 4.67 a | 2.50 ab | 3.58 a | 2.43 a | 1.44 a | 1.94 a |
| **T7 48 240** | 0.34 a | 3.83 a | 2.09 a | 0.41 a | 1.76 a | 1.09 a |
| **T8 48 285** | 3.27 a | 2.71 ab | 2.99 a | 2.66 a | 2.20 a | 2.43 a |
| **T9 48 330** | 1.46 a | 0.89 ab | 1.17 a | 1.36 a | 0.75 a | 1.06 a |
| **N 24** | 1.02 b | 1.45 a | 1.24 a | 1.26 a | 1.95 a | 1.61 a |
| **N 36** | 3.83 a | 1.97 a | 2.90 a | 2.48 a | 1.29 a | 1.89 a |
| **N 48** | 1.69 ab | 2.48 a | 2.09 a | 1.48 a | 1.57 a | 1.53 a |
| **K 240** | 0.88 a | 2.44 a | 1.66 a | 0.82 b | 1.68 a | 1.25 a |
| **K 285** | 3.02 a | 1.54 a | 2.28 a | 2.71 a | 1.76 a | 2.24 a |
| **K 330** | 2.65 a | 1.91 a | 2.28 a | 1.69 ab | 1.38 a | 1.54 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In 2005, T3 (the low nitrogen variant combined with the high level of potassium) resulted in a high content of proanthocyanidin (2) compared to T1, T2, T5, and T9.

The mean of the studied two years indicated that the highest content of proanthocyanidin (2) was achieved by T3 (1.20 mg/kg).

The anthocyanidin (3) was influenced by the N fertilization in the first year as well as affected by combined N and K fertilization in the second year of this study (Table 35).

The results in Table 35 stated that in first season, that medium N fertilization (36 kg/ha) had higher concentrations of anthocyanidin (3) 3.83 mg/kg than the low rate of nitrogen fertilization (24 kg/ha), which had 1.02 mg/kg. No variation has been found between the medium and high rate of N (36 kg/ha and 48 kg/ha). Also, no significant differences have been observed between the combined N and K fertilization treatments.

In the second season, T7 (the high nitrogen application dose combined with the low rate of potassium fertilizer) produced the high amount of proanthocyanidin (3) compared to T2 (the low nitrogen fertilization combined with the medium level of potassium).

The mean of the two seasons point out that the N and K fertilization treatments did not impact proanthocyanidin (3) in the skin of 'Crimson Seedless' grapes.

In 2004, the content of proanthocyanidin (4) increased with increasing the level of potassium fertilization from 240 to 285 kg $K_2O$/ha and the amount of proanthocyanidin (4) raised from 0.82 to 2.71 mg/kg. Whereas increasing the potassium level up to 330 kg $K_2O$/ha had no significant effect on the proanthocyanidin (4) content compared to the low and medium level of potassium fertilization (Table 35).

On the other hand, no significant variation was noticed in the content of proanthocyanidin (4) between the combined N and K fertilization treatments in 2004 and 2005 as well as in the mean of the two years.

Concerning the effect of nitrogen and potassium fertilization on the content of proanthocyanidin (5) the obtained data show that the content of proanthocyanidin (5) did not respond to fertilization treatments in both seasons of this study (Table 36) .

With regard to proanthocyanidin (6), in the first year, there was not significant varitiation between the treatments. In the second year, proanthocyanidin (6) was not detected.

Table (36): Effect of N and K fertilization on proanthocyanidin (5) and proanthocyanidin (6) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments N K | Proanthocyanidin (5) (mg/kg) | | | Proanthocyanidin (6) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.56 a | 1.41 a | 0.99 a | 1.23 a | 0.00 | 0.62 a |
| **T2 24 285** | 1.17 a | 0.30 a | 0.73 a | 1.66 a | 0.00 | 0.83 a |
| **T3 24 330** | 0.91 a | 1.50 a | 1.21 a | 1.03 a | 0.00 | 0.52 a |
| **T4 36 240** | 1.12 a | 0.93 a | 1.02 a | 1.45 a | 0.00 | 0.73 a |
| **T5 36 285** | 1.03 a | 0.88 a | 0.95 a | 1.97 a | 0.00 | 0.98 a |
| **T6 36 330** | 1.72 a | 1.37 a | 1.54 a | 2.02 a | 0.00 | 1.01 a |
| **T7 48 240** | 0.18 a | 1.25 a | 0.71 a | 0.62 a | 0.00 | 0.31 a |
| **T8 48 285** | 1.39 a | 1.22 a | 1.31 a | 2.50 a | 0.00 | 1.25 a |
| **T9 48 330** | 1.38 a | 0.22 a | 0.80 a | 2.97 a | 0.00 | 1.49 a |
| **N 24** | 0.88 a | 1.07 a | 0.98 a | 1.31 a | 0.00 | 0.66 a |
| **N 36** | 1.29 a | 1.06 a | 1.18 a | 1.81 a | 0.00 | 0.91 a |
| **N 48** | 0.98 a | 0.90 a | 0.94 a | 2.03 a | 0.00 | 1.02 a |
| **K 240** | 0.62 a | 1.19 a | 0.91 a | 1.09 a | 0.00 | 0.55 a |
| **K 285** | 1.20 a | 0.80 a | 1.00 a | 2.04 a | 0.00 | 1.02 a |
| **K 330** | 1.34 a | 1.03 a | 1.19 a | 2.01 a | 0.00 | 1.01 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Table 37 shows no significant differences in the concentration of proanthocyanidin (7) during two growing seasons.

Proanthocyanidin (8) decreased in first year by increasing the nitrogen fertilization rate from 24 to 48 kg/ha (Table 37).

Table (37): Effect of N and K fertilization on proanthocyanidin (7) and proanthocyanidin (8) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | | | Proanthocyanidin (7) (mg/kg) | | | Proanthocyanidin (8) (mg/kg) | | |
|---|---|---|---|---|---|---|---|---|
| | N | K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| T1 | 24 | 240 | 2.14 a | 4.73 ab | 3.43 a | 7.53 a | 4.62 a | 6.07 a |
| T2 | 24 | 285 | 3.67 a | 4,10 ab | 3.89 a | 6.33 a | 3.54 a | 4.93 a |
| T3 | 24 | 330 | 4.01 a | 6.53 ab | 5.27 a | 5.01 a | 5.57 a | 5.29 a |
| T4 | 36 | 240 | 3.50 a | 3.52 ab | 3.51 a | 4.11 a | 3.48 a | 3.80 a |
| T5 | 36 | 285 | 7.28 a | 4.27 ab | 5.77 a | 5.07 a | 3.40 a | 4.24 a |
| T6 | 36 | 330 | 8.38 a | 5.03 ab | 6.70 a | 3.12 a | 2.65 a | 2.88 a |
| T7 | 48 | 240 | 1.14 a | 8.12 a | 4.63 a | 1.16 a | 4.76 a | 2.96 a |
| T8 | 48 | 285 | 6.41 a | 5.45 ab | 5.93 a | 4.32 a | 4.49 a | 4.40 a |
| T9 | 48 | 330 | 5.19 a | 1.79 b | 3.49 a | 2.67 a | 2.11 a | 2.39 a |
| N | 24 | | 3.27 a | 5.12 a | 4.20 a | 6.29 a | 4.57 a | 5.43 a |
| N | 36 | | 6.39 a | 4.27 a | 5.33 a | 4.10 ab | 3.18 a | 3.64 ab |
| N | 48 | | 4.25 a | 5.12 a | 4.69 a | 2.72 b | 3.79 a | 3.26 b |
| K | | 240 | 2.26 a | 5.46 a | 3.86 a | 4.27 a | 4.29 a | 4.28 a |
| K | | 285 | 5.79 a | 4.61 a | 5.20 a | 5.24 a | 3.81 a | 4.53 a |
| K | | 330 | 5.86 a | 4.45 a | 5.16 a | 3.60 a | 3.44 a | 3.52 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The amount of proanthocyanidin (8) showed a sharp decrease from 6.29 to 2.72 mg/kg. There was no significant difference between the medium dose of nitrogen fertilization (4.10 mg/kg) and low and high N fertilization

The response of proanthocyanidin (8) to different N and K fertilization was studied. No significant differences among all N and K fertilization treatments were detected.

The amount of total flavan 3-ols was not affected by the treatments of N and K fertilization (Table 38); however, significant differences were observed for individual compound of this group.

Table (38): Effect of N and K fertilization on proanthocyanidin (9) and total flavan 3-ol in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Proanthocyanidin (9) (mg/kg)** | | | **Total flavan 3-ol (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **T1 24 240** | 0.37 a | 0.44 a | 0.40 a | 15.07 a | 20.02 a | 17.55 a |
| **T2 24 285** | 0.10 a | 0.00 a | 0.05 a | 18.02 a | 13.31 a | 15.66 a |
| **T3 24 330** | 0.45 a | 0.72 a | 0.58 a | 16.72 a | 26.71 a | 21.71 a |
| **T4 36 240** | 0.63 a | 0.43 a | 0.53 a | 16.44 a | 14.76 a | 15.60 a |
| **T5 36 285** | 1.13 a | 0.42 a | 0.77 a | 30.51 a | 15.29 a | 22.90 a |
| **T6 36 330** | 1.09 a | 0.67 a | 0.88 a | 26.55 a | 18.53 a | 22.54 a |
| **T7 48 240** | 0.14 a | 0.05 a | 0.10 a | 4.70 a | 27.17 a | 15.94 a |
| **T8 48 285** | 1.41 a | 0.87 a | 1.14 a | 25.26 a | 21.71 a | 23.49 a |
| **T9 48 330** | 1.39 a | 0.34 a | 0.86 a | 18.21 a | 8.10 a | 13.15 a |
| **N 24** | 0.31 a | 0.38 a | 0.35 a | 16.60 a | 20.01 a | 18.31 a |
| **N 36** | 0.95 a | 0.51 a | 0.73 a | 24.50 a | 16.19 a | 20.35 a |
| **N 48** | 0.98 a | 0.42 a | 0.70 a | 16.06 a | 19.00 a | 17.53 a |
| **K 240** | 0.38 a | 0.31 a | 0.35 a | 12.07 a | 20.65 a | 16.36 a |
| **K 285** | 0.88 a | 0.43 a | 0.66 a | 24.60 a | 16.77 a | 20.69 a |
| **K 330** | 0.98 a | 0.57 a | 0.78 a | 20.49 a | 17.78 a | 19.14 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The flavan 3-ols in ‘Crimson Seedless’ grapes and other cvs. have been studied by Cantos *et al.* (2002). They determined the total flavan 3- ols in ‘Crimson Seedless’ grapes [41.1 mg /kg] and did not identify any single compound of the flavan 3-ol group. Our study identified 2 compounds from 11 compound of this group, which have been found in ‘Crimson Seedless’ skin.

The results are in disagreement with those of Montealegre *et al.* (2006) who studied the flavan 3-ol in 10 grape varieties. They found that the main monomeric compound in the skins of white grape varieties was catechin (10-20 mg/kg), followed by epicatechin (0-10 mg/kg), which in some cases was below the detection level. No procyanidin B2 was found, whereas the concentrations of procyanidin B1 and B3 varied between 12- 48 mg/kg and the concentration of procyanidin B3 were slightly higher, with the exception of ‘Gewürztraminer’. ‘Viogner’ variety contained no quantifiable amounts of any of the monomers and dimers of flavanols and no quantifiable amounts of epicatechin were found in those of the Riesling variety.

Also, they found the concentration of flavan-3-ol in red grape skins was of the same order as in white grape skins. The concentration of procyanidin B3 was slightly higher and with similar concentration to those found in white grape skins and small amounts of procyanidin B2 were quantified in red grape skins.

#### 4.6.2.3.5 Anthocyanins

Anthocyanins are members of a class of nearly universal, water-soluble, terrestrial plant pigments that can be classified chemically as both flavonoid and phenolic.

They are responsible for the color of red grapes and have attracted great interest due to their antioxidant properties and their potentially beneficial effect for human health.

The primary problem associated with the production of ‘Crimson Seedless’ grapes is that it lacks sufficient berry color (Dokoozlian *et al.* 2000). This study investigate the effect of N and K fertilization treatment on the anthocyanin of ‘Crimson Seedless’ grapes.

The study detected 10 anthocyanins in the berry skin of ‘Crimson Seedless’ grapes; cyanidin 3-glucosid, peonidin 3-glucosid, malvidin 3-glucosid, and 7 further anthocyanins.

Table 39 presents the effect of N and K fertilization on cyanidin 3-glucoside in the skin of 'Crimson Seedless' grapes. In 2004, no significant differences were found between the treatments; the values of cyanidin 3-glucoside ranged between 1.04 to 14.13 mg/kg as affected by combined N and K-fertilization. In 2005, T2, T3 and T7 had the higher concentration of cyanidin 3-glucoside (19.06, 16.18, 18,15 mg/kg, respectively).

Table (39): Effect of N and K fertilization on cyanidin 3-glucoside and peonidin 3-glucoside in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Cyanidin 3-glucoside (mg/kg)** | | | **Peonidin 3-glucoside (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 9.01 a | 5.54 ab | 7.28 a | 133.18 a | 50.47 c | 91.82 b |
| **T2 24 285** | 9.50 a | 19.06 a | 14.28 a | 29.61 ab | 70.14 bc | 49.87 b |
| **T3 24 330** | 9.68 a | 16.18 a | 12.93 a | 65.04 ab | 301.82 a | 183.43 a |
| **T4 36 240** | 8.38 a | 7.29 ab | 7.83 a | 29.89 ab | 42.19 c | 36.04 b |
| **T5 36 285** | 14.13 a | 6.50 ab | 10.31 a | 81.66 ab | 41.91 c | 61.78 b |
| **T6 36 330** | 13.32 a | 11.47 ab | 12.40 a | 92.52 ab | 70.98 bc | 81.75 b |
| **T7 48 240** | 1.04 a | 18.15 a | 9.59 a | 21.41 b | 183.83 ab | 102.62 b |
| **T8 48 285** | 12.23 a | 10.30 ab | 11.26 a | 78.45 ab | 35.49 c | 56.97 b |
| **T9 48 330** | 13.03 a | 1.33 b | 7.18 a | 68.09 ab | 10.25 c | 39.17 b |
| **N 24** | 9.40 a | 13.59 a | 11.50 a | 75.94 a | 140.81 a | 108.38 a |
| **N 36** | 11.94 a | 8.42 a | 10.18 a | 68.02 a | 51.70 a | 59.86 a |
| **N 48** | 8.77 a | 9.92 a | 9.34 a | 55.98 a | 76.52 a | 66.25 a |
| **K 240** | 6.14 a | 10.32 a | 8.23 a | 61.49 a | 92.16 a | 76.83 a |
| **K 285** | 11.95 a | 11.94 a | 11.95 a | 63.24 a | 49.18 a | 56.21 a |
| **K 330** | 12.01 a | 9.66 a | 10.84 a | 75.22 a | 127.68 a | 101.46 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

'Crimson Seedless' grapes had a higher amount of peonidin 3-glucoside than the other anthocyanins (Table 39).

In 2004, T1 (the low nitrogen rate combined with the low potassium level) produced higher amounts of peonidin 3-glucoside (133.18 mg/kg) than T7 (the high nitrogen rate combined with the low potassium level), which had 21.41 mg/kg.

In 2005, T3 (the low nitrogen rate combined with the high potassium level) gave a higher amount of peonidin 3-glucoside (301.82 mg/kg) than T1, T2, T4, T5, T6, T8, T9 which had 50.47, 70.14, 42.19, 41.91, 70.98, 35.39, 10.25 mg/kg, respectively.

Table 40 shows the effect of combined nitrogen and potassium applications on the malvidin 3-glucoside during the two seasons of this study. In 2004, T6 (the medium nitrogen rate combined with the high potassium level) had a higher amount of malvidin 3-glucoside (33.33 mg/kg) than T2 (the low nitrogen rate combined with the meduim potassium level), which had 1.39 mg/kg (Table 40).

In 2005, T3 (the low nitrogen rate combined with the high potassium level) and T7 (the high nitrogen rate combined with the low potassium level) gave a higher amount of malvidin 3-glucoside (39.12 and 36.03 mg/kg, respectively) than T1, T2, T4, T5, T6, T8, T9 which had 4.62, 5.06, 3.89, 5.71, 8.30, 4.23, 0.00 mg/kg, respectively. These results are in the same trend of those for peonidin 3-glucoside in 2005.

The mean of malvidin 3-glucoside in the two years of this study stated that T3 improved the content of malvidin 3-glucoside 24.37 mg/kg compared with T1, T2, T4, T9 which had 6.68, 3.22, 3.71, 4.33 mg/kg, respectively.

In this study, 7 further anthocyanins have been detected. It is clear from Table 40 that in 2004, anthocyanins (1) was affected by the fertilization treatments. T6 had higher concentration of anthocyanins (1) 0.92 mg/kg than T2 , T3 , T4 , T7 (0.03 , 0.00 , 0.05 , 0.00 mg/kg , respectively).

The mean of 2004 and 2005 indicated that T6 and T7 had the highest concentration of anthocyanins (1) in the skin berry of 'Crimson Seedless' grape (0.54 and 0.50 mg/kg, respectively) than T2 and T4 (0.01 and 0.03 mg/kg). No differences have been found between the other treatments.

Table (40): Effect of N and K fertilization on malvidin 3-glucoside and anthocyanin (1) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Malvidin 3-glucoside (mg/kg)** | | | **Anthocyanin (1) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 8.73 ab | 4.62 b | 6.68 bc | 0.20 ab | 0.00 b | 0.10 ab |
| **T2 24 285** | 1.39 b | 5.06 b | 3.22 c | 0.03 b | 0.00 b | 0.01 b |
| **T3 24 330** | 9.61 ab | 39.12 a | 24.37 a | 0.00 b | 0.84 a | 0.42 ab |
| **T4 36 240** | 3.53 ab | 3.89 b | 3.71 bc | 0.05 b | 0.00 b | 0.03 b |
| **T5 36 285** | 15.30 ab | 5.71 b | 10.51 abc | 0.40 ab | 0.23 b | 0.32 ab |
| **T6 36 330** | 33.33 a | 8.30 b | 20.82 ab | 0.92 a | 0.16 b | 0.54 a |
| **T7 48 240** | 2.37 ab | 36.03 a | 19.20 abc | 0.00 b | 1.01 a | 0.50 a |
| **T8 48 285** | 16.51 ab | 4.23 b | 10.37 abc | 0.38 ab | 0.00 b | 0.19 ab |
| **T9 48 330** | 8.67 ab | 0.00 b | 4.33 bc | 0.19 ab | 0.00 b | 0.09 ab |
| **N 24** | 6.58 a | 16.27 a | 11.43 a | 0.08 a | 0.28 a | 0.18 a |
| **N 36** | 17.39 a | 5.97 a | 11.68 a | 0.46 a | 0.13 a | 0.30 a |
| **N 48** | 9.19 a | 13.42 a | 11.31 a | 0.19 a | 0.34 a | 0.27 a |
| **K 240** | 4.88 a | 14.85 a | 9.87 a | 0.09 a | 0.34 a | 0.22 a |
| **K 285** | 11.07 a | 5.00 a | 8.04 a | 0.27 a | 0.08 a | 0.18 a |
| **K 330** | 17.20 a | 15.81 a | 16.51 a | 0.37 a | 0.34 a | 0.36 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Concerning the anthocyanins (2) there were no significant differences between the treatments of N and K fertilization during 2 years of this study (Table 41).

Regarding to anthocyanins (3), in 2004, T6 had the highest content (0.56 mg/kg) compared to the other treatments (Table 41).

Table (41): Effect of N and K fertilization on anthocyanin (2) and anthocyanin (3) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Anthocyanin (2) (mg/kg)** | | | **Anthocyanin (3) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.07 a | 0.06 a | 0.06 a | 0.11 b | 0.03 cd | 0.07 b |
| **T2 24 285** | 0.02 a | 0.00 a | 0.01 a | 0.04 b | 0.32 ab | 0.18 ab |
| **T3 24 330** | 0.00 a | 0.00 a | 0.00 a | 0.09 b | 0.26 abc | 0.17 ab |
| **T4 36 240** | 0.14 a | 0.14 a | 0.14 a | 0.13 b | 0.14 bcd | 0.13 b |
| **T5 36 285** | 0.69 a | 0.00 a | 0.34 a | 0.18 b | 0.14 bcd | 0.16 ab |
| **T6 36 330** | 0.36 a | 0.10 a | 0.23 a | 0.56 a | 0.12 bcd | 0.34 a |
| **T7 48 240** | 0.00 a | 0.24 a | 0.12 a | 0.04 b | 0.38 a | 0.21 ab |
| **T8 48 285** | 0.10 a | 0.00 a | 0.05 a | 0.21 b | 0.19 abcd | 0.20 ab |
| **T9 48 330** | 0.30 a | 0.00 a | 0.15 a | 0.07 b | 0.00 d | 0.03 b |
| **N 24** | 0.03 a | 0.02 a | 0.03 a | 0.08 b | 0.20 a | 0.14 a |
| **N 36** | 0.40 a | 0.08 a | 0.24 a | 0.29 a | 0.13 a | 0.21 a |
| **N 48** | 0.13 a | 0.08 a | 0.11 a | 0.11 ab | 0.19 a | 0.15 a |
| **K 240** | 0.07 a | 0.15 a | 0.11 a | 0.10 a | 0.19 a | 0.15 a |
| **K 285** | 0.27 a | 0.00 a | 0.14 a | 0.14 a | 0.21 a | 0.18 a |
| **K 330** | 0.22 a | 0.03 a | 0.13 a | 0.24 a | 0.13 a | 0.19 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In 2004, the medium dose of nitrogen fertilization 36 kg/ha had the higher value of anthocyanins (3) 0.29 mg/kg as compared to low nitrogen application (24 kg/ha), which had 0.08 mg/kg. In the 2005, T7 gave the highest content of anthocyanins (3) with 0.38 mg/kg. The mean of the two years 2004 and 2005 stated that T6 produced higher concentration of unknown anthocyanidin (3) 0.34 mg/kg than T1, T4, T9 (0.07 , 0.13 , 0.03 mg/kg, respectively).

The effect of N and K fertilization on anthocyanin (4) in 2004 and 2005 have been studied (Table 42). In 2004, no differences were found between the N and K fertilization treatments.

Table (42): Effect of N and K fertilization on anthocyanin (4) and anthocyanin (5) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Anthocyanin (4) (mg/kg)** | | | **Anthocyanin (5) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.27 a | 0.01 c | 0.14 a | 0.32 a | 0.06 d | 0.19 ab |
| **T2 24 285** | 0.08 a | 0.35 abc | 0.22 a | 0.10 a | 0.38 bc | 0.24 ab |
| **T3 24 330** | 0.18 a | 0.58 ab | 0.38 a | 0.30 a | 0.49 ab | 0.40 ab |
| **T4 36 240** | 0.10 a | 0.16 c | 0.13 a | 0.15 a | 0.26 bcd | 0.20 ab |
| **T5 36 285** | 0.46 a | 0.26 bc | 0.36 a | 0.40 a | 0.27 bcd | 0.34 ab |
| **T6 36 330** | 0.29 a | 0.24 bc | 0.26 a | 0.52 a | 0.34 bc | 0.43 a |
| **T7 48 240** | 0.05 a | 0.70 a | 0.38 a | 0.11 a | 0.66 a | 0.39 ab |
| **T8 48 285** | 0.44 a | 0.24 bc | 0.34 a | 0.49 a | 0.22 cd | 0.35 ab |
| **T9 48 330** | 0.32 a | 0.00 c | 0.16 a | 0.24 a | 0.02 d | 0.13 b |
| **N 24** | 0.18 a | 0.32 a | 0.25 a | 0.24 a | 0.31 a | 0.28 a |
| **N 36** | 0.28 a | 0.22 a | 0.25 a | 0.36 a | 0.29 a | 0.33 a |
| **N 48** | 0.27 a | 0.32 a | 0.30 a | 0.28 a | 0.30 a | 0.29 a |
| **K 240** | 0.14 a | 0.29 a | 0.22 a | 0.20 a | 0.33 a | 0.27 a |
| **K 285** | 0.33 a | 0.29 a | 0.31 a | 0.33 a | 0.29 a | 0.31 a |
| **K 330** | 0.26 a | 0.27 a | 0.27 a | 0.36 a | 0.29 a | 0.33 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In 2005, T7 had higher concentrations of anthocyanins (4) with 0.70 mg/kg than T1, T4, T5 , T6, T8 , T9 ( 0.01 , 0.16 , 0.26 , 0.24 , 0.24 , 0.00, respectively). The mean of two season of this study reported that no differences have been noticed between the treatments.

Table (42) shows the response of anthocyanins (5) as affected by N and K fertilization. In 2004, there were no differences between the N and K fertilization treatments.

In 2005, T7 produced the highest content of anthocyanins (5) with 0.66 mg/kg compared with T1, T2 , T4 , T5 , T6 , T8 and T9 (0.06 , 0.38, 0.26 , 0.27, 0.34 , 0.22 , and 0.02 mg/kg , respectively).

The mean of the 2 periods 2004 and 2005 claimed that T6 gave a higher value of anthocyanins (5) (0.43 mg/kg) than T9 (0.13 mg/kg). There were not signicant differences between the T3 and the other combined N and K fertilization.

The obtained results, which are shown in Table (43), show the effect of N and K fertilization on anthocyanins (6).

In 2004, there were no differences between the combined N and K fertilization treatments. However, the medium level of potassium fertilization 285 kg/ha had the higher amount of anthocyanins (6) 1.90 mg/kg.

In 2005, T7 had a higher content of anthocyanins (6) (2.16 mg/kg) than T1, T9 (0.46 and 0.18 mg/kg, respectively). The mean of the two seasons 2004 and 2005 stated that there were not signicant differences between the treatments.

It is obvious from Table (43) that anthocyanins (7) was affected only in 2005 by combined N and K fertilization. T7 produced a higher amount (5.40 mg/kg) than T1, T4, T3, T5, T8, T9 (1.09, 1.47, 2.35, 2.08, 0.43 mg/kg, respectively), while T9 produced the lowest content of anthocyanins (7).

The data presented in Table (44) exhibit the effect of N and K fertilization on total anthocyanins in berry and total anthocyanins in berry skin of ‘Crimson seedless’ grape in 2004 and 2005.

Concerning the total anthocyanins in berry of ‘Crimson seedless’ grape, in 2004, T3 (the low nitrogen rate combined with high potassium level) had a higher amount (21.28 mg/kg) than T1, T2, T7, T8 (9.70, 9.83, 10.20, 10.60 mg/kg, respectively). The medium rate of nitrogen application 36 kg/ha gave a higher value of total anthocyanins than the lower nitrogen rate (24 kg/ha), however, there are no significant differences between the medium dose of nitrogen (17.57 mg/kg) and the high dose of nitrogen (48 kg/ha) which had 12.44 mg/kg. The high level of potassium application (330 kg/ha) also produced the higher amount of total anthocyanin in berries of 'Crimson seedless' grape (18.60 mg/kg) than the low and high level of potassium application (240 and 285 kg $K_2O$/ha) which had 12.38 and 12.64, respectively.

Table (43): Effect of N and K fertilization on anthocyanin (6) and anthocyanin (7) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Anthocyanin (6) (mg/kg)** | | | **Anthocyanin (7) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 1.17 a | 0.46 bc | 0.81 a | 2.46 a | 1.09 de | 1.78 a |
| **T2 24 285** | 1.58 a | 1.89 ab | 1.74 a | 1.82 a | 3.16 abcd | 2.49 a |
| **T3 24 330** | 1.25 a | 1.35 abc | 1.30 a | 2.26 a | 4.40 ab | 3.33 a |
| **T4 36 240** | 1.21 a | 0.98 abc | 1.10 a | 1.34 a | 1.47 cde | 1.41 a |
| **T5 36 285** | 2.21 a | 1.11 abc | 1.66 a | 4.79 a | 2.35 bcde | 3.57 a |
| **T6 36 330** | 1.89 a | 1.87 ab | 1.88 a | 4.13 a | 3.79 abc | 3.96 a |
| **T7 48 240** | 0.32 a | 2.16 a | 1.24 a | 0.94 a | 5.40 a | 3.17 a |
| **T8 48 285** | 1.90 a | 1.34 abc | 1.62 a | 4.99 a | 2.08 bcde | 3.53 a |
| **T9 48 330** | 1.15 a | 0.18 c | 0.67 a | 2.64 a | 0.43 e | 1.54 a |
| **N 24** | 1.33 a | 1.24 a | 1.29 a | 2.18 a | 2.88 a | 2.53 a |
| **N 36** | 1.77 a | 1.32 a | 1.55 a | 3.42 a | 2.54 a | 2.98 a |
| **N 48** | 1.12 a | 1.23 a | 1.18 a | 2.86 a | 2.64 a | 2.75 a |
| **K 240** | 0.90 b | 1.20 a | 1.05 a | 1.58 a | 2.66 a | 2.12 a |
| **K 285** | 1.90 a | 1.45 a | 1.68 a | 3.87 a | 2.53 a | 3.20 a |
| **K 330** | 1.43 ab | 1.14 a | 1.29 a | 3.01 a | 2.87 a | 2.94 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Table (44): Effect of N and K fertilization on total anthocyanins in berry and total anthocyanins in skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Total anthocyanins in berry (mg/kg berry weight)** | | | **Total anthocyanins in skin (mg/kg skin weight)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 9.70 b | 10.11 b | 9.91 d | 155.52 a | 62.35 b | 108.93 b |
| **T2 24 285** | 9.83 b | 10.12 b | 9.98 d | 44.17 a | 100.36 b | 72.26 b |
| **T3 24 330** | 21.28 a | 22.05 a | 21.67 a | 88.41 a | 365.04 a | 226.73 a |
| **T4 36 240** | 17.24 ab | 14.16 ab | 15.70 bc | 44.91 a | 56.52 b | 50.72 b |
| **T5 36 285** | 17.49 ab | 18.08 ab | 17.79 ab | 120.22 a | 58.47 b | 89.34 b |
| **T6 36 330** | 17.98 ab | 19.31 ab | 18.65 ab | 147.84 a | 97.37 b | 122.60 ab |
| **T7 48 240** | 10.20 b | 9.57 b | 9.89 d | 26.29 a | 248.58 a | 137.43 ab |
| **T8 48 285** | 10.60 b | 13.18 b | 11.89 cd | 115.71 a | 54.08 b | 84.90 b |
| **T9 48 330** | 16.52 ab | 21.98 ab | 19.25 ab | 94.70 a | 12.21 b | 53.45 b |
| **N 24** | 13.60 ab | 14.09 a | 13.85 b | 96.03 a | 175.92 a | 135.98 a |
| **N 36** | 17.57 a | 17.18 a | 17.38 a | 104.32 a | 70.79 a | 87.56 a |
| **N 48** | 12.44 b | 14.91 a | 13.68 b | 78.90 a | 104.96 a | 91.93 a |
| **K 240** | 12.38 b | 11.28 b | 11.83 b | 75.57 a | 122.48 a | 99.03 a |
| **K 285** | 12.64 b | 13.79 b | 13.22 b | 93.37 a | 70.97 a | 82.17 a |
| **K 330** | 18.60 a | 21.11 a | 19.86 a | 110.32 a | 158.21 a | 134.27 a |

Means within a column followed by different letter (s) are statistically different at 95 % level by Duncan's multiple range test.

The same trend of the effect of N and K fertilization on the total anthocyanins in the berries of 'Crimson Seedless' grapes have been found in 2005, T3 had the higher amount (22.05 mg/kg) than T1, T2 , T7, T8 (10.11, 10.12, 9.75, 13.18 mg/kg, respectively). The high level of potassium application 330 kg/ha also had a higher amount of total anthocyanins in berries (21.11 mg/kg) than the low and high level of potassium application (240 and 285 kg $K_2O$/ha) which had 11.28 and 13.79, respectively.

Generally, the mean of the two years of this study show that the best treatment for production of anthocyanins in the berries of 'Crimson Seedless' grapes was T3 (the low rate of nitrogen 24 kg/ha combined with high level of potassium 330 kg/ha) which produced 21.67 mg/kg compared with the mean of treatments T1, T2, T4, T7, T8 which produced 9.91, 9.98, 9.89, 11.89 mg/kg, respectively.

There were no significant differences between the mean of T3 (21.67 mg/kg) and T5, T6, T9 which gave 17.79, 18.65, 19.25 mg/kg, respectively.

The mean of the two years of this study gave this conclusion that the medium nitrogen application (36 kg/ha) gave the highest value of total anthocyanins (17.38 mg/kg). Also, the high level of potassium application (330 kg/ha) produced a high value of total anthocyanin (19.86 mg/kg).

Regarding to the effect of N and K fertilization on the total anthocyanins in the skin of 'Crimson Seedless' grapes (Table 44), there were no significant differences between treatments in the first year (2004), but in the second year (2005) T3 and T7 had a higher concentration of total anthocyanins in the skin (365.04 and 248.58 mg/kg respectively) than the other treatments (T1, T2, T4, T5, T6, T8, T9 which had 62.35, 100.36, 56.52, 58.47, 97.37, 54.08, 12.21 mg/kg, respectively.

The mean of 2004 and 2005 reported that T3 produced the highest content of the total anthocyanins in the skin of 'Crimson Seedless' grapes (226.73 mg/kg).

Peonidin 3-glucoside was the most abundant anthocyanin in 'Crimson Seedless' grapes. In contrast, Keller *et al.* (1999) found malvidin 3-glucoside was the most prominent anthocyanin in skins of 'Pinot Noir' grapevines. It accounted for 75 % of total anthocyanins and the high N-supply (90 kg/ha) increased the percentage of malvidin 3-glucoside. On the other side, the result show that peonidin 3- glucoside in 'Crimson Seedless' grapes was not affected by N-supply alone but was affected by the combined N and K fertilization treatments.

The results are in accordance with those of Keller *et al.* (1999) who studied 4 rates of N-supply (0, 30, 60, 90 kg/ha) on phenolic compounds in the berries of 'Pinot Noir' grapevines and found that high rate of N fertilization (90 kg/ha) decreased anthocyanins in juice. The best treatment for fruit quality, in terms of color and oxidative stability, was low amount of N fertilizer (30 kg/ha) and the worst was high N fertilization (90 kg/ha). In our study, medium rate of N application (36 kg/ha) had the highest amount of total anthocyanins in berries of 'Crimson Seedless' grapes.

Our results are also in the trend of these described by Delgardo *et al.* (2004) and Martin *et al.* (2004) who stated that the average dose of nitrogen (50 g N / vine) increased the levels of anthocyanins in the skin compared with the untreated control vine (0 g N/vine) and the high N-supply rate (200 g N/vine).

Furthermore, similar results were found by many authors who mentioned that high rate of nitrogen reduced skin anthocyanins (Mark 1977, Keller *et al.* 1999, Abd-El-Mohsen 2003)

Our results indicate that a high level of potassium (330 kg $K_2O$/ha) increased the total anthocyanins in berries. The role of potassium fertilization on improving anthocyanin levels in the berry skin of grapes was claimed by many researchers. In this respect, Scienza *et al.* (1981) who confirmed that the concentration of anthocyanin in 'Schiava' grapes enhanced with increasing K application. Moreover, Morris and Cawthon (1982) reported that K-supply significantly improved color of 'Concord' grape berries. Furthermore, Chris *et al.* (1999) showed that the content of anthocyanin in 'Shiras' grapes was higher with any dose of K applications than the control (no K application).

From the other stand point, the result showed that the best combined N and K fertilization treatment is the low N rate combined with the high level of K application (T3), which had the average of 21.67 mg/kg berry fresh weight. In this respect the result of Arutuyan (1978) suggest that N fertilization depressed pigmint accumulation in the berries, but K fertilization improved grape color.

Concerning the determination of anthocyanins in the 'Crimson Seedless' grapes, the results of Cantos *et al.* (2002) who determined the ancothyanins in 4 varieties; 'Crimson Seedless', 'Red Globe', 'Flame Seedless', and 'Napoleon' grapes show that the anthocyanins of 'Crimson Seedless' and the others grapes were delphinidin 3-glucoside, cyanidin 3-glucoside, petunidin 3-glucoside, peonidin 3-glucoside, malvidin 3-glucoside, cyanidin 3-*p*-coumaroylglucoside, and peonidin 3-*p* coumaroyl glucoside.

Also, the results are in parallel with those reported by Cantos *et al.* (2002) who found that peonidin 3-glucoside was the most abundant anthocyanin in 'Crimson Seedless' grapes (65.4 mg/kg). However our results determined the quantity of peonidin 3-

glucoside in ‘Crimson Seedless’ skin berries grapes and found their amount varied in the two seasons of study between the N and K fertilization as follows:

From 21.41 to 133.18 mg/kg in the first season and from 10.25 to 301.82 mg/kg berry skins in the second season.

Our results show also that ‘Crimson Seedless’ grapes contain low amounts of total anthocyanins compared with the other red varieties. Cantos *et al.* (2002) found the total anthocyanins were 115.3, 150.7, 75.7 and 68.5 in ‘Red Globe’, ‘Flame Seedless’, ‘Napoleon’ and ‘Crimson Seedless’ grapes. In addition, Hülya-Orak (2007) evaluated total anthocyanin contents in 16 grape cultivars and found that the total anthocyanins varied from 40.3 mg/kg in Md. Jean Matthias grapvines to 990.8 mg/kg in cabarnet Sauvignon vines.

#### 4.6.2.3.6 Other phenolic compounds

This study also detected further 16 unknown phenolic compounds. Unknown phenolic compound (1) concentration in the skin berry of ‘Crimson Seedless’ grapes presented in Table 45, decreased with increasing N fertilization. Low N application (24 kg/ha) had the highest value of unknown phenolic compound (1) (10.09 mg/kg) compared to the high N application (48 kg/ha) that gave 4.91 mg/kg. No significant difference has been found between the medium dose of N-supply (36kg/ha) and both the low and high N-supply. The same trend has been observed also by the mean of 2 periods of this study.

The combined N and K fertilization affected on the unknown phenolic compound (1), in 2004, T1 (low nitrogen rate combined with low potassium level) had a higher amount compared with the other treatments except T2 (low nitrogen dose combined with medium level of potassium application). In 2005, T2 had a higher concentration (12.64 mg/kg) of unknown phenolic compound (1) than T8 and T9 (4.76 and 2.54 mg /kg, respectively). The mean of 2 growing seasons showed that T1 and T2 produced a higher amount of unknown phenolic compound (1) [11.17 and 11.16 mg/kg, respectively] compared with T8, T9 (5.07 and 3.90 mg/kg, respectively).

Concerning the unknown phenolic compound (2), in the first year, T1 had a higher value of unknown phenolic compound (2) with 11.56 mg/kg than T7 with 4.23 mg/kg (Table 45).

In the second year, the low nitrogen improved the unknown phenolic compound (2) with 8.75 mg/kg than the high N (5.60 mg/kg). No variation was between the medium N-supply and the low and high N-supply. The the mean of the two years confirmed these results.

Table (45): Effect of N and K fertilization on unknown phenolic compound (1) and unknown phenolic compound (2) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (1) (mg/kg)** | | | **Unknown phenolic compound (2) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 15.17 a | 7.18 abc | 11.17 a | 11.56 a | 8.12 ab | 9.84 a |
| **T2 24 285** | 9.69 ab | 12.64 a | 11.16 a | 8.28 ab | 9.30 a | 8.79 a |
| **T3 24 330** | 5.41 b | 6.88 abc | 6.15 ab | 6.02 ab | 8.82 ab | 7.42 ab |
| **T4 36 240** | 5.28 b | 7.53 abc | 6.40 ab | 6.73 ab | 8.60 ab | 7.67 ab |
| **T5 36 285** | 7.47 b | 6.66 abc | 7.07 ab | 6.91 ab | 5.76 abc | 6.34 ab |
| **T6 36 330** | 6.89 b | 8.90 ab | 7.90 ab | 6.77 ab | 7.87 ab | 7.32 ab |
| **T7 48 240** | 4.08 b | 11.32 a | 7.70 ab | 4.23 b | 8.81 ab | 6.52 ab |
| **T8 48 285** | 5.38 b | 4.76 bc | 5.07 b | 7.57 ab | 4.85 bc | 6.21 ab |
| **T9 48 330** | 5.25 b | 2.54 c | 3.90 b | 5.95 ab | 3.13 c | 4.54 b |
| **N 24** | 10.09 a | 8.90 a | 9.50 a | 8.62 a | 8.75 a | 8.69 a |
| **N 36** | 6.55 ab | 7.70 a | 7.13 ab | 6.81 a | 7.41 ab | 7.11 ab |
| **N 48** | 4.91 b | 6.21 a | 5.56 b | 5.92 a | 5.60 b | 5.76 b |
| **K 240** | 8.18 a | 8.68 a | 8.43 a | 7.51 a | 8.51 a | 8.01 a |
| **K 285** | 7.51 a | 8.02 a | 7.76 a | 7.59 a | 6.64 a | 7.12 a |
| **K 330** | 5.85 a | 6.11 a | 5.98 a | 6.25 a | 6.61 a | 6.43 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

In 2005, T2 had a higher concentration of unknown phenolic compound (2) [9.30 mg/kg] compared with T8 and T9 (4.85 and 3.13 mg/kg, respectively). The mean of 2 years concluded that T1 and T2 considered the best treatment gave a higher value of unknown proanthocyanin (2) with 9.84 and 8.79 mg/kg, respectively compared to T9 (the high rate of N application combined with the high level of K) with 4.54 mg/kg.

Unknown phenolic compound (3) was impacted by N-supply (Table 46). In the first period of this study, the low N-supply (24 kg/ha) had higher content of unknown phenolic compound (3) with 3.47 mg/kg than the high N-supply (48 kg/ha) with 1.73 mg/kg.

In the second period, the low N-application had higher concentration (3.33 mg/kg) of unknown phenolic compound (3) compared with the high N-application ( 1.91 mg/kg). Moreover, T2 was the best combined N and K fertilization. It gave the highest value of unknown phenolic compound (3) concentration compared to the other treatments except T7.

The mean of the 2 periods stated that T2 produced higher content (4.36 mg/kg) of unknown phenolic compound (3) than both of T8 , T9 ( 2.09 and 1.29 mg/kg, respectively). Furthermore, the low nitrogen application had a higher amount (3.33 mg/kg) of unknown phenolic compound (3) than the high nitrogen application (1.91mg/kg).

Regarding the effect of N and K fertilizer treatments on the unknown phenolic compound (4), it is obvious from Table 46 that in 2004, T1 had a higher value with 4.02 mg/kg than T7 with 0.76 mg/kg. No significant difference was between T1 and the other treatments.

In 2005, the low N fertilization improved the unknown phenolic compound (4) with 2.64 mg/kg than the high N fertilization with 1.45 mg/kg.

The medium level of potassium fertilization (285 kg/ha) increased the content of unknown phenolic compound (4) to 2.52 mg/kg, whereas the high level of potassium fertilization (330 kg/ha) decreased this compound to 1.26 mg/kg.

The combined N and K fertilizers treatment T2 had the highest content of unknown phenolic compound (4) compared to the others.

Table (46): Effect of N and K fertilization on unknown phenolic compound (3) and unknown phenolic compound (4) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Unknown phenolic compound (3) (mg/kg) | | | Unknown phenolic compound (4) (mg/kg) | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 3.72 a | 1.86 bc | 2.79 ab | 4.02 a | 1.95 bc | 2.98 ab |
| **T2 24 285** | 3.71 a | 5.01 a | 4.36 a | 3.17 ab | 4.66 a | 3.91 a |
| **T3 24 330** | 2.98 a | 2.70 bc | 2.84 ab | 1.48 ab | 1.30 bc | 1.39 bc |
| **T4 36 240** | 2.11 a | 2.62 bc | 2.37 ab | 1.28 ab | 1.98 bc | 1.63 bc |
| **T5 36 285** | 3.43 a | 2.63 bc | 3.03 ab | 2.84 ab | 1.59 bc | 2.22 bc |
| **T6 36 330** | 2.51 a | 2.94 abc | 2.73 ab | 1.64 ab | 1.87 bc | 1.76 bc |
| **T7 48 240** | 1.00 a | 3.74 ab | 2.37 ab | 0.76 b | 2.43 b | 1.59 bc |
| **T8 48 285** | 2.39 a | 1.78 bc | 2.09 b | 1.76 ab | 1.31 bc | 1.53 bc |
| **T9 48 330** | 1.81 a | 0.76 c | 1.29 b | 1.49 ab | 0.61 c | 1.05 c |
| **N 24** | 3.47 a | 3.19 a | 3.33 a | 2.89 a | 2.64 a | 2.77 a |
| **N 36** | 2.69 ab | 2.73 a | 2.71 ab | 1.92 a | 1.81 ab | 1.87 b |
| **N 48** | 1.73 b | 2.09 a | 1.91 b | 1.34 a | 1.45 b | 1.40 b |
| **K 240** | 2.28 a | 2.74 a | 2.51 a | 2.02 a | 2.12 ab | 2.07 ab |
| **K 285** | 3.18 a | 3.14 a | 3.16 a | 2.59 a | 2.52 a | 2.56 a |
| **K 330** | 2.43 a | 2.13 a | 2.28 a | 1.54 a | 1.26 b | 1.40 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The mean point out that low nitrogen (24 kg/ha) produced the highest concentration of unknown phenolic compound (4) with 2.77 mg/kg than the meduim and high N application (1.87 and 1.40 mg/kg).

Also, the meduim dose of K application (285 kg /ha) improved the content of phenolic compound (4) to 2.56 mg/kg compared with the high level of potassium fertilization (330 kg /ha) with 1.40 mg/kg. In addition, T2 was the best combined N and K treatment. It improved the content of unknown phenolic compound (4) compared to the others.

Unknown phenolic compound (5) was affected by the N and K application (Table 47). The low nitrogen application had a higher content of with 3.12 mg/kg than the meduim nitrogen applied with 1.24 mg/kg. No significant difference was between low and high nitrogen fertilization. The similar trend was found by the mean of the 2 years.

Unknown phenolic compound (5) affected by combined N and K fertilization. In 2005, T2 had the highest content than T4, T5, T6 and T9 and no significant variation was between T2 and the others treatments. The mean indicated that T2 had higher concentration of unknown phenolic compound (5) with 3.82 mg/kg compared to T4 and T6 (0.88 and 1.28 mg/kg, respectably).

The data presented in Table 47 shows the effect of N and K fertilization on the unknown phenolic compound (6), which was affected in the second season. T7 gave the higher content of unknown phenolic compound (6) with 3.08 mg/kg compared with T2 and T9 (1.02 and 0.72 mg/kg, respectively).

Unknown phenolic compound (7) was influenced by potassium fertilization (Table 48). The mean of two seasons showed that medium potassium fertilization level (285 kg/ha) enhanced the concentration of unknown phenolic compound (7) with 1.09 mg/kg than the low level of potassium fertilization (240 kg/ha) with 0.66 mg/kg. The combined N and K supply T8 had a higher concentration of unknown phenolic compound (7) with 1.21 mg/kg than T7 with 0.43 mg/kg. No difference was between T8 and the other combined N and K fertilizer treatments.

Table 48 shows the effect of the N and K supply on unknown phenolic compound (8). In 2004, there was significant difference between T1 (17.24 mg/kg) and T3, T4, T7 (4.26, 4.44, 4.09 mg/kg).

In 2005, there was significant variation between the treatments. T2, T1, T4, T5 had a higher value of unknown phenolic compound (8) followed by T6, T9, T8, T7, whereas T3 produced the lower value of unknown phenolic compound (8).

Table (47): Effect of N and K fertilization on unknown phenolic compound (5) and unknown phenolic compound (6) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (5) (mg/kg)** | | | **Unknown phenolic compound (6) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 1.89 a | 2.87 ab | 2.38 ab | 0.69 a | 1.62 ab | 1.15 a |
| **T2 24 285** | 3.45 a | 4.18 a | 3.82 a | 1.16 a | 1.02 b | 1.09 a |
| **T3 24 330** | 1.91 a | 2.31 ab | 2.11 ab | 1.47 a | 2.67 ab | 2.07 a |
| **T4 36 240** | 0.91 a | 0.84 b | 0.88 b | 1.38 a | 1.23 ab | 1.31 a |
| **T5 36 285** | 2.57 a | 1.35 b | 1.96 ab | 2.49 a | 1.55 ab | 2.02 a |
| **T6 36 330** | 1.03 a | 1.52 b | 1.28 b | 3.15 a | 1.75 ab | 2.45 a |
| **T7 48 240** | 0.69 a | 2.73 ab | 1.71 ab | 0.40 a | 3.08 a | 1.74 a |
| **T8 48 285** | 3.08 a | 2.30 ab | 2.69 ab | 3.17 a | 2.38 ab | 2.77 a |
| **T9 48 330** | 2.76 a | 0.90 c | 1.83 ab | 1.79 a | 0.72 b | 1.26 a |
| **N 24** | 2.42 a | 3.12 a | 2.77 a | 1.11 a | 1.77 a | 1.44 a |
| **N 36** | 1.51 a | 1.24 b | 1.38 b | 2.34 a | 1.51 a | 1.93 a |
| **N 48** | 2.18 a | 1.98 ab | 2.08 ab | 1.79 a | 2.06 a | 1.93 a |
| **K 240** | 1.17 a | 2.15 a | 1.66 a | 0.82 a | 1.98 a | 1.40 a |
| **K 285** | 3.03 a | 2.61 a | 2.82 a | 2.28 a | 1.65 a | 1.97 a |
| **K 330** | 1.90 a | 1.58 a | 1.74 a | 2.14 a | 1.71 a | 1.93 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The mean of the two studied seasons claimed that the amount of unknown phenolic compound (8) was influenced by combined N and K fertilization. T1 produced a higher than T3, T6, T7, T8 and T9.

Table (48): Effect of N and K fertilization on unknown phenolic compound (7) and unknown phenolic compound (8) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Unknown phenolic compound (7) (mg/kg) | | | Unknown phenolic compound (8) (mg/kg) | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.99 a | 0.79 a | 0.89 ab | 17.24 a | 7.62 ab | 12.43 a |
| **T2 24 285** | 1.27 a | 0.87 a | 1.07 ab | 11.52 ab | 11.70 a | 11.61 ab |
| **T3 24 330** | 0.97 a | 0.89 a | 0.93 ab | 4.26 b | 0.43 c | 2.35 c |
| **T4 36 240** | 0.67 a | 0.62 a | 0.64 ab | 4.44 b | 7.22 ab | 5.83 bc |
| **T5 36 285** | 0.89 a | 1.06 a | 0.98 ab | 8.28 ab | 5.99 abc | 7.13 abc |
| **T6 36 330** | 0.85 a | 0.64 a | 0.74 ab | 7.85 ab | 4.41 bc | 6.13 bc |
| **T7 48 240** | 0.32 a | 0.54 a | 0.43 b | 4.09 b | 2.57 bc | 3.33 c |
| **T8 48 285** | 1.28 a | 1.14 a | 1.21 a | 7.49 ab | 2.76 bc | 5.12 c |
| **T9 48 330** | 0.55 a | 0.45 a | 0.50 ab | 7.88 ab | 4.09 bc | 5.99 c |
| **N 24** | 1.08 a | 0.85 a | 0.97 a | 11.01 a | 6.58 a | 8.80 a |
| **N 36** | 0.81 a | 0.77 a | 0.79 a | 6.85 a | 5.87 a | 6.36 a |
| **N 48** | 0.72 a | 0.71 a | 0.72 a | 6.49 a | 3.14 a | 4.82 a |
| **K 240** | 0.66 a | 0.65 a | 0.66 b | 8.59 a | 5.80 a | 7.20 a |
| **K 285** | 1.15 a | 1.03 a | 1.09 a | 9.10 a | 6.82 a | 7.96 a |
| **K 330** | 0.79 a | 0.66 a | 0.73 ab | 6.66 a | 2.98 a | 4.82 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Regarding to unknown phenolic compound (9), the results in Table 49 point out that in the first year, T2 had higher value (16.02 mg/kg) than T6 (2.10 mg/kg).

In 2005, unknown phenolic compound (9) was affected by the combined N and K fertilization. T2 had the highest value with 19.18 mg/kg. The mean of two years confirmed these results.

Table (49): Effect of N and K fertilization on Unknown phenolic compound (9) and unknown phenolic compound (10) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (9) (mg/kg)** | | | **Unknown phenolic compound (10) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 3.21ab | 7.66 bc | 5.44 b | 26.38 a | 5.85 a | 16.12 a |
| **T2 24 285** | 16.02 a | 19.81 a | 17.91 a | 8.36 b | 6.26 a | 7.31 bc |
| **T3 24 330** | 8.50 ab | 10.10 b | 9.30 b | 6.89 b | 4.28 a | 5.59 bc |
| **T4 36 240** | 3.17 ab | 2.14 c | 2.66 b | 10.03 b | 11.95 a | 10.99 ab |
| **T5 36 285** | 9.67 ab | 3.80 bc | 6.73 b | 5.91 b | 4.83 a | 5.37 bc |
| **T6 36 330** | 2.10 b | 1.29 c | 1.69 b | 4.02 b | 6.27 a | 5.14 bc |
| **T7 48 240** | 4.87 ab | 4.98 bc | 4.93 b | 1.75 b | 6.12 a | 3.93 c |
| **T8 48 285** | 9.60 ab | 5.45 bc | 7.53 b | 2.23 b | 2.42 a | 2.32 c |
| **T9 48 330** | 5.77 ab | 6.80 bc | 6.29 b | 5.76 b | 0.91 a | 3.34 c |
| **N 24** | 9.24 a | 12.52 a | 10.88 a | 13.88 a | 5.47 a | 9.68 a |
| **N 36** | 4.98 a | 2.41 b | 3.70 b | 6.65 b | 7.69 a | 7.17 a |
| **N 48** | 6.75 a | 5.74 b | 6.25 b | 3.25 b | 3.15 a | 3.20 b |
| **K 240** | 3.75 b | 4.93 b | 4.34 b | 12.72 a | 7.97 a | 10.35 a |
| **K 285** | 11.77 a | 9.68 a | 10.73 a | 5.50 b | 4.51 a | 5.01 b |
| **K 330** | 5.46 b | 6.06 ab | 5.76 b | 5.56 b | 3.82 a | 4.69 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Unknown phenolic compound (9) was affected by K fertilization in the two seasons, medium K level (285 kg/ha) had the highest value. There was no significant difference between meduim and high K levels in 2005.

Unknown phenolic compound (10) was affected by N and K fertilization in the first season (Table 49). T1 had the highest amount with 26.38 mg/kg compared with the other treatments. The low N and K supply had the highest value. So, T1 (low nitrogen rate combined with low potassium level) had the highest value.

In 2005, there were no differences between the treatment, but the mean of the two years indicated that T1 had the highest value of unknown phenolic compound (10).

The mean confirmed also that the low and medium nitrogen application had a higher concentration than high N application. Low K fertilization produced the highest content.

Unknown phenolic compound (11) was affected by the nitrogen fertilization in 2004 (Table 50). Low N supply (24 kg/ha) produced a higher amount with 9.83 mg/kg than high N supply (48 kg/ha) with 1.67 mg/kg. However, no significant difference was between the combined N and K fertilization.

In 2005, T3 had the highest value of the unknown phenolic compound (11) with 39.03 mg/kg. The high level of K fertilization had a higher value with 16.03 mg/kg than medium K application with 3.95 mg/kg.

The mean showed that T3 had the highest concentration of the unknown phenolic compound (11) compared to the other treatments. This result related to the low nitrogen that produced the high value with 12.20 mg/kg and related to the high K level that had a higher concentration with 12.15 mg/kg.

Table 50 shows the effect of N and K fertilization on the amount of the unknown phenolic compound (12). In the first year, T1 had a higher value than T7. On the other hand, in 2005, T7 had a higher amount than the other treatment except T3 and T6.

There were significant differences between the treatments. T7,T3,T6 had a higher content than T9.

The mean claimed that T3 had the highest concentration of the unknown phenolic compound (12) compared with T8 and T9 as well as T1 and T6 improved the concentration than T9.

Table (50): Effect of N and K fertilization on unknown phenolic compound (11) and unknown phenolic compound (12) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (11) (mg/kg)** | | | **Unknown phenolic compound (12) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 11.23 a | 1.98 c | 6.61 b | 2.24 a | 1.46 bc | 1.85 ab |
| **T2 24 285** | 4.54 a | 2.66 c | 3.60 b | 1.30 ab | 1.32 bc | 1.31 abc |
| **T3 24 330** | 13.71 a | 39.03 a | 26.37 a | 1.70 ab | 2.35 ab | 2.03 a |
| **T4 36 240** | 6.53 a | 6.84 bc | 6.69 b | 1.47 ab | 1.38 bc | 1.43 abc |
| **T5 36 285** | 2.97 a | 4.27 bc | 3.62 b | 1.76 ab | 0.92 bc | 1.34 abc |
| **T6 36 330** | 8.52 a | 8.83 bc | 8.68 b | 1.71 ab | 2.29 ab | 2.00 ab |
| **T7 48 240** | 0.60 a | 15.06 b | 7.83 b | 0.32 b | 3.46 a | 1.89 ab |
| **T8 48 285** | 1.85 a | 4.91 bc | 3.38 b | 0.96 ab | 0.84 bc | 0.90 bc |
| **T9 48 330** | 2.56 a | 0.23 c | 1.39 b | 1.44 ab | 0.06 c | 0.75 c |
| **N 24** | 9.83 a | 14.56 a | 12.20 a | 1.75 a | 1.71 a | 1.73 a |
| **N 36** | 6.01 ab | 6.65 a | 6.33 ab | 1.65 a | 1.53 a | 1.59 a |
| **N 48** | 1.67 b | 6.73 a | 4.20 b | 0.91 a | 1.45 a | 1.18 a |
| **K 240** | 6.12 a | 7.96 ab | 7.04 ab | 1.35 a | 2.10 a | 1.73 a |
| **K 285** | 3.12 a | 3.95 b | 3.54 b | 1.34 a | 1.03 a | 1.19 a |
| **K 330** | 8.26 a | 16.03 a | 12.15 a | 1.61 a | 1.57 a | 1.59 a |

Means within a column followed by different letter (s) are statistically different at 95 % level by Duncan's multiple range test.

Unknown phenolic compound (13) affected by the N and K fertilization in the second year and T3 had the highest content (Table 51). The high level of K fertilization had the highest value with 4.39 mg/kg. The mean of two years pointed out that T3 had the highest concentration with 6.27 mg/kg. The low N fertilization had the highest concentration 4.47 mg/kg.

Table (51): Effect of N and K fertilization on unknown phenolic compound (13) and unknown phenolic compound (14) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Unknown phenolic compound (13) (mg/kg) | | | Unknown phenolic compound (14) (mg/kg) | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 5.55 a | 3.58 b | 4.56 ab | 4.30 a | 2.41 bcd | 3.35 ab |
| **T2 24 285** | 1.78 a | 3.32 b | 2.55 b | 1.91 b | 3.11 abc | 2.51 abcd |
| **T3 24 330** | 4.73 a | 7.82 a | 6.27 a | 2.41 ab | 5.04 a | 3.72 a |
| **T4 36 240** | 2.97 a | 3.10 b | 3.03 b | 2.39 ab | 2.52 bcd | 2.46 abcd |
| **T5 36 285** | 3.09 a | 2.54 b | 2.82 b | 2.25 ab | 1.93 cd | 2.09 bcd |
| **T6 36 330** | 2.98 a | 3.08 b | 3.03 b | 2.31 ab | 2.21 bcd | 2.26 bcd |
| **T7 48 240** | 1.02 a | 3.99 b | 2.51 b | 1.28 b | 4.25 ab | 2.76 abc |
| **T8 48 285** | 3.59 a | 2.20 b | 2.90 b | 1.29 b | 1.49 cd | 1.39 cd |
| **T9 48 330** | 4.03 a | 2.26 b | 3.15 b | 1.67 b | 0.81 d | 1.24 d |
| **N 24** | 4.02 a | 4.91 a | 4.47 a | 2.87 a | 3.52 a | 3.20 a |
| **N 36** | 3.01 a | 2.90 a | 2.96 b | 2.32 ab | 2.22 a | 2.27 b |
| **N 48** | 2.88 a | 2.82 a | 2.85 b | 1.42 b | 2.18 a | 1.80 b |
| **K 240** | 3.18 a | 3.56 ab | 3.37 a | 2.66 a | 3.06 a | 2.85 a |
| **K 285** | 2.82 a | 2.69 b | 2.76 a | 1.82 a | 2.17 a | 2.00 b |
| **K 330** | 3.91 a | 4.39 a | 4.15 a | 2.13 a | 2.69 a | 2.41 ab |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

The data in Table 51 shows the effect of N and K fertilization on the concentration of unknown phenolic compound (14). T1 produced a higher concentration than T2, T7, T8, T9. The low nitrogen had a higher value with 2.87 mg/kg than the high N fertilization with 1.42 mg/kg. In 2005, the concentration of unknown phenolic compound (14) showed sharply variation between the treatments. The highest concentration was obtaind by T3 and the lowest was in T9. The mean of the two years showed the same trend, T3 was had a higher amount and T9 was the lowest. The low N fertilization improves the content than the medium and high N fertilization. Also, the low K fertilization had a higher content than the medium K fertilization, however, no significant difference was between the low and high K fertilization.

Table (52): Effect of N and K fertilization on unknown phenolic compound (15) and unknown phenolic compound (16) in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (15) (mg/kg)** | | | **Unknown phenolic compound (16) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| N K | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **T1 24 240** | 0.27 a | 0.25 ab | 0.26 a | 2.80 a | 0.22 c | 1.51 b |
| **T2 24 285** | 0.48 a | 1.30 ab | 0.89 a | 2.57 a | 5.74 a | 4.15 a |
| **T3 24 330** | 0.38 a | 1.29 ab | 0.83 a | 1.64 a | 3.32 b | 2.48 b |
| **T4 36 240** | 0.31 a | 0.36 ab | 0.33 a | 0.57 a | 0.82 bc | 0.69 b |
| **T5 36 285** | 0.22 a | 0.35 ab | 0.28 a | 2.20 a | 1.14 bc | 1.67 b |
| **T6 36 330** | 0.51 a | 1.18 ab | 0.85 a | 2.71 a | 1.20 bc | 1.95 b |
| **T7 48 240** | 0.00 a | 1.70 a | 0.85 a | 0.32 a | 1.43 bc | 0.87 b |
| **T8 48 285** | 0.36 a | 0.41 ab | 0.39 a | 2.00 a | 0.80 bc | 1.40 b |
| **T9 48 330** | 0.46 a | 0.00 b | 0.23 a | 2.76 a | 1.34 bc | 2.05 b |
| **N 24** | 0.38 a | 0.95 a | 0.67 a | 2.34 a | 3.09 a | 2.72 a |
| **N 36** | 0.35 a | 0.63 a | 0.49 a | 1.83 a | 1.05 b | 1.44 b |
| **N 48** | 0.27 a | 0.70 a | 0.49 a | 1.69 a | 1,19 b | 1.44 b |
| **K 240** | 0.19 a | 0.77 a | 0.48 a | 1.23 a | 0.82 a | 1.03 b |
| **K 285** | 0.35 a | 0.69 a | 0.52 a | 2.26 a | 2.56 a | 2.41 a |
| **K 330** | 0.45 a | 0.82 a | 0.64 a | 2.37 a | 1.95 a | 2.16 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Unknown phenolic compound (15) was influenced by the N and K application in the second year (Table 52). T7 had a higher amount compared to T9, but the mean of the two years indicated that the treatments had not effect.

Unknown phenolic compound (16) affected by N and K fertilization treatments in the second season (Table 52). T2 had the highest content.

The low N fertilization (24 kg/ha) had a higher concentration with 3.09 mg/kg compared to the medium and high N fertilization with 1.05 and 1.19 mg/kg, respectively.

The mean of two season concluded that T2 had the highest concentration of unknown phenolic compound (16). The low nitrogen had a higher amount than both medium and low N fertilization. Moreover, the medium and high K fertilization had the highest concentration.

#### 4.6.2.3.7 Total phenolic compounds

In the second season, the combined N and K fertilization varied in total phenolic compounds. T2 had the highest concentration (786.62 mg/kg). Also, T3 and T7 had a higher amount of total phenolic compounds than T1, T4, T5, T8 and T9. The low N application (24 kg/ha) produced the highest total phenolic compounds (562.56 mg/kg).

The mean of two years indicated that total phenolic compounds were influenced by the combined N and K fertilization. T2 had a higher content of total phenolic compound (633.84 mg/kg) than T4 and T9 (249.93, 275.97 mg/kg, respectively).

Our result found the medium and high N fertilization (36 and 48 kg/ha) reduced the total phenolic compound in ‘Crimson Seedless’ skin in the second year. This obtained results are in accordance with the sequence trend of Keller *et al.* (1999) who applied 4 rates of N-supply (0, 30, 60, 90 kg/ha) for ‘Pinot Noir’ grapevines and found that high N fertilization (90 kg/ha) reduced skin phenols.

The result in the same findings of many investigators reported the effect of N and K fertilization on the total phenols in the grape berries. Downey *et al.* (2006) confirmed that the levels of phenolic compounds are influenced by several environmental, cultural, physiological, and genetic factors. More important among the environmental factors affecting the coloration of grapes are air temperature, solar reduction, nitrogen and potassuim fertilization that are the two main nutriton elemnts in vineyards.

Also, the result in the similar direction of many researchers menthioned that total phenolic compounds in grapes depends on the variety of grapevine and is influenced by environmental and viticulture factors such as the fertilization (Cheynier *et al.* 1998, Broussaud *et al.* 1999, Ojeda *et al.* 2002).

Table (53): Effect of N and K fertilization on total phenolic compounds in berry skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Total phenolic compounds (mg/kg)** | | |
|---|---|---|---|
| N K | 2004 | 2005 | Mean |
| **T1 24 240** | 445.27 a | 240.67 c | 342.97 ab |
| **T2 24 285** | 481.07 a | 786.62 a | 633.84 a |
| **T3 24 330** | 379.12 a | 660.40 ab | 519.76 ab |
| **T4 36 240** | 242.10 a | 257.77 c | 249.93 b |
| **T5 36 285** | 438.67 a | 218.29 c | 328.48 ab |
| **T6 36 330** | 378.93 a | 371.28 bc | 375.10 ab |
| **T7 48 240** | 83.05 a | 562.47 ab | 322.76 ab |
| **T8 48 285** | 487.19 a | 247.55 c | 367.37 ab |
| **T9 48 330** | 450.08 a | 101.87 c | 275.97 b |
| **N 24** | 435.15 a | 562.56 a | 498.86 a |
| **N 36** | 353.23 a | 282.45 b | 317.84 a |
| **N 48** | 340.08 a | 303.96 b | 322 .02 a |
| **K 240** | 256.81 a | 353.63 a | 305.22 a |
| **K 285** | 468.98 a | 417.49 a | 443.24 a |
| **K 330** | 402.71 a | 377.85 a | 390.28 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

Concerning the determination of total phenolic components in grape varieties, Cantos *et al.* (2002) determined their concentration and claimed that total phenolic components were 225.4, 361.2, 131.9, 135.9, 135.7., 114.9, 145.1 mg/kg in 'Red globe', 'Flame Seedless', 'Crimson Seedless', 'Napoleon', 'Superior Seedless', 'Dominga', 'Moscatel Italica' grapes, consecutively. On the other side, the obtained data in this study cleared that the total phenolic compound in 'Crimson Seedless' grapes ranged between N and K fertilization from 83.05 to 487.19 mg/kg in the first year and from 101.87 to 786.62 mg/kg in the second year.

Also, Montealegre *et al.* (2006) determined the concentration of phenolic compounds in many grapes cultivars and concluded the total content of polyphenolic compounds in the skins of white grapes was lower than in red grape skins because myricetin glucuronide and glucoside and quercetin glucosylxyloside appear in red grape skins but not present in white grape skins.

Moreover, Hülya-Orak (2007) evaluated total phenols in 16 grape cultivars and found that the phenol concentration was determined between 965 unit in 'Tekidag Cekirdeksizi' grapes and 3062 unit in 'Mourvedre' grapes (unit = µg/gallic acid equivalent of phenolic compounds in 1 ml of the methanol extracts). So, our result determined the phenolic compounds with mg/kg berry skin and that consider clear content of these compounds in 'Crimson Seedless' grapes.

## 4.7 Effect of defoliation and fruit thinning on Cluster characteristics and fruit quality

### 4.7.1 Cluster weight and dimensions

The cluster characteristics have been affected by the canopy management during two growing season (Table 54).

Table 54 shows that most canopy managements produced bigger clusters compared with the treatment of leaf basel removal + fruit thinning and the control. However, there is a little increment between the treatments in the cluster width but this increment was non-significant and the cluster width did not change.

These results are in agreement of these findings of Vargas (1984) on 'Alphonse Lavallee' and 'Cardinal' grape cvs, Pondev (1987) on grape cv. 'Rkatsiteli', Zoecklein *et al.* (1992) on 'Riesling' and 'Alicante Grenache noir' cvs, Abd El-Wahab *et al.* (1997) on 'Thompson Seedless grapvines, Vasconcelos and Castagnoli (2000) on 'Pinot noir' vines. They reported that basal leaf removal as well as hedging and laterals shoots removed increase the cluster weight.

The results are similar with the results of Abd El-Wahab *et al.* (1997) who recorded that head suckering + pinching main shoots + maintaining laterals of 'Thompson Seedless grapevines increased cluster length. Our results show that the cluster width not change by leaf removal treatment; however, Abd El-Wahab *et al.* (1997) noticed an increase in cluster width.

Furthermore the obtained results are in the same trend of Inmyung *et al.* (2000) who noted that removing over the 6 th to 9 th node from the shoot basis of 'Cambel Early' grapevines after full bloom gave longest clusters.

Table (54): Effect of canopy management practices on cluster weight and dimensions of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Cluster weight (g)** | | **Cluster length (cm)** | | **Cluster width (cm)** | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 403.12 ab | 418.06 a | 21.65 a | 22.05 a | 14.50 a | 15.13 a |
| **LBR + H** | 417.25 ab | 429.79 a | 22.70 a | 23.23 a | 14.75 a | 15.50 a |
| **LBR + SSR** | 425.86 a | 435.42 a | 22.23 a | 22.65 a | 14.50 a | 15.25 a |
| **LBR + H + SSR** | 393.36 b | 413.91 a | 21.40 a | 21.95 a | 13.88 a | 14.75 a |
| **LBR + FTH** | 338.11 c | 365.70 b | 17.80 b | 17.93 b | 13.13 a | 13.25 a |
| **Control** | 354.75 c | 379.55 b | 18.45 b | 18.80 b | 13.63 a | 13.88 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning.

**Control** = untreated vines.

In contrast, the results are in the contrary of those mentioned by Bledsoe *et al.* (1988) on ' Sauvignon blanc' vines, Reynolds and Wardle (1989 c) on 'de Chaunac' vines, Wolf *et al.* (1990) on 'White Riesling' grapevines, Howell *et al.* (1994) on 'Point noir' grapes, Main and Morris (2004) on 'Cynthiana' vines who found that cluster weight was not affected by leaf removal.

### 4.7.2 Number of berries per cluster and cluster compactness

The treatment of leaf basal removal + fruit thinning produced the lowest number of berries during all treatments because their clusters were tipped to 5 raichis lateral (cluster branches). Also, no significant differences have been found between the other treatments and the control concerning the number of berries per cluster (Table 55).

The treatment of leaf basal removal + hedging gave less compact clusters than the control in the first year. In the second, all of the treatments produced clusters with reduced compactness compared to the control.

Table (55): Effect of canopy management practices on number of berries / cluster and Cluster compactness of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **No. of berries / cluster** | | **Cluster compactness** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 116.3 a | 118.13 a | 5.42 ab | 5.39 b |
| **LBR + H** | 113.86 a | 116.38 a | 5.08 b | 5.08 b |
| **LBR + SSR** | 117.67 a | 119.21 a | 5.34 ab | 5.30 b |
| **LBR + H + SSR** | 116.49 a | 113.36 a | 5.49 ab | 5.18 b |
| **LBR + FTH** | 88.51 b | 89.83 b | 5.43 ab | 5.27 b |
| **Control** | 114.37 a | 116.53 a | 6.21 a | 6.20 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control =** untreated vines.

The production of a reduced cluster compactness by the treatments was related to the increasing cluster length.

The results are in accordance with those of Howell *et al.* (1994) as well as of Koblet *et al.* (1994) who concluded that basal leaf removal application did not reduce the number of berries per cluster in ‘Point noir’ grapevines.

From the other standpoint, Reynolds and Wardle (1989 c) cleared that increased severity of summer heading reduced the number of berries per cluster of ‘de Chaunac’ vines in the second year. No discernible effect was observed in the first or the third year.

Candolfi-Vasconcelos and Koblet (1990) found that removing all main leaves 2 weeks after full bloom for 'Pinot Noir’ grapevines declined the number of berries per cluster only in the second season (study consist of two seasons). The other leaf removal treatment had no effect.

On the other side, the obtained results are in contrast to those reported by Vargas (1984) who tipped the shoots (removal of 15 cm of the shoot apex) in addition to removing the lateral shoots of ‘Alphonse Lavallee’ and ‘Cardinal’ cvs and found an increasing in the number of berries /cluster in both of grape cultivars.

Furthermore, Vasconcelos and Castagnoli (2000) found that tipping shoots of ‘Pinot noir’ grapevines at bloom gave a high number of berries per cluster due to increasing fruit set.

On the other hand, Poni *et al.* (2006) reported that the number of berries per cluster of cultivars ‘Sangiovese’ and ‘Trebbiano’ grapevines was reduced by defoliation.

### 4.7.3 Berry dimensions

Table 56 presents the effect of canopy management practices on the berry dimensions of ‘Crimson Seedless’ grapes during two periods.

It is clear from the obtained data that all treatments gave bigger berries compared with the control except the treatment of leaf basal removal + hedging + sterile shoot removal.

The treatment of leaf basal removal + hedging + sterile shoot removal did not improve the berry dimension because the excessive leaf removal may have reduced carbohydrate synthesis. Due to this reason, the vines may have produced small berries compared with the other defoliation treatment

Table (56): Effect of canopy management practices on berry dimensions of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Berry length (cm)** | | **Berry width (cm)** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 2.18 b | 2.20 b | 1.67 ab | 1.70 ab |
| **LBR + H** | 2.22 b | 2.25 b | 1.66 ab | 1.69 ab |
| **LBR + SSR** | 2.19 b | 2.21 b | 1.73 ab | 1.74 ab |
| **LBR + H + SSR** | 2.07 bc | 2.04 bc | 1.60 bc | 1.65 bc |
| **LBR + FTH** | 2.49 a | 2.50 a | 1.78 a | 1.80 a |
| **Control** | 1.86 c | 1.98 c | 1.54 c | 1.56 c |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

The other canopy management treatments improved berry dimension as a result to leaving a proper number of leaves per shoot that achieve a maximum carbohydrate synthesis in the vines compared with the control, which had more shaded interior leaves that impeded nutrient supply from the leaves to the clusters.

These results are in agreement with those found by Abd El-Wahab *et al.* (1997) who stated that removing leaves from head of the vine plus pinching main shoots with maintaining laterals increased berry dimensions of 'Thompson Seedless' grapes compared to other summer pruning treatments and control.

Also, the result are in parallel with the findings of Kingston and Van Epenhuijsen (1989) who conducted 8 treatments of leaf removal on 'Italia' grapevines (nine, 13-, 11, 9-, 7-, 5-, 3-leaf per shoot) and found that partial defoliation of 11-, 13- leaf had larger diameters than other excessive treatments (9-, 7-, 5-, 3-leaf per shoot). Plants with three leaves per shoot always had a smaller berry diameter than any treatment.

### 4.7.4 Berry weight and volume

Table 57 shows the effect of canopy management practices on berry weight and volume of ‘Crimson Seedless’ grapes during two years. With the exception of treatment of leaf basel removal + hedging + sterile shoot removal, all defoliation treatments increased berry weight and volume during the two seasons of this study.

The treatment of leaf basel removal + fruit thinning produced the heaviest berry weight and the largest berry volume compared with the other defoliation treatments. This increment in the berry weight and size in this treatment related to the increasing in the allowance of nutrient supply for thinned berries compared with the unthinned berries in clusters of the other defoliation treatments. The control produced the lowest weight and size due to the competition between the high numbers of leaves in the shoots and the berries.

There were no significant differences in berry weight and volume between the control and the excessive leaf removal treatment ( LBR+ H + SSR).

The treatment of leaf basel removal + hedging + sterile shoot removal provided the berries with insufficient amount of carbohydrates. As a result it produced berries with low weight and small size.

The results in the same trend of Reynolds and Wardle (1989 c) who found summer heding increased berry weight of ‘de Chaunac’ vines.

Similar results were noticed by Caspari et al. (1998) who confirmed that the removal of leaves increased berry weight of ‘Sauvignon blanc’ grapes.

The obtained results from the excessive defoliation treatment in the same trend of Bledsoe *et al*. (1988) who stated that berry weight of ‘Sauvignon blanc’ vines was not significantly affected by increasing the level of leaf removal.

Furthermore, Wolf *et al.* (1990) noticed that increasing the leaf removal level reduced the berry weight since, they found that berry weight of ‘White Riesling’ grapevines significantly lower in vines topped to 10 leaves than did vines topped to 20 leaves. But, this difference was only significant in the last season of this study that carried out during three years.

Table (57): Effect of canopy management practices on weight and volume of 100 berries of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Weight of 100 berries (g) | | Volume of 100 berries ($cm^3$) | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 346.90 b | 354.44 bc | 341.13 bc | 349.57 bc |
| **LBR + H** | 363.16 b | 369.87 b | 359.85 b | 363.52 b |
| **LBR + SSR** | 362.27 b | 366.41 b | 355.71 b | 355.25 b |
| **LBR + H + SSR** | 338.37 bc | 353.98 bc | 332.38 bc | 348.10 bc |
| **LBR + FTH** | 403.18 a | 407.35 a | 405.29 a | 403.78 a |
| **Control** | 310.80 c | 326.66 c | 310.82 c | 321.36 c |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

The same direction of the obtained result was reported also by Koblet *et al.,*(1994) who found the berry weight of 'Pinot noir' grapes decreased with increasing level of leaf removal. In addition, the same observation has been shown before by Sidahmed and Kliewer (1980) in 'Thompson Seedless' grapes.

On the other hand, Vargas (1984) cleared out that tipping (removal of 15 cm of the shoot apex) plus removal of lateral shoots for 'Alphonse Lavallee' and 'Cardinal' grapes decreased average berry weight by 14% in both cultivars compared with control. Moreover, Williams *et al.,* (1987) concluded that leaf removal had no significant effect on berry weight of 'Thompson Seedless' grapes.

Meanwhile, Zoecklein *et al.* (1992) proved that leaf removal did not affect berry weight in 'Chardonnay' and 'White Riesling' grapevines.

Reynolds *et al.* (1996 a) proved that basal leaf removal had no significant effect on berry weight of 'Riesling' vines. The same trend was found also by Main and Morris

(2004) who claimed that leaf removal treatments had no effect on berry weight of 'Cynthiana' grapes.

Although, it is worth noting that decreases in berry weight have been observed in response to basal leaf removal and high fruit exposure in 'Gewürztraminer' grapevines (Reynolds and Wardle 1989 a, Reynolds and Wardle 1989 b, Reynolds *et al.* 1989). The same trend has been found in 'Seyval Blanc' grapevines (Reynolds *et al.* 1986), in 'Pinot noir' vines (Candolfi-Vasconcelos and Koblet, 1990), in 'Caberent Sauvignon' grapevines (Hunter *et al.* 1991) and in 'Sovereign Coronation' table grapes (Reynolds *et al*. 2006).

Also, this trend has been found by Poni *et al.* (2006) showed that shoots trimming to nod 6 and lateral retaining reduced berry weight of cultivars 'Sangiovese' and 'Trebbiano' grapes.

The effect of the defoliation on the berry weight and size has been reported by many authors. In this respect, Koblet (1984) who stated that the light intensity required for maximum photosyntheis ranges from 30 000 to 50 000 lx. Since leaves in the canopy interior don't receive sufficient light, shoot positioning and leaf removal are important in canopy management. Young and old leaves produce less sugar than mature leaves. Light and temperature also influence bud fertility. Temperature has a positive influence on grape quality during ripening. Well-exposed fruits contain more sugar and less acid than poorly exposed.

Moreover, English *et al.* (1990) confirmed that removing basal leaves slightly changed temperature, atmospheric humidity, wind speed, and leaf wetness around grape clusters.

Also, Hunter *et al.* (1995) who concluded that the more shaded interior of non-defoliated vines probably also impeded nutrient supply from the leaves to the buds, decreasing bud fertility and bud capacity.

### 4.7.5 Berry softening, firmness and adherence

Table 58 clears the effect of defoliation treatment and the fruit thinning on the juice weight, volume and percentage in the 'Crimson Seedless' grape berries.

It become clarified from the results that the treatment of leaf basal removal + fruit thinning gave the highest juice weigh and volume followed by the other defoliation treatments.

Table (58): Effect of canopy management practices on juice weight, volume and berry juice % of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Juice weight of 100 berries (g)** | | **Juice volume of 100 berries ($cm^3$)** | | **Berry juice (%)** | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **2004** | **2005** | **2004** | **2005** |
| **LBR** | 254.48 b | 263.53 b | 248.97 b | 258.27 b | 73.38 c | 74.41 a |
| **LBR + H** | 265.74 b | 280.22 b | 267.09 b | 274.95 b | 74.70 bc | 75.74 a |
| **LBR + SSR** | 267.01 b | 274.13 b | 261.27 b | 268.65 b | 73.71 bc | 74.88 a |
| **LBR + H + SSR** | 255.91 b | 270.80 b | 251.69 b | 265.70 b | 75.63 ab | 76.58 a |
| **LBR + FTH** | 310.13 a | 312.81 a | 302.54 a | 307.63 a | 76.90 a | 76.79 a |
| **Control** | 219.25 c | 231.37 c | 214.51 c | 225.78 c | 70.55 d | 70.87 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

These results related to the effect of defoliation treatments, which gave more exposure for the berries to the light and temperature that caused berry softening in defoliated berries than non-defoliated berries. The juice weight, volume and percentage increased as the berry softening increased.

The results of berry firmness and adherence in Table 59 confirmed the same effect of defoliation on the berry softening as a result to exposure the berries to the light and temperature.

Also, the berry firmness affected by the level of defoliation. The treatment of LBR + H + SSR, which considered the excessive defoliation gave the lowest berry firmness compared with the other defoliation treatment.

All defoliation treatments had less berry firmness than the control. This means the defoliation treatments had more ripe berries than the control. As well as, the defoliation treatments contribute in the ripening of berries and it accelerated the ripening process.

Table (59): Effect of canopy management practices on berry firmness and adherence of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Berry firmness (g/berry) | | Berry adherence (g) | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 4072 b | 4002 b | 655 b | 617 b |
| **LBR + H** | 3946 bc | 3886 bc | 612 bc | 597 bc |
| **LBR + SSR** | 3969 b | 3917 b | 641 bc | 602 b |
| **LBR + H + SSR** | 3718 c | 3658 c | 606 bc | 587 bc |
| **LBR + FTH** | 4008 b | 3941 b | 594 c | 552 c |
| **Control** | 4346 a | 4277 a | 765 a | 681 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

### 4.7.6 TSS % and acidity

The results presented in Table 60 show the effect of canopy management on the total soluble solids percentage (T.S.S %), acidity and TSS/acid ratio in the berries of 'Crimson Seedless' red table grape. It is appeared from the results that all of defoliation treatments increased the total soluble solids (T.S.S %), and TSS /acid ratio and decreased the acidity in the berries of 'Crimson Seedless' grape.

Defoliation treatments increased the exposure of the berries to the light and temperature that accumulated more sugar in the berries. So, the total soluble solids in the berries increased due to the exposure for the light and temperature.

Furthermore, leaf removal treatments increased the light penetration into the canopy that reflected on the berry maturity, which was associated with decreased acidity in the berries.

Table (60): Effect of canopy management practices on T.S.S, acidity and T.S.S/ acid of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | T.S.S (%) | | Acidity (g/100 ml juice) | | T.S.S /acid ratio | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 21.7 a | 21.8 a | 0.636 b | 0.623 b | 34.12 a | 34.93 a |
| **LBR + H** | 21.9 a | 22.2 a | 0.628 b | 0.620 b | 34.84 a | 35.65 a |
| **LBR + SSR** | 21.6 a | 22.0 a | 0.645 b | 0.619 b | 33.46 a | 35.54 a |
| **LBR + H + SSR** | 20.8 a | 21.3 a | 0.624 b | 0.635 b | 33.34 a | 33.72 a |
| **LBR + FTH** | 21.2 a | 21.4 a | 0.618 b | 0.626 b | 34.30 a | 34.16 a |
| **Control** | 18.1 b | 18.6 b | 0.731 a | 0.731 a | 26.06 b | 26.40 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Many investigators explained the effect of leaf removal on the TSS % and acidity of grape berry, who found that sunlight-exposed fruits are generally greater in total soluble solids and lower in titratable acidity, compared to nonexposed or canopy shaded (Smart *et al*. 1985, Crippen and Morrison 1986 a, Crippen and Morrison 1986 b, Reynolds *et al*. 1986, Dokoozlian and Kliewer 1995, Jackson and Lombard 1993, Bergquvist *et al.* 2001, Ferree *et al.* 2004, Kliewer and Dokoozlian 2005, Santesteban and Royo 2006).

Also, Koblet (1984) claimed that since leaves in the canopy interior don't receive sufficient light, shoot positioning and leaf removal are important in canopy management. Young and old leaves produce less sugar than mature leaves.

In addition, Reynolds *et al.* (2006) mentioned that basal leaf removal delayed berry maturity slightly but increased light penetration into the canopy. Increased berry maturity was associated with decreased titrable acidity of 'Sovereign Coronation' table grapes.

As shown from the results, defoliation treatments are considered to be very important canopy management practices since they improve TSS and decrease acidity. Irrespective of their effect on the berry weight, dimensions, volume, juice weight, juice volume, firmness, and adherences, rising of total soluble solids and decreasing the acidity are the major target for the grape production. So, the leaf removal practices are prominent tools to improve the quality.

The obtained result is in the trend of Mansfield and Howell (1981) who found that leaf removal for ‘Concord’ grapevines accumulated more sugar and had significantly higher soluble solids than the other treatments in harvest, probably due to the small amount of fruits and the improved exposure of leaves.

Also, Bledsoe *et al.* (1988) found that the total soluble solids were significantly higher in fruit from vines with leaves removed. Titratable acidity, malic acid, pH, and juice potassium concentration were all significantly reduced by leaf removal. Increased severity of leaf removal further reduced the pH and potassium concentration in the berry juice at harvest. Earlier leaf removal tended to advance sugar accumulation. Also, Palliotti and Cartechini (2000) mentioned that early heading improved TSS of ‘Caberent Sauvignon’ grapes. Moreover, Reynolds *et al.* (2005 b) noticed that early shoot-thinning treatments on ‘Pinot noir’ resulted in increased soluble solids and titrable acidity in berries. Also, they found that early shoot-thinning treatments on ‘Cabernet Franc’ grapes generally resulted in higher soluble solids and lower titrable acidity in berries.

The same trend was found by Wolf *et al.,* (1990) who noticed that shoot resulted in soluble solids concentration was greatest by topping of ‘White Riesling’ grapevines and it reduced also the acidity in berries than the untreated vines during three years of this study. Meanwhile, Reynolds and Wardle (1989 c) who stated that TSS increased by increasing severity of summer hedging for ‘de Chaunac’ vines in the first and third years, however, TSS decreased by the same treatments in the second season. The summer hedging reduced the acidity in the second and third years but had not effect in the first year. In addition, Main and Morris (2004) ensured that leaf removal treatments did not affect soluble solids of ‘Cynthiana’ grapes during two seasons, but in the third season defoliated vines had higher TSS.

Wolf *et al.,* (1986) on young ‘chardonnay’ grapevines, Main and Morris (2004) on ‘Cynthiana’ grapes and Fox (2006) on ‘Blauburgunder Samtrot‘ grapes concluded titratable acidity reduced by leaf removal treatments compared to no leaf removal (the untreated vines).

As well as, Reynolds *et al.,* (1996 a) on ‘Riesling’ vines observed that basal leaf removal reduced TSS and acidity.

In addition, Ezzahouni and Williams (2003) on ‘Ruby Seedless’ grapes found an increase in TSS (7.3 %) and decrease in titratable acidity as affected by the defoliation treatments.

On the other side, Sidahmed and Kliewer (1980) and Williams *et al.* (1987) who found that defoliation had no significant effect on soluble solids and titratable acidity in ‘Thompson Seedless’ grapes. The same result on ‘Pinot noir’ grapevines has been reported by Howell *et al.* (1994). Also, Percival *et al.* (1994) found the similar findings in ‘Riesling’ grapes, Kingston and Van Epenhuijsen (1989) on ‘Italia’ grapevines found also this similar trend.

In contrast, Hunter *et al.* (1995) noticed that partial defoliation had no effect on total soluble solids accumulation in the fruit of ‘Cabernet Sauvignon’ grapes, but increased acidity. Furthermore, Reynolds *et al.* (1996 b) who claimed that leaf removal for ‘Gewürztraminer’ grapevines produced berries with lowest TSS and highest titratable acidity. Also, Naor and Gal (2002) reported that TSS of ‘Sauvignon blanc’ grapes increased with increasing leaf area per gram of fruit. No consistent effect of the defoliation treatments was apparent in the three-experimental years.

On the other hand, the results are disagreement with the findings of El-Ghany (2000) who found that Shoot tipping for ‘Thompson Seedless’ grapevines had no effect on acidity.

Moreover, Candolfi-Vasconcelos and Koblet (1990) noticed that removing all main leaves 2 weeks after full bloom for 'Pinot Noir’ grapevines decreased TSS. Also, the same treatment reduced the acidity, whereas the other leaf removal treatments had no effect on TSS or acidity. In addition, Zoecklein *et al.* (1992) found that leaf removal reduced TSS in ‘Chardonnay’ and ‘White Riesling’ grapes and leaf removal generally reduced fruit titratable acid.

Also, Koblet *et al.* (1994) stated that TSS decreased with increasing defoliation, however, the defoliation treatments had not effect on acidity of 'Pinot noir' grapes.

The results are in contrary to those mentioned by Poni *et al.* (2006) on cultivars 'Sangiovese' and 'Trebbiano' as well as Vasconcelose and Castagnoli (2000) on 'Pinot noir' grapes, who claimed that shoot trimming decreased TSS.

#### 4.7.7 Sugar fractions

The sugars fraction of 'Crimson Seedless grapes included 4 components, glucose, fructose, sorbitol and unknown sugar.

Tables 61 and 62 show the sugars fraction of 'Crimson Seedless' grapes as affected by the defoliation and fruit thinning treatments during two seasons. It is obvious from the results that the berries of defoliated vines had higher amount of glucose and fructose than non-defoliated vines.

Table (61): Effect of canopy management practices on the glucose and fructose fraction of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Glucose (mg/g fresh weight )** | | **Fructose (mg/g fresh weight )** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 103.34 a | 113.68 a | 118.69 a | 128.32 a |
| **LBR + H** | 100.89 a | 117.13 a | 107.08 a | 126.00 a |
| **LBR + SSR** | 117.23 a | 107.36 a | 121.88 a | 119.00 a |
| **LBR + H + SSR** | 122.89 a | 120.57 a | 130.74 a | 136.62 a |
| **LBR + FTH** | 95.97 a | 102.93 a | 112.74 a | 118.70 a |
| **Control** | 73.67 b | 83.61 b | 90.38 b | 101.35 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

In the second season, defoliated treatments had the highest value of sorbitol (Table 62). However, in the first year, LBR + H + SSR and LBR + SSR had a higher amount of sorbitol compared to the untreated vines. Also, No significant differences were found between the other defoliation treatments and the control.

There were no significant differences between the leaf removal treatments and the control in the concentration of the unknown sugar (Table 62).

The results are parallel with those found by Hunter *et al.* (1991) who confirmed that the concentration of glucose and fructose were mostly higher in partial defoliated 'Cabernet Sauvignon' grapes than non-defoliated vines.

Table (62): Effect of canopy management practices on the sorbitol and unknown sugar fraction of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Sorbitol (mg/g fresh weight )** | | **Unknown sugar (mg/g fresh weight )** | |
|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 |
| **LBR** | 16.81 ab | 26.01 a | 5.13 a | 1.20 a |
| **LBR + H** | 17.43 ab | 15.08 a | 5.46 a | 4.05 a |
| **LBR + SSR** | 34.84 a | 22.60 a | 10.48 a | 2.07 a |
| **LBR + H + SSR** | 31.71 a | 30.92 a | 7.34 a | 9.1 a |
| **LBR + FTH** | 15.27 ab | 22.55 a | 8.52 a | 2.07 a |
| **Control** | 13.70 b | 6.89 b | 4.48 a | 4.81 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning.

**Control =** untreated vines.

Zoecklein *et al.* (1992) found that the fruit glucose/fructose ratio did not vary between leaf removal and control vines in ‘Chardonnay’ grapes during the first season, however, in ‘Riesling’ grapevines, the berries had a lower glucose/fructose than the control. In the second season, there were no differences in fruit glucose/fructose ratio between leaf removal and control vines in ‘Riesling’ grapes. Whereas, they found that ‘Chardonnay’ berries had higher glucose/fructose ratio in the leaf removal vines than the control.

In addition to Main and Morris (2004) who studied the effect of leaf removal treatments (none, east side, and both sides) on sugars fraction in ‘Cynthiana’ grapes during three seasons. In the first season, there were no differences between the treatments. In the second season, leaf removal on both sides resulted in berries with less glucose and fructose than other treatments. In the last year of study, the leaf removal treatments (east side, and both sides) had juice with more glucose and fructose than the untreated vines (no leaf removal).

## 4.7.8 Phenolic compounds

### 4.7.8.1 Phenolic acids

Tables 63 and 64 present the effect of defoliation and the berry thinning on the phenolic acids in the skin of ‘Crimson seedless’ grapes during 2004 and 2005.

Table 63 shows that caffeoyltartaric acid was affected by defoliation treatments in the second year. The treatment of basal leaf removal plus thinned cluster had a higher amount than the two defoliation treatments leaf basal removal or leaf basel removal plus sterile shoot removal as well as than the control.

No significant differences were between the treatments in the first year and the mean of the two years.

Concerning the hydroxycinnamic acid (1), the second season and the mean of the two years indicated that LBR + FTH had a higher amount than the other defoliation treatments and the control.

However, in the first season, there was no significant difference between LBR + FTH and the control, but there was different between LBR + FTH and LBR + H + SSR, whereas the LBR + FTH had a higher amount of hydroxycinnamic acid (1) than LBR + H + SSR.

Table (63): Effect of canopy management practices on caffeoyltartaric acid and hydroxycinnamic acid (1) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Caffeoyltartaric acid (mg/kg) | | | hydroxycinnamic acid (1) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 4.86 a | 2.27 b | 3.56 a | 1.42 ab | 1.44 b | 1.43 b |
| **LBR + H** | 3.04 a | 4.15 ab | 3.59 a | 2.82 ab | 1.64 b | 2.23 b |
| **LBR + SSR** | 2.67 a | 2.06 b | 2.36 a | 1.60 ab | 2.39 b | 1.99 b |
| **LBR + H + SSR** | 3.70 a | 4.85 ab | 4.28 a | 1.03 b | 2.38 b | 1.71 b |
| **LBR + FTH** | 2.63 a | 9.43 a | 6.03 a | 3.65 a | 6.32 a | 4.99 a |
| **Control** | 2.18 a | 2.60 b | 2.39 a | 2.16 ab | 3.21 b | 2.69 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control =** untreated vines.

In 2005, LBR + FTH had a higher content of hydroxycinnamic acid (1) than LBR, LBR + SSR and the control.

Table 64 shows the influence of the canopy management practices and fruit thinning on the hydroxycinnamic acid (2) and the total hydroxycinnamic acids during two periods.

The hydroxycinnamic acid (2) did not affect by the defoliation treatments during this study.

Total hydroxycinnamic acids was affected by LBR + FTH than the other defoliation treatments and the control in the second season. The mean of two years indicated that the other leaf removal treatments had no effect on the total hydroxycinnamic acids during this study.

Table (64): Effect of canopy management practices on hydroxycinnamic acid (2) and total hydroxycinnamic acids in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Hydroxycinnamic acid (2) (mg/kg)** | | | **Total Hydroxycinnamic acids (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 2.54 a | 2.13 a | 2.33 a | 8.82 a | 5.83 b | 0.94 b |
| **LBR + H** | 3.33 a | 2.36 a | 2.84 a | 9.20 a | 8.14 b | 0.87 b |
| **LBR + SSR** | 1.89 a | 2.20 a | 2.04 a | 6.16 a | 6.65 b | 1.50 b |
| **LBR + H + SSR** | 2.49 a | 2.48 a | 2.49 a | 7.22 a | 9.71 b | 2.05 b |
| **LBR + FTH** | 2.49 a | 3.91 a | 3.20 a | 8.77 a | 19.66 a | 3.21 a |
| **Control** | 1.47 a | 2.56 a | 2.02 a | 5.81 a | 8.36 b | 1.50 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control =** untreated vines.

#### 4.7.8.2 Stilbene derivatives

Tables 65 and 66 exhibit the impact of canopy management and fruit thinning on stilbene derivatives during two seasons.

Table 65 shows that LBR + H + SSR had a higher amount of *cis*-piceid than the LBR + FTH in 2004. There were no significant differences between the defoliation treatments and the control. In the second year, defoliation treatments had the highest amount of *cis*-piceid. The mean of the two seasons shows that LBR + FTH had the lowest concentration of *cis*-piceid. No significant difference was between the other leaf removal treatments and the control.

Regarding the effect of the defoliation treatment on the *trans*-piceid in the, there was no difference between leaf removal treatments and the control in the first season.

Table (65): Effect of canopy management practices on *cis*-piceid and *trans*-piceid in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | *cis*-Piceid (mg/kg) | | | *trans*-Piceid (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 2.09 ab | 1.09 b | 1.59 ab | 1.36 a | 1.12 b | 1.24 bc |
| **LBR + H** | 1.58 ab | 1.33 b | 1.45 ab | 1.40 a | 1.37 b | 1.38 bc |
| **LBR + SSR** | 1.04 ab | 1.31 b | 1.18 ab | 2.39 a | 6.44 ab | 4.41 ab |
| **LBR + H + SSR** | 2.22 a | 1.56 b | 1.89 ab | 3.87 a | 0.86 b | 2.37 bc |
| **LBR + FTH** | 0.40 b | 1.22 b | 0.81 b | 4.06 a | 8.52 a | 6.29 a |
| **Control** | 1.40 ab | 4.00 a | 2.70 a | 0.00 a | 0.07 b | 0.03 c |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control =** untreated vines.

In the second season, LBR + FTH had a higher concentration of *trans*-piceid than the other defoliation treatments and the control, except LBR + SSR.

The mean of the two seasons pointed out that the LBR + FTH had the highest amount of *trans*-piceid than the other defoliation treatments, except LBR + SSR.

Also, the mean indicated that LBR + FTH and LBR + SSR produced the highest amount than the control. No significant difference was between the other defoliation treatments and the control.

Table 66 shows the effect of defoliation and the fruit thinning on resveratrol in the skin of 'Crimson seedless' grapes during two periods. In the first year, LBR + SSR and LBR + H + SSR produced resveratrol. LBR + SSR had a higher content of resveratrol than LBR + H + SSR. LBR + H + SSR had non-significant amount compared to the other treatments.

Table (66): Effect of canopy management practices on resveratrol and total stilbenes in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Resveratrol (mg/kg)** | | | **Total stilbenes (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 0.00 b | 2.48 a | 1.24 ab | 3.45 a | 4.69 a | 4.07 ab |
| **LBR + H** | 0.00 b | 0.00 a | 0.00 b | 2.97 a | 2.70 a | 2.83 b |
| **LBR + SSR** | 2.98 a | 1.01 a | 1.99 a | 6.41 a | 8.76 a | 7.58 a |
| **LBR + H + SSR** | 0.76 b | 0.00 a | 0.38 ab | 6.85 a | 2.42 a | 4.64 ab |
| **LBR + FTH** | 0.00 b | 0.00 a | 0.00 b | 4.46 a | 9.73 a | 7.09 ab |
| **Control** | 0.00 b | 0.00 a | 0.00 b | 1.40 a | 4.07 a | 2.73 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

In the second year, LBR and LBR + SSR had resveratrol with non-significant amount compared to the other treatments.

The mean of this study confirmed that LBR + SSR had a significant amount compared to the other defoliation treatments and the control, except LBR + H and LBR+ H+ SSR.

The mean of this study claimed that LBR + SSR had the highest content of total stilbenes compared to LBR + H and the control. Moreover, the mean concluded that there were no significant differences in total stilbene between the other defoliation treatments and the control.

#### 4.7.8.3 Flavonols

Tables 67-70 present the effect of canopy management and fruit thinning on the flavonols in the skin of 'Crimson Seedless' grapes during 2004 and 2005. Flavonols were not affected by defoliation treatments in the first season, except flavonol (4).

Table (67): Effect of canopy management practices on quercetin - 3 glucoside and kaempfrol - 3 glucoside in berry skin of 'Crimson seedless' grape in 2004 and 2005.

| Treatments | Quercetin 3-glucoside (mg/kg) | | | Kaempfrol 3-glucoside (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| LBR | 86.28 a | 146.73 ab | 116.51 ab | 6.21 a | 18.03 ab | 12.12 ab |
| LBR + H | 171.53 a | 119.48 ab | 145.50 ab | 15.37 a | 8.16 ab | 11.77 ab |
| LBR + SSR | 100.13 a | 311.67 a | 205.90 ab | 9.32 a | 39.16 a | 24.24 ab |
| LBR + H + SSR | 261.71 a | 69.45 ab | 165.58 ab | 32.41 a | 6.58 b | 19.50 ab |
| LBR + FTH | 347.60 a | 257.91 ab | 302.75 a | 33.74 a | 24.39 ab | 29.06 a |
| Control | 21.76 a | 44.50 b | 33.13 b | 0.94 a | 4.09 b | 2.51 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

LBR + SSR had a higher amount of quercitin 3-glocoside than the control in the second season. The mean of the two years indicated that LBR + FTH had a higher amount than the control. No significant differences were between the other defoliation treatments and the control (Table 67).

Kaempfrol 3-glucoside was affected by LBR + SSR in the second season (Table 67). No significant different were between the other defoliation treatments and the control. The mean of two seasons concluded that LBR + FTH improved kaempfrol 3-glucoside.

LBR + SSR had a higher value of flavonol (1) than the other treatments in the second year, except LBR + FTH (Table 68).

The mean of two years confirmed that LBR + FTH had the highest concentration of unknown flavonol (1) than the control. There were no significant differences between the other defoliation treatments and the control.

Table (68): Effect of canopy management practices on flavonol (1) and flavonol (2) in the skin of ‘Crimson Seedless’ grape in 2004 and 2005.

| **Treatments** | **Flavonol (1) (mg/kg)** | | | **Flavonol (2) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 1.50 a | 3.47 b | 2.49 ab | 8.84 a | 16.72 ab | 12.78 ab |
| **LBR + H** | 2.11 a | 1.10 b | 1.61 ab | 19.89 a | 12.39 ab | 16.14 ab |
| **LBR + SSR** | 2.54 a | 10.93 a | 6.74 a | 12.73 a | 43.98 a | 28.36 a |
| **LBR + H + SSR** | 5.67 a | 1.18 b | 3.42 ab | 34.32 a | 6.28 b | 20.30 ab |
| **LBR + FTH** | 7.03 a | 4.94 ab | 5.98 a | 37.34 a | 27.23 ab | 32.29 a |
| **Control** | 0.21 a | 0.57 b | 0.39 b | 1.82 a | 6.97 b | 4.40 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan’s multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Concerning flavonol (2), LBR + SSR had a higher content than LBR + H + SSR and the control in the second season. The mean of two seasons claimed that both LBR + SSR and LBR + FTH had the highest amount of flavonol (2) than the untreated vines.

It appeared from Table 69, flavonol (3) did not affect by defoliation and fruit thinning treatments during 2 years.

Regarding flavonol (4), LBR + FTH had the highest value compared to the untreated vines in the first year (Table 69). No significant value was between the other defoliation treatments and the untreated vines. In the second year, flavonol (4) did not affect by defoliation and fruit thinning treatments. The mean confirmed the same result of the first year.

Table (69): Effect of canopy management practices on flavonol (3) and flavonol (4) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Flavonol (3) (mg/kg)** | | | **Flavonol (4) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 21.51 a | 23.71 a | 22.61 a | 1.68 ab | 4.86 a | 3.27 ab |
| **LBR + H** | 34.53 a | 27.15 a | 30.84 a | 3.79 ab | 2.04 a | 2.91 ab |
| **LBR + SSR** | 28.20 a | 96.30 a | 62.25 a | 2.78 ab | 10.27 a | 6.52 ab |
| **LBR + H + SSR** | 51.32 a | 19.23 a | 35.28 a | 8.75 ab | 1.68 a | 5.21 ab |
| **LBR + FTH** | 45.08 a | 53.60 a | 49.34 a | 11.28 a | 7.36 a | 9.32 a |
| **Control** | 15.71 a | 58.78 a | 37.25 a | 0.36 b | 1.60 a | 0.98 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

In Table 70, flavonol (5) was affected by the canopy management and fruit thinning treatments in the second season. Both LBR + H and BLR + FTH had the highest content than the untreated vines.

The mean shows 3 defoliation treatments affected flavonol (5) LBR + H, LBR + H + SSR and BLR + FTH. It showed also that total flavonols were affected by LBR + FTH.

Table (70): Effect of canopy management practices on flavonol (5) and total flavonols in the skin of 'Crimson seedless' grape in 2004 and 2005.

| **Treatments** | Flavonol (5) (mg/kg) | | | Total flavonols (mg/kg) | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 9.44 a | 10.17 ab | 9.80 ab | 135.46 a | 223.69 a | 179.58 ab |
| **LBR + H** | 15.87 a | 18.75 a | 17.31 a | 263.09 a | 189.08 a | 226.08 ab |
| **LBR + SSR** | 9.45 a | 11.17 ab | 10.31 ab | 165.16 a | 523.48 a | 344.32 ab |
| **LBR + H + SSR** | 19.52 a | 9.94 ab | 14.73 a | 413.71 a | 114.34 a | 264.02 ab |
| **LBR + FTH** | 18.14 a | 20.60 a | 19.37 a | 500.21 a | 396.03 a | 448.12 a |
| **Control** | 1.30 a | 0.94 b | 1.12 b | 42.09 a | 117.45 a | 79.77 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

#### 4.7.8.4 Flavan 3-ols

Table 71 shows the influence of defoliation treatments on procyanidin B2. The second year as well as the mean of this study indicated that B2 was higher by LBR + FTH than the other defoliation treatments and non-defoliated vines.

There were no differences in B2 content between the other defoliation treatments and untreated vines during this study.

Epicatechin did not affected by leaf removal or fruit thinning treatments during this study (Table 71).

Table 72 exhibit the effect of leaf removal treatments and fruit thinning on the content of proanthocyanidins (1) and proanthocyanidins (2).

Table (71): Effect of canopy management practices on B2 and epicatechin in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **B2 (mg/kg)** | | | **Epicatechin (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| LBR | 0.96 a | 0.93 b | 0.94 b | 0.76 a | 0.53 a | 0.64 a |
| LBR + H | 1.74 a | 0.94 b | 1.34 b | 1.40 a | 1.63 a | 1.51 a |
| LBR + SSR | 1.22 a | 1.78 b | 1.50 b | 1.05 a | 0.57 a | 0.81 a |
| LBR + H + SSR | 1.89 a | 2.21 b | 2.05 b | 1.06 a | 2.70 a | 1.88 a |
| LBR + FTH | 1.99 a | 4.43 a | 3.21 a | 1.00 a | 1.79 a | 1.40 a |
| Control | 0.89 a | 2.11 b | 1.50 b | 0.60 a | 0.62 a | 0.61 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

LBR + FTH produced proanthocyanin (1) with non-significant amount in the first season (Table 72).

In the second season, 3 defoliation treatments produced also proanthocyanin (1) which were LBR + H, LBR + SSR and LBR + FTH.

LBR + FTH produced a significant amount of proanthocyanin in 2005.

The mean of two years indecated that LBR + FTH had the highest value of proanthocyanin (1).

Concerning the proanthocyanin (2), LBR + FTH had the highest value in the two seasons of this study (Table 72)..

Table (72): Effect of canopy management practices on proanthcyanin (1) and proanthocyanin (2) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Proanthocyanidin (1) (mg/kg) | | | Proanthocyanidin (2) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| LBR | 0.00 a | 0.00 b | 0.00 b | 0.00 b | 0.00 b | 0.00 b |
| LBR + H | 0.00 a | 0.15 b | 0.07 b | 0.35 ab | 0.42 b | 0.39 b |
| LBR + SSR | 0.00 a | 0.42 b | 0.21 b | 0.08 b | 0.81 ab | 0.45 b |
| LBR + H + SSR | 0.00 a | 0.00 b | 0.00 b | 0.21 b | 0.00 b | 0.10 b |
| LBR + FTH | 0.15 a | 0.48 a | 0.31 a | 1.11 a | 2.08 a | 1.60 a |
| Control | 0.00 a | 0.00 b | 0.00 b | 0.00 b | 0.00 b | 0.00 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Table 73 shows the effect of leaf removal and fruit thinning treatments on the concentration of proanthocyanin (3) and proanthocyanin (4).

In the first season, there was not difference in the content of proanthocyanin (3) between all treatments.

In the second season, all treatments reduced the concentration of proanthocyanin (3). The mean of this study confirmed this result.

Proanthocyanin (4) was affected by canopy management practices in the second year. LBR + FTH had a higher content than LBR. No significant difference was between treatments and the untreated grapevines. The mean of two years confirmed also this result.

Table (73): Effect of canopy management practices on proanthocyanin (3) and proanthocyanin (4) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Proanthocyanin (3) (mg/kg) | | | proanthocyanin (4) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 1.22 a | 0.97 b | 1.09 b | 1.58 a | 1.32 b | 1.45 b |
| **LBR + H** | 2.16 a | 2.29 b | 2.23 b | 2.07 a | 2.33 ab | 2.20 ab |
| **LBR + SSR** | 1.62 a | 2.77 b | 2.20 b | 0.97 a | 2.69 ab | 1.83 b |
| **LBR + H + SSR** | 1.71 a | 2.20 b | 1.95 b | 1.91 a | 2.09 ab | 2.00 ab |
| **LBR + FTH** | 1.78 a | 10.52 a | 6.15 a | 1.76 a | 5.52 a | 3.64 a |
| **Control** | 2.11 a | 2.18 b | 2.15 b | 1.72 a | 2.94 ab | 2.33 ab |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control =** untreated vines.

Table 74 shows that LBR + FTH enhanced the concentration of proanthocyanin (5) compared to the other treatments in the second season. The same result has been concluded by the mean of this study.

There were not significant differences in the content of proanthocyanin (6) between all treatments during the two seasons of this study (table 74).

The results in Table 75 indicate that proanthocyanin (7) affected by the treatments in the second year. LBR + FTH produced a higher concentration than LBR. There were not significant differences between the defoliation treatments and untreated vines. The mean of this study concluded that LBR + FTH had the highest amount of proanthocyanin (7).

Table (74): Effect of canopy management practices on proanthocyanin (5) and proanthocyanin (6) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Proanthocyanin (5) (mg/kg) | | | Proanthocyanin (6) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| LBR | 0.90 a | 1.07 b | 0.98 b | 2.94 a | 1.08 a | 2.01 a |
| LBR + H | 1.10 a | 0.97 b | 1.03 b | 1.68 a | 1.98 a | 1.83 a |
| LBR + SSR | 0.70 a | 0.96 b | 0.83 b | 1.27 a | 2.30 a | 1.78 a |
| LBR + H + SSR | 1.13 a | 1.03 b | 1.08 b | 1.58 a | 2.11 a | 1.84 a |
| LBR + FTH | 1.26 a | 2.72 a | 1.99 a | 1.78 a | 2.34 a | 2.06 a |
| Control | 1.24 a | 1.44 b | 1.34 ab | 1.27 a | 2.85 a | 2.06 a |

Table (75): Effect of canopy management practices on proanthocyanin (7) and proanthocyanin (8) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Proanthocyanin (7) (mg/kg) | | | Proanthocyanin (8) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| LBR | 4.09 a | 3.01 b | 3.55 b | 4.11 a | 4.31 a | 4.21 ab |
| LBR + H | 7.27 a | 5.86 ab | 6.57 b | 5.50 a | 7.01 a | 6.26 ab |
| LBR + SSR | 2.76 a | 6.44 ab | 4.60 b | 2.25 a | 3.64 a | 2.94 b |
| LBR + H + SSR | 4.94 a | 7.03 ab | 5.99 b | 5.10 a | 12.13 a | 8.61 a |
| LBR + FTH | 6.26 a | 13.58 a | 9.92 ab | 4.55 a | 8.50 a | 6.53 ab |
| Control | 4.14 a | 6.24 ab | 5.19 b | 3.28 a | 4.65 a | 3.97 ab |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Concerning to the proanthocyanin (8), there were not differences was between the treatments in 2004 and 2005 but the mean of the two years confirmed that LBR + H + SSR had a higher concentration than LBR + SSR and no differences were found between the other treatments.

In Table 76, proanthocyanin (9) was not affected by defoliation treatments in 2004 and 2005 but the mean indicated that LBR + H + SSR had a higher amount than both LBR and LBR + SSR. No significant differences were between the other treatments .

Total flavan 3-ols were affected by defoliation treatments in 2005 (Table 76). LBR + FTH produced a higher value than LBR. No differences were between the other treatments. The mean of this study claimed that LBR+ FTH had a higher amount than LBR, LBR + SSR, and untreated vines

Table (76): Effect of canopy management practices on proanthocyanin (9) and total flavan 3-ols in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Proanthocyanin (9) (mg/kg)** | | | **Total flavan 3-ols (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 0.68 a | 0.39 a | 0.53 b | 17.24 a | 13.60 b | 15.42 b |
| **LBR + H** | 1.02 a | 0.87 a | 0.94 ab | 24.29 a | 25.49 ab | 24.89 ab |
| **LBR + SSR** | 0.64 a | 0.68 a | 0.66 b | 12.56 a | 23.05 ab | 17.81 b |
| **LBR + H + SSR** | 1.35 a | 1.28 a | 1.32 a | 18.98 a | 32.78 ab | 25.88 ab |
| **LBR + FTH** | 0.17 a | 1.33 a | 0.75 ab | 21.81 a | 53.28 a | 37.54 a |
| **Control** | 0.56 a | 1.35 a | 0.96 ab | 15.82 a | 24.38 ab | 20.10 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

### 4.7.8.5 Anthocyanins:

10 anthocyanins were detected in 'Crimson Seedless' grapes that are cyanidin 3-gloucose, paeonidin 3-glucose, malvidin 3-gloucose and 7 further anthocyanins.

Table 77 shows the effect of canopy managements on cyanidin 3- glucoside and paeonidin 3-glucoside. LBR + FTH had the highest content of cyanidin 3- glucoside compared with the other defoliation treatments and the untreated vines (except, LBR + H + SSR) in the first year. the mean of this study confirmed these resultes.

Concerning paeonidin 3-glucoside, LBR + H + SSR and LBR + FTH had the highest amount compared to the untreated vines in 2004 (Table 77). In 2005, LBR + H produced a higher amount compared to LBR, LBR + SSR and the untreaded vines.

The mean indicated that LBR + H, LBR + H + SSR and LBR + FTH had the highest value of paeonidin-3-glucose than the untreated vines.

Table (77): Effect of canopy management practices on cyanidin 3-glucoside and paeonidin 3-glucoside in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Cyanidin 3-gloucose (mg/kg)** | | | **Paeonidin 3-glucose (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 10.26 b | 16.25 a | 13.25 b | 110.97 ab | 69.20 b | 90.09 ab |
| **LBR + H** | 19.54 b | 19.19 a | 19.37 b | 255.34 ab | 426.37 a | 340.85 a |
| **LBR + SSR** | 12.62 b | 40.79 a | 26.71 b | 139.99 ab | 91.68 b | 115.83 ab |
| **LBR + H + SSR** | 33.44 ab | 8.61 a | 21.03 b | 445.59 a | 189.49 ab | 317.54 a |
| **LBR + FTH** | 65.62 a | 39.63 a | 52.63 a | 467.90 a | 272.98 ab | 370.44 a |
| **Control** | 1.11 b | 0.81 a | 0.96 b | 7.12 b | 9.86 b | 8.49 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

In Table 78, malvidin 3-glucoside was increased by LBR + H + SSR than both LBR and untreated vines in 2004. In the second period, LBR + FTH followed by LBR + H enhanced the concentration of malvidin 3-gloucose than non-defoliated grapevines in 2005. The mean of the two years concluded that LBR + H + SSR followed by LBR + FTH improved the content of malvidin-3-glucoside in skin berries than the untreated vines.

Defoliation treatments produced anthocyanin (1) compared with the untreated vines during this study (Table 78). In the first season, anthocyanin (1) was produced with significant value by LBR + FTH. The mean of two seasons indicated that both of LBR + H + SSR and LBR + FTH had the highest content compared with the other treatments.

Table (78): Effect of canopy management practices on malvidin 3-glucoside and anthocyanin (1) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Malvidin 3-gloucose (mg/kg) | | | Anthocyanin (1) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 12.98 b | 7.72 bc | 10.35 bc | 0.33 ab | 0.05 a | 0.19 b |
| **LBR + H** | 31.19 ab | 52.84 ab | 42.02 abc | 0.29 ab | 1.16 a | 0.72 ab |
| **LBR + SSR** | 32.70 ab | 10.83 bc | 21.76 abc | 0.58 ab | 0.23 a | 0.41 ab |
| **LBR + H + SSR** | 103.86 a | 34.13 abc | 69.00 a | 1.80 a | 0.70 a | 1.25 a |
| **LBR + FTH** | 47.23 ab | 69.88 a | 58.55 ab | 1.41 ab | 1.13 a | 1.27 a |
| **Control** | 0.00 b | 0.10 c | 0.05 c | 0.00 b | 0.00 a | 0.00 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Defoliation treatments produced also anthocyanin (2) compared to the non-defoliated vines during this study (Table 79). In 2004, LBR + FTH had significant content than the other treatments. No significant values were found between the defoliation treatments and the control in the second year.

The mean of this study claimed that LBR + FTH had significant content of anthocyanin (2) than the other treatments.

Leaf removal treatments produced also anthocyanin (3) compared with the control during this study (Table 79). In the first year, LBR + H + SSR had the highest value. In the second year, LBR + FTH followed by LBR + SSR had the highest amount.

The mean of two periods pointed out that defoliation treatments (except LBR) had the highest content of anthocyanin (3).

Table (79): Effect of canopy management practices on anthocyanin (2) and anthocyanin (3) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Anthocyanin (2) (mg/kg) | | | Anthocyanin (3) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 0.34 b | 0.15 a | 0.25 ab | 0.17 ab | 0.19 bc | 0.18 bc |
| **LBR + H** | 0.24 b | 0.67 a | 0.46 ab | 0.30 ab | 0.28 abc | 0.29 ab |
| **LBR + SSR** | 0.14 b | 0.31 a | 0.22 ab | 0.28 ab | 0.32 ab | 0.30 ab |
| **LBR + H + SSR** | 0.56 b | 0.85 a | 0.71 ab | 0.63 a | 0.07 bc | 0.35 ab |
| **LBR + FTH** | 1.63 a | 0.32 a | 0.97 a | 0.46 ab | 0.50 a | 0.48 a |
| **Control** | 0.00 b | 0.00 a | 0.00 b | 0.00 b | 0.00 c | 0.00 c |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

It is clear from Table 80 that anthocyanin (4) result from the defoliation treatments in the first year. LBR + H + SSR and LBR + FTH had the highest content.

Leaf removal treatments produced anthocyanin (5) during two years (Table 80) and LBR + FTH had the highest concentreation.

Table 81 shows the influence of defoliation treatments on anthocyanin (6). In the first year, LBR + FTH had a higher content compared to LBR, LBR + SSR and untreated vines. In the second season, LBR + FTH followed by LBR + SSR had a higher amount than the non-defoliated grapevines.

The mean confirmed that LBR + FTH followed by LBR + H and LBR + SSR had the highest amount of anthocyanin (6).

Table (80): Effect of canopy management practices on anthocyanin (4) and anthocyanin (5) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Anthocyanin (4) (mg/kg)** | | | **Anthocyanin (5) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 0.30 ab | 0.00 a | 0.15 a | 0.26 bc | 0.19 c | 0.23 cd |
| **LBR + H** | 0.70 ab | 0.00 a | 0.35 a | 0.72 ab | 0.74 ab | 0.73 ab |
| **LBR + SSR** | 0.53 ab | 0.00 a | 0.30 a | 0.44 abc | 0.35 bc | 0.39 bc |
| **LBR + H + SSR** | 0.86 a | 0.00 a | 0.43 a | 0.75 ab | 0.33 bc | 0.54 bc |
| **LBR + FTH** | 1.10 a | 0.00 a | 0.55 a | 0.99 a | 0.93 a | 0.96 a |
| **Control** | 0.00 b | 0.00 a | 0.00 b | 0.00 c | 0.00 c | 0.00 d |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Table 81 exhibit that LBR + FTH and LBR + H + SSR improved concentration of anthocyanin (7) compared with LBR and untreated vines in 2004. In 2005, LBR + FTH and LBR + H produced the highest concentration of anthocyanin (7).

The mean stated that LBR + FTH, LBR + H and LBR + H + SSR had the highest concentration of anthocyanin (7). Moreover, LBR + FTH produced a higher concentration than both LBR and LBR + SSR.

In addition, the hedging (H) treatment improved anthocyanin (7), since LBR + H had a higher amount compared to LBR.

Table 82 shows the effect of leaf removal and fruit thinning treatments on the total anthocyanins in the berries and in skins during two seasons.

Table (81): Effect of canopy management practices on anthocyanin (6) and anthocyanin (7) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Anthocyanin (6) (mg/kg)** | | | **Anthocyanin (7) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 0.91 b | 1.19 bc | 1.05 cb | 2.46 b | 1.93 c | 2.19 cd |
| **LBR + H** | 2.48 ab | 1.83 bc | 2.16 b | 6.95 ab | 8.45 ab | 7.70 ab |
| **LBR + SSR** | 1.76 b | 2.55 b | 2.16 b | 5.44 ab | 2.98 c | 4.21 bcd |
| **LBR + H + SSR** | 2.76 ab | 0.88 bc | 1.82 cb | 9.67 a | 3.65 bc | 6.66 abc |
| **LBR + FTH** | 5.22 a | 4.94 a | 5.08 a | 9.91 a | 10.48 a | 10.19 a |
| **Control** | 0.11 b | 0.08 c | 0.10 c | 0.12 b | 0.13 c | 0.13 d |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Concerning the total anthocyanins in the berry, in the first season, all defoliation treatments had the highest concentration (Table 82). In the second season, LBR + FTH and LBR + H produced the highest content followed by LBR and LBR + H + SSR. There was not difference between LBR + SSR and untreated vines.

The mean of study gave a conclusion that all treatments of leaf removal and fruit thinning improved the concentration of total anthocyanins compared to non-defoliated grapevines.

Also, the defoliation treatments varied in the content of total anthocyanins in berries, whereas, LBR + FTH was the highest one followed by LBR + H and LBR + H + SSR in the last order. LBR + SSR and LBR produced the lowest concentration than the other defoliation treatments.

Table (82): Effect of canopy management practices on total anthocyanins in the berry and skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Total anthocyanins in the berry (mg/kg)** | | | **Total anthocyanins in the skin (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 13.10 a | 10.30 ab | 11.70 c | 138.97 ab | 96.98 b | 117.97 bc |
| **LBR + H** | 13.48 a | 22.37 a | 17.93 b | 317.75 ab | 512.56 a | 415.15 ab |
| **LBR + SSR** | 12.12 ab | 11.65 bc | 11.89 c | 194.48 ab | 150.33 ab | 172.41abc |
| **LBR + H + SSR** | 15.30 a | 13.47 b | 14.39 bc | 599.93 a | 238.95 ab | 419.44 ab |
| **LBR + FTH** | 20.98 a | 27.82 a | 24.40 a | 601.47 a | 401.86 ab | 501.66 a |
| **Control** | 2.26 b | 2.43 c | 2.35 d | 8.46 b | 10.98 b | 9.72 c |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

With regard to the effect of leaf removal on total anthocyanins in the berry skin. In 2004, LBR + FTH and LBR + H + SSR had the highest amount (Table 82). In 2005, LBR + H produced a higher amount than LBR and untreated vines.

The mean of two years confirmed that LBR + FTH had the highest content of total anthocyanins in the skin berry followed by LBR + H and LBR + H + SSR.

LBR + FTH produced a higher value of anthocyanins in the berry skin than LBR. This effect related to the fruit thinning from the cluster.

Generally, LBR + FTH produced the highest concentration of total anthocyanins in the berries and skins because the fruit remaining in the thinned clusters have more exposure to the light and temperature, as a results it ripe more than those in the compacted clusters. Moreover, the lower part of the clusters, which removed by fruit thinning process may be save the carbohydrate to the remaining berries in the thinned clusters and this reflect on the nutrient supply to the remaining fruit and improved the anthocyanins concentration in the berries and skins.

our results are in agreement with those reported by Herrera (2002) who noticed that remove about one-half of each culster (the lower part of the main stem), leaving four or five branches near the cluster's base improved the anthocyanins concentration. The lower part of the cluster is usually compact, and the berries ripen later than those on the upper part and that affected the anthocyanins concentration.

Guidioni *et al.* (2002) confirmed also our results, since they mentioned that the concentration of anthocyanins in ripe berries is affected by cluster exposure to direct sunlight. Moreover, manipulations of plant assimilate partitioning through leaf or cluster removal induce significant modification of the concentration of total anthocyanins.

The result concluded also that defoliation improved the anthocyanins, in this respect, LBR + FTH affected cyanidin 3-glucose. Moreover, LBR + H, LBR + H + SSR , and LBR + FTH impacted peonidin 3-glucose. In addition, LBR + H + SSR followed by LBR + FTH influenced malvidin 3-glucose.

These result were confirmed by Guidioni *et al* (2002) who found that cluster thinning increased the concentration of cyanidin 3-glucoside, paeonidin 3-glucoside and to a lesser extent, petunidin 3-glucoside. But our result are partial different with them since they mentioned that the concentration of malvidin 3-glucoside was not affected by cluster thinning.

Our result claimed the variation between the defoliation treatments related to the exposure of berries to temperature, which varied by different severity of leaf removing.

This result is in accordance with those of Reynolds *et al* (2005 b) found that shoot-thinning treatments on 'Caberent Franc' grapevines resulted in increased color intensity and total anthocyanin.

Reynolds *et al.* (2006) mentioned that basal leaf removal increased color intensity and anthocyanins.

Fox (2006) recorded that the several levels of defoliation for cultivar 'Blauburgunder Samtrot ' grapes improved the anthocyanin.

This result is contrary with the findings of Main and Morris (2004) who stated that total pigment color of 'Cynthiana' grapes was not affected by of leaf removal during two seasons, but in the third year due to warm temperatures, leaf removal treatments had a higher color than no leaf removal.

Our results are also in agreement with those reported by many authors who found that Sunlight-exposed fruits had a higher anthocyanins compared to non-exposed or canopy shaded (Smart *et al*. 1985, Reynolds *et al*. 1986, Dokoozlian and Kliewer 1995, Jackson and Lombard (1993), Bergquvist *et al.* (2001), Ferree *et al.* (2004), Kliewer and Dokoozlian (2005), Santesteban and Royo 2006).

Also, Müller (2004) reported that the foliage pruning considred a very important tool to control grape quality. Partial defoliation is a common foliage pruning technique in Switzerland, however not in Germany. The advantages of this tool are better light use, less Botrytis and hence higher grape qualities, while higher contents of fruit aroma and polyphenols are produced.

### 4.7.8.6 Other phenolic compounds

Tables 83-91 show the effect of canopy management and fruit thinning on phenolic compound in the skin berry of 'Crimson Seedless' grapes during two growing seasons.

In Table 83, in the first season, LBR + H had a higher amount of unknown phenolic compound (1) compared to untreated vines. In the second, LBR + H produced a higher concentration compared with LBR and LBR + SSR.

The mean of the two growing years confirmed that LBR + H enhanced unknown phenolic compound (1) concentration in the berry skin than LBR, LBR + SSR and the untreated vines.

Unknown phenolic compound (2) did not affect in the first season by treatments. The mean of two years confirmed the same result (Table 83). However, In the second season the untreated vines had a higher value of than LBR and LBR + SSR.

Table (83): Effect of canopy management practices on unknown phenolic compound (1) and unknown phenolic compound (2) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (1) (mg/kg)** | | | **Unknown phenolic compound (2) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 5.76 ab | 5.55 bc | 5.65 b | 7.20 a | 5.27 b | 6.23 a |
| **LBR + H** | 14.18 a | 11.10 a | 12.64 a | 11.04 a | 8.85 ab | 9.94 a |
| **LBR + SSR** | 6.78 ab | 3.97 c | 5.38 b | 6.46 a | 5.62 b | 6.04 a |
| **LBR + H + SSR** | 10.94 ab | 8.81 abc | 9.88 ab | 10.04 a | 8.31 ab | 9.18 a |
| **LBR + FTH** | 10.16 ab | 10.09 ab | 10.13 ab | 8.38 a | 9.31 ab | 8.85 a |
| **Control** | 3.82 b | 8.20 abc | 6.01 b | 6.02 a | 10.55 a | 8.28 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Table 84 exhibit the effect defoliation treatments on unknown phenolic compound (3). No significant differences have been found in the first year.

In the second year, with exception of LBR + H + SSR, LBR + FTH had the highest value of unknown phenolic compound (3) than the other treatments and the untreated vines. Also the mean of this study confirmed this result too.

Unknown phenolic compound (4) was not affect by defoliation in the first period. The same result has been found by the mean of the study. Whereas, in the second year, LBR + FTH had the highest concentration compared to the other treatments (except, LBR + H + SSR ) and the untreated grapevines.

Table (84): Effect of canopy management practices on unknown phenolic compound (3) and unknown phenolic compound (4) in the skin of ‘Crimson Seedless’ grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (3) (mg/kg)** | | | **Unknown phenolic compound (4) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 2.26 a | 1.88 b | 2.07 b | 1.89 a | 1.29 b | 1.59 a |
| **LBR + H** | 1.89 a | 2.03 b | 1.96 b | 2.25 a | 2.27ab | 2.26 a |
| **LBR + SSR** | 2.14 a | 1.63 b | 1.89 b | 1.26 a | 1.51 ab | 1.39 a |
| **LBR + H + SSR** | 2.67 a | 2.63 ab | 2.65 ab | 2.55 a | 2.20 ab | 2.38 a |
| **LBR + FTH** | 3.23 a | 4.25 a | 3.74 a | 1.98 a | 3.77 a | 2.88 a |
| **Control** | 0.75 a | 2.15 b | 1.45 b | 1.43 a | 3.23 ab | 2.33 a |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan’s multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Also, unknown phenolic compound (5) was not impact by leaf removal and fruit thinning treatments in the first period. (Table 85). In the second year, LBR + FTH had the highest content compared to the other treatments (except, LBR + SSR).

The mean of study confirmed that LBR + FTH improved the content of unknown phenolic compound (5) compared with the other treatments, (except, LBR + SSR) and untreated vines.

Concerning the unknown phenolic compound (6), it was not affected in the first period, but in the second, LBR + FTH enhanced it than the other treatments and untreated vines (Table 85).

The mean indicated that LBR + FTH enhanced the content of unknown phenolic compound (6) than the other treatments (except, LBR + H) and non-defoliated vines.

Table (85): Effect of canopy management practices on unknown phenolic compound (5) and unknown phenolic compound (6) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (5) (mg/kg)** | | | **Unknown phenolic compound (6) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 1.85 a | 0.87 b | 1.36 b | 1.59 a | 1.23 b | 1.41 b |
| **LBR + H** | 1.67 a | 1.10 b | 1.38 b | 2.83 a | 2.22 b | 2.52 ab |
| **LBR + SSR** | 1.27 a | 2.90 ab | 2.08 ab | 0.98 a | 2.36 b | 1.67 b |
| **LBR + H + SSR** | 1.89 a | 1.31 b | 1.60 b | 1.91 a | 2.09 b | 2.00 b |
| **LBR + FTH** | 2.03 a | 4.07 a | 3.05 a | 2.19 a | 5.37 a | 3.78 a |
| **Control** | 1.17 a | 2.63 ab | 1.90 b | 1.42 a | 2.13 b | 1.77 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

In Table 86, unknown phenolic compound (7) was not influence by canopy management and fruit thinning treatments during this study.

the untreated vines and LBR + H had a higher amount of unknown phenolic compound (8) than LBR + FTH in the second season (Table 86). However, there were not differences between the treatments in the first season.

The mean confirmed that LBR + H and LBR + H + SSR produced a higher concentration of unknown phenolic compound (8) than LBR + FTH. There were not differences between the other defoliatied and non-defoliated vines.

Table (86): Effect of canopy management practices on unknown phenolic compound (7) and unknown phenolic compound (8) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Unknown phenolic compound (7) (mg/kg) | | | Unknown phenolic compound (8) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| LBR | 0.94 a | 1.00 a | 0.97 a | 7.74 a | 4.96 ab | 6.35 ab |
| LBR + H | 0.93 a | 1.42 a | 1.18 a | 11.95 a | 10.23 a | 11.09 a |
| LBR + SSR | 0.80 a | 0.91 a | 0.85 a | 5.43 a | 6.07 ab | 5.75 ab |
| LBR + H + SSR | 0.90 a | 1.77 a | 1.34 a | 9.26 a | 8.31 ab | 8.79 a |
| LBR + FTH | 0.39 a | 1.10 a | 0.74 a | 2.92 a | 0.74 b | 1.83 b |
| Control | 0.64 a | 0.95 a | 0.79 a | 4.77 a | 9.44 a | 7.10 ab |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Table 87 shows the effect of defoliation and fruit thinning treatments on the concentration of unknown phenolic compound (9), which was not affected in the first season. In the second season, the untreated vines and LBR + FTH had the highest value compared with the other treatments.

The mean stated that LBR + FTH had the highest content of unknown phenolic compound (9), compared to the other treatments except LBR + H + SSR.

The mean of unknown phenolic compound (10) was affected by defoliation treatments, LBR + H + SSR had higher concentration than both LBR + FTH and the untreated grapevines (Table 87).

Table (87): Effect of canopy management practices on unknown phenolic compound (9) and unknown phenolic compound (10) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Unknown phenolic compound (9) (mg/kg) | | | Unknown phenolic compound (10) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 3.75 a | 1.86 b | 2.80 b | 19.26 a | 12.74 a | 16.00 ab |
| **LBR + H** | 2.58 a | 1.56 b | 2.07 b | 24.21 a | 26.17 a | 25.19 ab |
| **LBR + SSR** | 2.84 a | 3.65 b | 3.25 b | 21.82 a | 6.11 a | 13.96 ab |
| **LBR + H + SSR** | 8. 53 a | 2.40 b | 5.47 ab | 33.08 a | 27.43 a | 30.26 a |
| **LBR + FTH** | 9.09 a | 9.02 a | 9.06 a | 4.40 a | 5.47 a | 4.93 b |
| **Control** | 2.41 a | 2.44 b | 2.42 b | 3.48 a | 7.37 a | 5.43 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

It is appeared from Table 88 that the unknown phenolic compound (11) was affected only in the second season. LBR + H + SSR and LBR + FTH had the highest value compared to the other treatments.

The mean claimed that LBR + H + SSR and LBR + FTH had a higher concentration than BLR and the untreated grapevines.

Moreover, LBR + FTH produced a higher content of unknown phenolic compound (11) than BLR + SSR.

Unknown phenolic compound (12) was impacted by canopy management and fruit thinning treatments in the second year of this study. LBR + FTH produced a higher amount than LBR, LBR + H + SSR and the untreated vines (Table 88).

Table (88): Effect of canopy management practices on unknown phenolic compound (11) and unknown phenolic compound (12) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Unknown phenolic compound (11) (mg/kg) | | | Unknown phenolic compound (12) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 5.16 a | 4.63 b | 4.90 c | 1.58 a | 1.88 b | 1.73 bc |
| **LBR + H** | 9.65 a | 7.25 b | 8.45 abc | 3.53 a | 2.69 ab | 3.11 ab |
| **LBR + SSR** | 9.23 a | 6.61 b | 7.92 bc | 1.89 a | 2.66 ab | 2.28 abc |
| **LBR + H + SSR** | 9.78 a | 16.41 a | 13.09 ab | 3.26 a | 1.54 b | 2.40 abc |
| **LBR + FTH** | 9.83 a | 20.40 a | 15.12 a | 2.60 a | 4.91 a | 3.76 a |
| **Control** | 2.94 a | 3.65 b | 3.30 c | 0.84 a | 1.36 b | 1.10 c |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control =** untreated vines.

The mean concluded that LBR + FTH, followed by LBR + H had the highest concentration of unknown phenolic compound (12).

The mean of unknown phenolic compound (13) indicated that the high content resulted from LBR + H + SSR than LBR + SSR (Table 89). No significant differences were between the defoliation treatments and the control.

The highest amount of unknown phenolic compound (14) resulted in LBR + H + SSR than the untreated vines in the first season. (Table 89).

In the second season, LBR + FTH produced the highest concentration compared to the other treatments.

The mean confirmed that LBR + FTH, LBR + H + SSR and LBR + H had a higher content than the untreated vines.

Table (89): Effect of canopy management practices on unknown phenolic compound (13) and unknown phenolic compound (14) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| **Treatments** | **Unknown phenolic compound (13) (mg/kg)** | | | **Unknown phenolic compound (14) (mg/kg)** | | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **Mean** | **2004** | **2005** | **Mean** |
| **LBR** | 4.54 a | 3.92 a | 4.23 ab | 2.85 ab | 2.42 b | 2.63 ab |
| **LBR + H** | 5.93 a | 4.76 a | 5.35 ab | 4.33 ab | 3.81 b | 4.07 a |
| **LBR + SSR** | 3.65 a | 3.60 a | 3.63 b | 3.17 ab | 2.44 b | 2.80 ab |
| **LBR + H + SSR** | 7.32 a | 6.99 a | 7.15 a | 4.46 a | 3.91 b | 4.18 a |
| **LBR + FTH** | 4.39 a | 4.83 a | 4.61 ab | 2.73 ab | 6.50 a | 4.61 a |
| **Control** | 4.53 a | 6.37 a | 5.45 ab | 1.20 b | 1.75 b | 1.47 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

Table 90 shows the effect of canopy managements on the concentration of unknown phenolic compound (15) in the skin berry of 'Crimson Seedless' grapes in 2004 and 2005.

In 2004, LBR + FTH had a higher content than LBR, LBR + H and the untreated grapevines. In 2005, LBR + FTH had a higher content than non-defoliated vines.

The mean concluded that LBR + FTH had the highest content of unknown phenolic compound (15) compared to the other treatments except LBR + SSR.

It is obvious from Table 90 that LBR + SSR had the highest value of unknown phenolic compound (16) than the other treatments except LBR + FTH in the second year. The mean of the two years confirmed this result too.

Table (90): Effect of canopy management practices on unknown phenolic compound (15) and unknown phenolic compound (16) in the skin of 'Crimson Seedless' grape in 2004 and 2005.

| Treatments | Unknown phenolic compound (15) (mg/kg) | | | Unknown phenolic compound (16) (mg/kg) | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | Mean | 2004 | 2005 | Mean |
| **LBR** | 0.15 b | 1.62 ab | 0.88 b | 1.23 a | 0.93 b | 1.08 b |
| **LBR + H** | 0.07 b | 0.80 ab | 0.44 b | 0.49 a | 0.99 b | 0.74 b |
| **LBR + SSR** | 1.13 ab | 1.72 ab | 1.43 ab | 2.04 a | 6.77 a | 4.40 a |
| **LBR + H + SSR** | 0.98 ab | 0.68 ab | 0.83 b | 2.49 a | 0.66 b | 1.57 b |
| **LBR + FTH** | 2.81 a | 2.28 a | 2.54 a | 2.63 a | 3.27 ab | 2.95 ab |
| **Control** | 0.00 b | 0.06 b | 0.03 b | 0.19 a | 1.46 b | 0.82 b |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan's multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

### 4.7.8.7 Total phenolic compounds

Table 91 exhibit the influence of canopy management and fruit thinning on the total phenolic compounds in the skin of ‘Crimson Seedless’ grapes during two periods. In the first season, LBR + H + SSR and LBR + FTH produced the highest content of total phenolic compounds (1156.75 and 1206.46 mg/kg).

The other defoliation treatments produced a higher amount than the control but was not significant in the first year.

However, in the second season, all the defoliation treatments varied in total phenolic compounds from 396.83 to 975.97.

LBR + FTH gave the highest amount of total phenolic compound (1091.21 mg/kg), followed by LBR + H and LBR + H + SSR (765.46 and 825.20 mg/kg). No significant differences were found between both LBR and LBR + SSR (384.25 and 613.23) and the control.

Table (91): Effect of canopy management practices on total phenolic compounds in in the skin of ‘Crimson Seedless’ grape in 2004 and 2005.

| **Treatments** | **Total phenolic compounds (mg/kg)** | | |
|---|---|---|---|
| | **2004** | **2005** | **Mean** |
| **LBR** | 371.67 ab | 396.83 a | 384.25 bc |
| **LBR + H** | 714.83 ab | 816.08 a | 765.46 ab |
| **LBR + SSR** | 455.66 ab | 770.8 a | 613.23 abc |
| **LBR + H + SSR** | 1156.75 a | 493.66 a | 825.20 ab |
| **LBR + FTH** | 1206.46 a | 975.97 a | 1091.21 a |
| **Control** | 109.18 b | 228.97 a | 169.07 c |

Means within a column followed by different letter (s) are statistically different at 5 % level by Duncan’s multiple range test.

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning. **Control** = untreated vines.

The results are in accordance with those of Guidioni *et al.* (2002) who stated that manipulations of plant assimilate partitioning through leaf or cluster removal and stem girdling above or below clusters induce significant modification of the flavonoids concentration.

The results are in accordance of those reported by Reynolds *et al.* (2006) who found that basal leaf removal increased color intensity, anthocyanin, phenols, methyle anthranilate, and total volatile esters.

The results are in parallel with those resulted from shoot hedging by Keller *et al.* (1999) who confirmed that the best treatment for fruit quality, in terms of colour and oxidative stability, was shoot topping.

In addition, the results are in the same trend of those resulted from shoot thinning (Sterile Shoot Removal; SSR), by Reynolds *et al.* (2005 b) who reported that early shoot-thinning treatments on ‘Cabernet Franc’ grapevines resulted in increased color intensity, total anthocyanin and total phenolics in berries.

Also, the obtained results were confirmed by Fox (2006) who noticed that the several levels of defoliation for cultivar ‘Blauburgunder Samtrot ‘ grapes increased the phenol levels and improved the anthocyanin contents.

On the other side, the results are in agreement with those mentioned by Hunter *et al.* (1991) on ‘Cabernet Sauvignon’ grapevines and Zoecklein *et al.* (1992) on ‘Chardonnay’ and ‘White Riesling’ grapevines who found that leaf removal and partially defoliation did not affect fruit total phenols or flavonoids.

Generally, the obtained results show the same trend as those mentioned by several authors that sunlight-exposed fruits are generally higher in total soluble solids, anthocyanins, and phenolics and lower in titratable acidity and berry weight compared to non-exposed or canopy shaded (Smart *et al*. 1985, Reynolds *et al*. 1986, Crippen and Morrison 1986 a, Crippen and Morrison 1986 b, Dokoozlian and Kliewer 1995, Jackson and Lombard 1993, Bergqvist *et al.* 2001, Ferree *et al.* 2004, Kliewer and Dokoozlian 2005, Santesteban and Royo 2006).

# 5 Conclusion

The present investigation was carried out during the two consecutive seasons of 2004 and 2005 on 5-year-old "Crimson Seedless" grapvines (*Vitis vinifera* L.) grown in a private vineyard at Cairo- Ismailia Road at 73 Km, Egypt. The chemical analysis of sugars, flavonoids and other phenolic compounds were performed at the Unit of Fruit Science, Center of Life Sciences Weihenstephan (WZW), Technische Universtät München (TUM), Freising, Germany.

This investigation was established to solve some of the problems in growing of ‘Crimson Seedless’ grapes, which are less fruitfulness, insufficient berry color and small berry size.

Objectives of this study were:

(A) To find the most efficient amount of N and K fertilization that improves productivity and fruit quality by studying the effect of different N rates combined with K fertilization levels on vine nutritional status, bud behavior, growth vigor, yield and fruit quality parameters including physical properties such as cluster weight, length, width, number of berry per cluster, cluster compactness, and berry weight, volume, firmness, adherence, juice weight and volume, juice percentage as well as chemical properties such as TSS, acidity, sugar fraction, flavonoids and other phenolic compounds.

(B) To define proper canopy management which improves fruit quality of ‘Crimson Seedless’ by studying the effect of leaf removal and fruit thinning practices.

(C) To determine the flavonoids and other phenolic compounds in fruit as affect by N and K fertilization, by leaf removal and fruit thinning practices.

Considering the importance of N and K fertilization, leaf removal and fruit thinning practices for ‘Crimson Seedless’ grapes, until now, little is known about how they can improve the productivity and fruit quality especially, flavonoids and other phenolic compounds in ‘Crimson Seedless’ grape, which are responsible for color, flavor and antioxidant properties.

Two experiments were designed to achieve the objectives of this study:

1- N&K fertilization experiment.

2- Defoliation & fruit thinning experiment.

The results can be summarized as follows:

## 5.1 N&K fertilization experiment:

- Increasing N supply from 24 to 48 kg/ha enhanced N-concentrations in the petioles and also increased K-concentrations in the petioles. The K-fertilization variants (240, 285, 330 kg $K_2O$/ha) themselves did not alter the K content of the petioles.
- Excessive N-supply (48 kg/ha) negatively affected yield by reducing the number of clusters per vines.
- In both seasons, highest yield was obtained with medium N level (36 kg/ha) combined with high K levels (285 / 330 kg $K_2O$/ha).
- Bud burst, bud fertility and fruitfulness was found to be best with low and medium N fertilization (24 and 36 kg/ha).
- High N-fertilization (36 and 48 kg/ha) favoured vegetative growth (leaf area, cane diameter).
- Cluster weight and size was improved with increasing N-nutrition to 48 kg/ha., however, the number of berries per cluster and the cluster compactness remained unchanged. The single berries were bigger (size, weight) with increasing the nitrogen fertilization and their shape remained typical for the cv.
- The amount of juice per berry increased and fruit firmness and adherence decreased in the high N-variant (48 kg/ha).
- T.S.S / acid ratio was optimized with high K fertilization (330 kg $K_2O$/ha) combined with medium N-level (36 kg/ha).
- Sugars fraction varied between N and K treatments. Glucose was enhanced by T9 compared to T2 in the first year. Fructose enhanced by T7 than T2 in the first year. Whereas, sorbitol remined constant.
- Three phenolic acids were detected in this study: caffeoyltartaric acid and two unknown hydroxycinnamic acid derivatives. T3 (low nitrogen rate 24 kg/ha combined with high K level 330 $K_2O$/ha) gave highest concentration of caffeoyltartaric acid.

- 3 Stilbene derivatives were detected and identified: *cis* and *trans*-piceid, and resveratrol. *cis* -Piceid was highest by T2 (low nitrogen rate 24 kg/ha combined with medium potassium level 285 $K_2O$/ha) and lowest by T7. A similar tendency was found for *Trans*-piceid. The aglycone resveratrol was rarely detected.
- Flavonols were detected: quercetin 3-glucoside, kaempferol 3-glucoside and five unknown flavonols. Medium K fertilization resulted in higher concentration in the skin.
- Flavan 3-ols that were detected are: procyanidin B2, epicatechin and nine unknown proanthocyanidins. T3 and T7 had highest value of procyanidin B2 and T9 the lowest one.in the second season. Epicatechin was not affected by the N and K fertilization treatments.
- Total anthocyanins content in the berry generally show a high variability in the experiment. Therefore, the color of berries might have been more influenced by the ripening process than by the fertilizer treatments.
- 10 anthocyanins were detected in the skin berry: cyanidin 3-glucoside, paeonidin 3-glucoside, malvidin 3-glucosidee and seven unknown anthocyanins.
- Cyanidin 3-glucoside was produced with a larger content by T2 and T3 than T9 in the second year.
- Paeonidin 3-glucoside was the most abundant anthocyanin in ‘Crimson Seedless’ skin berry. T3 had a high amount compared with all other N and K fertilization treatments.
- Malvidin 3-glucoside was increased by T3 than T1, T2, T4 and T9. No significant value has found between T3 and the other N and K fertilization treatments.
- Total anthocyanin content in the berry skin was improved by T3 (low nitrogen rate 24 kg/ha combined with high K level 330 $K_2O$/ha) compared to the other N an K fertilization.
- The study detected also 16 unknown phenolic compounds. All of them were differently affected by N and K fertilization.

- Total phenolic compounds were impacted by N and K fertilization treatments, T2 had the biggest amount compared to T4 and T9. no signficant diffrence was found between T2 and the other N and K ferilization.

## 5.2 Defoliation experiment

- Cluster weight and length was improved by all defoliation treatments, except the defoliation + berry thinning.
- The number of berries per cluster remained unchanged in all defoliation treatments, except the treatment where berries were removed (LBR+FTH).
- Cluster compactness was improved by leaf basel removal + hedging (LBR+H) in the first year and by all defoliation treatments in the second year.
- The single berries were biggest (size, weight) with LBR + FTH, followed by the other defoliation treatments than the control, except the treatment of leaf basal removal + hedging +Steril shoot removal (LBR+H+SSR).
- The amount of juice per berry (weight and volume) increased by LBR + FTH, followed the other defoliation treatments. Berry juice % was improved by all defoliation treatments.
- Fruit firmness and adherence was decreased by all defoliation treatments.
- Glucose and fructose showed a similar tendency.
- All leaf removal treatments increased total soluble solids (T.S.S %) and decreased the acidity concentration.
- Caffeoyltartaric acid influenced only in the second season. The treatment of LBR+FTH produced a big amount compared with the untreated vines, leaf basal removal (LBR) and leaf basal removal plus sterile shoot removal (LBR+SSR).
- Stilbene derivatives (*cis*-piceid and *Trans*-piceid) decreased in the LBR+FTH treatment. No significant differences were found between the other treatments.
- The concentration of flavonols in the skin were highest in the LBR+FTH treatments.
- Procyanidin B2 was enhanced by LBR+FTH. The same tendency was found for most other proanthocyanidins. The monomeric epicatechin was not affected.

- Total anthocyanins in the berry was improved by all treatments. LBR+FTH showed the highest amount, followed by LBR+H and LBR+H+SSR in the second order, and by LBR and LBR + SSR.
- Cyanidin 3-glucose was enhanced by LBR + FTH.
- Peonidin 3-glucoside the most abundant anthocyanin in 'Crimson Seedless' skin was enhanced by all treatments.
- Malvidin 3-glucoside was increased by LBR+H+SSR and LBR + FTH.
- Total anthocyanins content in the skin was improved by LBR + FTH, LBR+H and LBR+H+SSR.

T6 (medium nitrogen rate 24 kg/ha combined with high K level 330 $K_2O$/ha) was the best treatment that improves productivity and fruit quality of 'Crimson Seedless' grapes due to it improves the vine nutritional status, increases the bud fertility and optimizes the growth vigor.

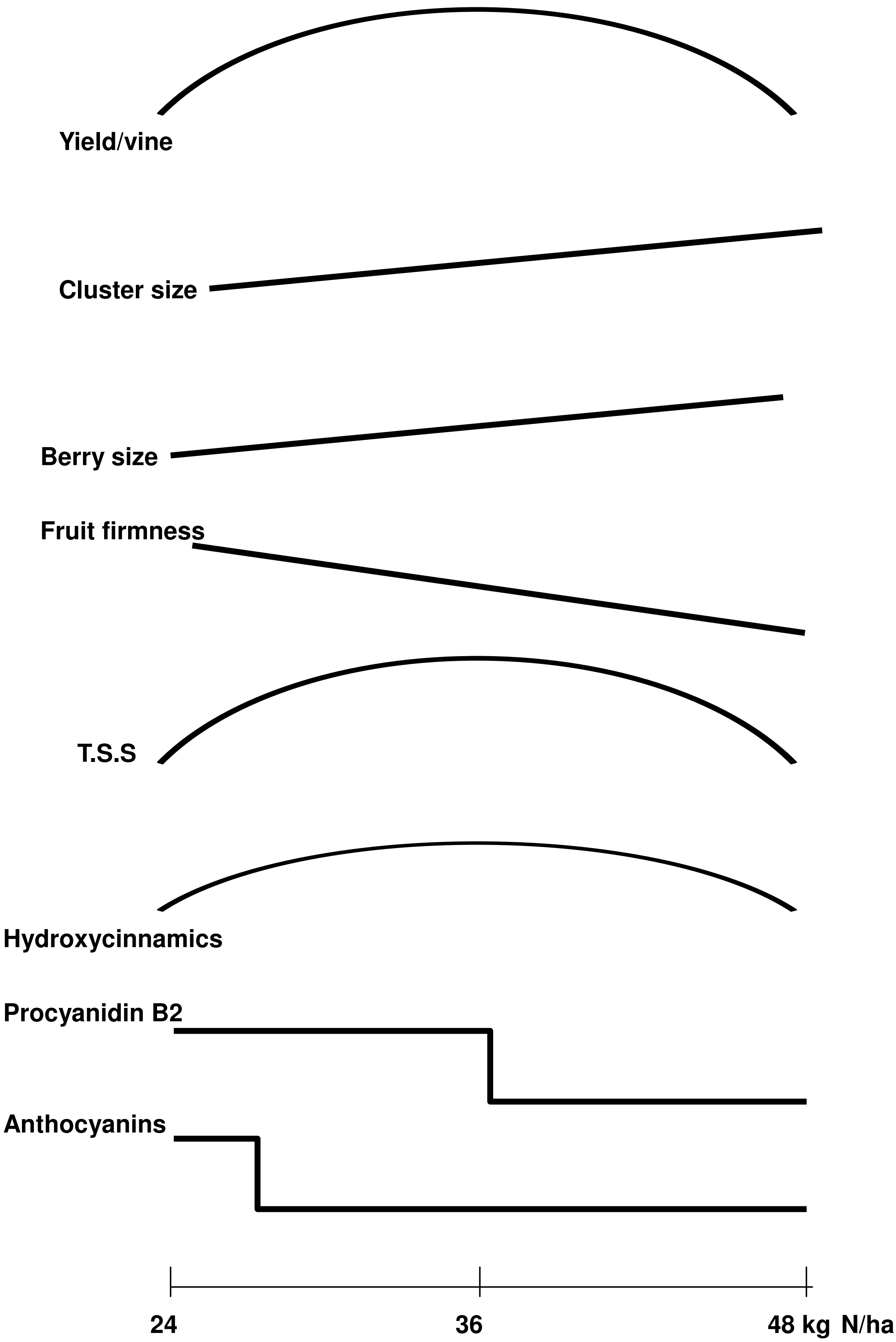
The canopy managements which improve fruit quality of 'Crimson Seedless' were LBR + FTH followed by LBR + H and LBR +H + SSR.

LBR + FTH had a higher concentration of anthocyanin compared with LBR + H and LBR + H + SSR. It was the highest in caftaric acid, stilbenes and flavonols.

**The following figure and table summarize the results of this study:**

**Trends of N effect on quantity and quality**

**of 'Crimson Seedless' grapes**



**Effect of canopy management practices on 'Crimson Seedless' fruit quality:**

| Management | Berry size, Berry weight | Amount of juice per berry | Fruit firmness | Sugars, TSS | Anthocyanins | Caftaric acid | Stilbenes | Flavonols |
|---|---|---|---|---|---|---|---|---|
| **LBR** | + | + | ↓ | + | + | | | |
| **LBR + H** | + | + | ↓ | + | ++ | | | |
| **LBR + SSR** | + | + | ↓ | + | + | | | |
| **LBR+H + SSR** | + | + | ↓ | + | ++ | | | |
| **LBR+ FTH** | +++ | +++ | ↓ | + | +++ | + | + | + |

**LBR** = Leaf Basal Removal.

**LBR + H** = Leaf Basal Removal + Hedging.

**LBR + SSR** = Leaf Basal Removal + Sterile Shoot Removal.

**LBR+H + SSR** = Leaf Basal Removal + Hedging + Sterile Shoot Removal.

**LBR+ FTH** = Leaf Basal Removal + Fruit Thinning.

## 6 Summary

The effect of the nutritional status of grapevine 'Crimson Seedless' on growth, fruit set and quality was studied in two growing periods. The vines were treated with three levels of nitrogen (24, 36, 48 kg/ha) combined with three potassium levels (240, 285, 330 kg/ha). Increasing N supply enhanced N-concentrations in the petioles. N-fertilization also increased K concentrations in the petioles. The K-fertilization variants themselves did not alter the K content of the petioles. High N-fertilization improved vegetative growth (leaf area, cane diameter) and reduced bud burst, bud fertility and fruitfulness. Excessive N-supply negatively affected yield per vine by reducing the number of fruit clusters. Cluster size, however, was improved with increasing N-nutrition whereas the number of berries per cluster and the cluster compactness remained unchanged. The single berries were bigger (size,weight) and their shape remained typically for the cultivar. The amount of juice per berry increased and fruit firmness decreased in the high N-variants. The only effect of high K fertilization was an increase of total soluble solids and a decrease of acid concentration. T.S.S / acid ratio was optimized with high K fertilization (330 kg $K_2O$/ha) combined with medium N-level (36 kg/ha). Sugar fractions varied between N & K treatments. Glucose was enhanced by high N level combined with high K level. Fructose was enhanced by high N level combined with medium K level, whereas, sorbitol remained constant. Phenolic acids and stilbene derivatives were also enhanced by N and K applications. Caffeoyltartaric acid was highest in low nitrogen combined with high K level. *cis* -Piceid was highest by low N level combined with medium K level. Flavan 3-ols increased by N & K supply. Procyanidin B2 had highest value by low N level combined with high K level or by high N level combined with meduim K level. However, epicatechin was not affected. The flavonols quercetin 3-glucoside and kaempferol 3-glucoside reached in higher concentration with medium K fertilization (285 kg/ha). Anthocyanin contents generally show a high variability in the experiment. Cyanidin 3-glucoside was produced in higher amounts with low N fertilization. Paeonidin 3-glucoside was the most abundant anthocyanin. Paeonidin 3-glucoside, malvidin 3-glucoside and total anthocyanins in the skin were increased by the low N level combined with high K level.

‘Crimson Seedless’ vines were treated also with 6 defoliation managements: (1) leaf basal removal (LBR), (2) leaf basal removal + hedging (LBR+H), (3) leaf basal removal + sterile shoot removal (SSR+LBR), (4) leaf basal + sterile shoot removal + hedging

(LBR+SSR+H), (5) leaf basal removal + fruit thinning (LBR+FTH), (6) untreated vines (control). Defoliation improved cluster weight, size, compactness and their berries were bigger (size,weight) with LBR + FTH, followed by the other treatments except LBR+H+SSR, however, the number of berries per cluster was unchanged. Moreover, it accelerated the ripening process, the berry juice was increased and fruit firmness & adherence were decreased. Also, it increased the T.S.S and decreased the acidity in the berries. Glucose and fructose showed a similar tendency. LBR+FTH improved also caffeoyltartaric acid, stilbenes and flavonols compared to the other treatments. Procyanidin B2 was enhanced by LBR + FTH. Epicatechin was not affect by treatments. Cyanidin 3-glucoside was in the highest amount by LBR + FTH. Peonidin 3-glucoside the most abundant anthocyanin was increased by all treatments. Malvidin 3-glucoside was increased by LBR + H + SSR and LBR + FTH. Total anthocyanins in the berry were improved by all treatments, LBR + FTH showed the highest amount, followed by LBR+H and LBR+H+SSR in the second order, and by LBR and LBR + SSR. Total anthocyanins in the skin were the highest by LBR + FTH, followed by LBR + H and LBR + H + SSR.

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**Abd El-Razek, D. Treutter, M. M. S. Saleh, M. El-Shammaa, N. Abdel-Hamid and M. Abou-Rawash 2008.** Effect of nitrogen and potassium fertilization on productivity and fruit quality of 'Crimson Seedless' gapes. First Symposium in Horticulture in Europe17-20 February, University of Vienna - Biozentrum, Austria (P T5-9).

**International Societies Membership:**

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**(2) 'Individualkurs für biologische Fachsprache'**
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**Internationale Gartenbauwissenschaftskurse:**

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**(2)'Biotechnology in Horticulture' (SS 2006)**

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**Internationale Symposien:**

**(1) '3$^{rd}$ International Symposium of SFB 607, March 07$^{th}$ – 08$^{th}$, 2006: 'Mechanisms of Growth, Competition and Stress Defense in Plants'**

Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung and Umwelt (WZW), Technische Universität München (TUM), Freising, Deutschland.

**(2) 'First Symposium in Horticulture in Europe, 17-20 February 2008'**

Universität Wien - Biozentrum, Österreich.

**Publikation:** **Abd El-Razek, E., D. Treutter, M. M. S. Saleh, M. El-Shammaa, N. Abdel-Hamid and M. Abou-Rawash 2008.** Effect of nitrogen and potassium fertilization on productivity and fruit quality of 'Crimson Seedless' gapes. First Symposium in Horticulture in Europe, 17-20 February, University of Vienna - Biozentrum, Austria (P T5-9).

**Mitgliederschaft der internationalen Gesellschaften:**

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**(1) Zentrale Mittelstufenprüfung Zeugnis**

Goethe – Institut, Kairo, Ägypten, 14. 06.2005 Nr. 01330-ZMP-05-38

**(2) 'Individualkurs für biologische Fachsprache'**
Goethe – Institut, München, Deutschland (02.02.2006 - 02.05.2006).

**(3) 'DaF für Mittelstufe 2'** (SS 2006).
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**Englisch : 'English for Scientific Purposes'** (SS 2006),

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**Computerfähigkeiten**

**ICDL** (International Computer Driving Licence )

1- Basic Concepts of Information Technology.
2- Using the Computer and Managing Files.
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