Journal of the American Pomological Society 68(2): 89-96 2014

Optimizing Fruit Yield, Size, and Quality Attributes in 'Malase Torshe Saveh' Pomegranate through Hand Thinning

Azam Jafari[1], Kazem Arzani[2], Esmaeil Fallahi[3], and Mohsen Barzegar[4]

Additional index words: hand thinning, *Punica granatum,* soluble solids concentration

Abstract

Pomegranate (*Punica granatum* L.*)* is a fruit of the "old world" that has gained considerable popularity in many countries worldwide due to its health benefits. The competitive nature of fruit marketing mandates improving the quality of this fruit, while keeping yield at an optimum level. To pursue this objective, the effects of severity of hand-thinning on fruit size and quality attributes of 'Malase Torshe Saveh' pomegranate were studied during two consecutive seasons. In this study, 0, 10, 20, 30 and 40% hand thinning of fruit were applied when fruitlet diameter was about 30 mm. Mean fruit weight, length, diameter and volume increased with increased severity of thinning. Fruit from trees thinned at 20 and 30%, had significantly higher soluble solids concentration (SSC) compared to those from un-thinned control trees and fruit from trees thinned at 30 and 40% had significantly higher SSC/titratable acidity ratio compared to 20% thinned trees. Fruit from 40% hand thinning trees had significantly higher color hue factor (a*) than control fruit. Overall, thinning increased commercial value and marketability by increasing fruit quality and size.

Pomegranate (*Punica granatum* L.) is an important commercial fruit crop cultivated extensively in Iran, India, USA, China, Japan and Russia (Mansouri et al., 2010; Varasteh et al., 2009). Iran is the center of origin of this ancient fruit that is associated with legends, culture, art, and symbolic importance. This country is one of the world's leading producers and exporters of pomegranate (Anonymous, 2005). The fruit is consumed fresh or processed in forms of juice, jam, syrup, sauce, and seasoning (Al-Maiman and Ahmad, 2002).The edible part of pomegranate fruit contains considerable amounts of acids, sugars, vitamins, polysaccharides, polyphenols, and important minerals. This fruit has high antioxidant activity and beneficial anti-carcinogenic properties (Afaq et al., 2003; Gil et al., 2000; Kulkarni et al., 2004; Varasteh et al., 2012).

Flowering and subsequent fruit set in pomegranate may last for up to one month. During this period, there are three phases of flowering, depending on climatic conditions (El Sese et al., 1988; Mars, 2000; Shulman et al., 1984). In a tropical climate, flowering and fruit-set is almost all-year-round but those occur only once a year in sub-tropical regions (Stover and Mercure, 2007).

Pomegranate trees with excessive fruit will produce small fruit with poor quality. These trees may lose their cold tolerance due to depletion of tree reserves and branches may break under heavy crop loads as documented in apple (De Salvador et al., 2006).

The competitive nature of pomegran-

[1] Ph.D. Student, Department of Horticultural Science, Tarbiat Modares University, P.O. Box 14115-336, Tehran, Iran

[2] Professor of Pomology and corresponding author, Department of Horticultural Science, Tarbiat Modares University, P.O. Box 14115-336, Tehran Iran; e-mail: arzani_k@modares.ac.ir

[3] Professor and Director of Pomology and Viticulture Program and corresponding author, University of Idaho, Parma Research and Extension Center, 29603 U of I Lane, Parma, ID 83660, USA; e-mail: efallahi@uidaho.edu

[4] Associate Professor of Food Science and Technology, Department of Food Science and Technology, Tarbiat Modares University, P.O. Box 14115-336, Tehran, Iran

ate fruit marketing mandates production of fruit with large size and high quality. Webster and Spencer (2000) reported that crop load adjustment in plums and apricots can be achieved using one of the following methods: 1) reducing inflorescence, either in terms of abundance or density; 2) preventing fruit set in a proportion of the flowers (i.e., by flower thinning); and 3) increasing natural abscission of fertilized fruit by thinning fruitlets. Manual or hand thinning of stone fruit is still a common practice, as it remains the most reliable method of achieving optimum crop load, and facilitates good fruit distribution on the tree canopy (Fallahi et al., 2006b; Webster and Spencer, 2000). Blossom (flower) thinning is often considered too risky, especially in those regions where weather conditions cannot be predicted reliably and a risk of subsequent freeze injury may drastically reduce yield. In such regions, post-bloom thinning is a preferred strategy (Webster and Spencer, 2000), although blossom thinning is commonly practiced in other regions on apples (Fallahi et al., 2006a) and stone fruit (Fallahi et al., 2006b).

Different cultivars of any fruit species may require a different level of fruit thinning relating to their genetic and physiological differences. Although there is some information on thinning of pomegranates in other countries (Hussein et al., 1994; Padmavathamma and Hulamani, 1996; Sharma and Singh, 2000), there are no guidelines for thinning of Iranian pomegranates. Thus, the objective of this study was to investigate the effect of hand thinning on fruit-size and quality attributes of the cultivar 'Malase Torshe Saveh', which is one of the most commercially important cultivars in Iran.

Materials and Methods

Plant materials and experimental design. This study was conducted on15-year old self-rooted 'Malase Torshe Saveh' pomegranate trees in Saveh, Iran for two successive seasons (2011-12 and 2012-13). Trees were planted at 2 × 3 m spacing and all cultural practices in this orchard, except for that of severity of fruit thinning, were similar to those of commercial orchards in the region.

Twenty uniform trees were selected and the same trees were used for the study in both years. The experiment was laid out by following a completely randomized block design with five levels of fruit thinning as treatments and four single-tree replications per treatment. The treatments consisted of: 1) un-thinned control; 2) hand-thinned at 10%; 3) hand-thinned at 20%; 4) hand-thinned at 30%; and 5) hand-thinned at 40%.

Measurements of yield and quality attributes. All fruit per tree were counted and weighed at harvest to calculate total production in terms of number of fruit and total yield in each treatment. Fifteen fruit per tree were taken randomly for measurements of quality attributes at commercial harvest dates in mid- November in both 2012 and 2013. Fruit were immediately transported to the Pomology Laboratory, Department of Horticultural Science, Tarbiat Modares University for determination of quality attributes, including fruit weight, diameter, length, volume, soluble solids concentration (SSC), and titratable acidity (TA). Fruit diameter and length were measured using a digital caliper (Electronic Digital Caliper, CB, Chicago, IL.). Fruit volume was measured by liquid displacement. Soluble solids concentration of fruit juice was measured with a temperature-compensated hand refractometer (Atago, NSG Precision Cells, Inc., Hicksville, USA) and titratable acidity was determined in juice by titrating with 0.1 N sodium hydroxide, using phenolphthalein as the indicator (Ranganna, 1979), with results being expressed as percentage of citric acid. The major acid accounting for titrable acidity in pomegranate arils is citric acid (Melgarejo et al., 2000). Aril color was measured for redness (a*), and yellowness (b*) using a Hunter colorimeter (Colorfex®, Reston VA, USA) (Yawadio and Morita, 2007).

Statistical analysis of data. Analysis of variance (ANOVA) was done on each yield

or quality parameter, using a SAS statistical package. Mean separation was made using the Fisher's Protected Least Significant Differences (LSD) test at $P \leq 0.05$. Regression analysis was also performed to determine relationships between some fruit quality parameters and the levels of severity of fruit thinning.

Results and Discussion

Interactions between treatments and years. There were no significant interactions between treatments and years for any of the yield and fruit quality attributes that were measured. Therefore, in addition to the treatments effects within each year, the average values over the two years are also reported for each parameter.

Effects on fruit number, yield, fruit weight, size and volume. As compared to the unthinned control, fruit number decreased with hand thinning treatments (Table 1). However, fruit number per tree did not closely track intended thinning levels (Table 1). Trees in untreated control could have had a higher number of fruit drop due to higher competition for carbohydrates, and this area deserves further study.

Yield, expressed as kg/tree, tended to decline with 10% and 20% hand thinning treatments in both years, but started to increase when the level of thinning reached 30% (Table 1; Figs. 1 and 2). Fruit weight increased with every incremental increase in the level of hand thinning (Table 2). Only in one out of eight cases (2 years, each year with 4 data points = 8 cases) yield in untreated control was different than that in hand-thinned treatments (Table 1). Thus, in most cases, total yield in the untreated control was statistically similar to other treatments. These results are supported by those of 'Jyoti' pomegranate, where only 25 fruit per tree were retained after hand thinning (Padmavathamma and Hulamani, 1996). Our results are also in general agreement with Hussein et al. (1994), who studied effects of Sevin, naphthalene acetic acid (NAA) and hand thinning on fruit thinning in 'Manfalouty' pomegranate and found that total yield was not significantly affected.

In general, fruit weights were markedly higher in most treatments in 2012 (Table 2) which could be due to more favorable weather conditions in that year (data not shown). Reaching a desirable balance between total yield and number of fruit per tree or fruit size is the ultimate goal for any successful fruit grower. A high production may lead to small fruit size with undesirable quality at-

Table 1. Effect of hand thinning on number of fruit per tree and total yield per tree in 'Malase Torshe Saveh' pomegranate during 2011 and 2012.

Thinning treatment	Number of fruit per tree (crop load)			Yield ($kg \cdot tree^{-1}$)		
	2011	2012	Mean	2011	2012	Mean
Control	87 a	87 a	87 a	22.9 a	27.5 ab	25.2 ab
Hand thin. 10%	68 b	83 ab	76 b	19.1 ab	25.4 b	22.2 bc
Hand thin. 20%	52 d	71 abc	62 c	17.2 b	23.5 b	20.4 c
Hand thin. 30%	65 bc	67 c	66 c	21.6 ab	25.0 b	23.3 bc
Hand thin. 40%	57 cd	70 bc	63 c	21.4 ab	33.7 a	27.5 a

Values within each column followed by the same letter are not significantly different at 5% level, using Fisher's Protected Least Significant Difference (LSD) test.

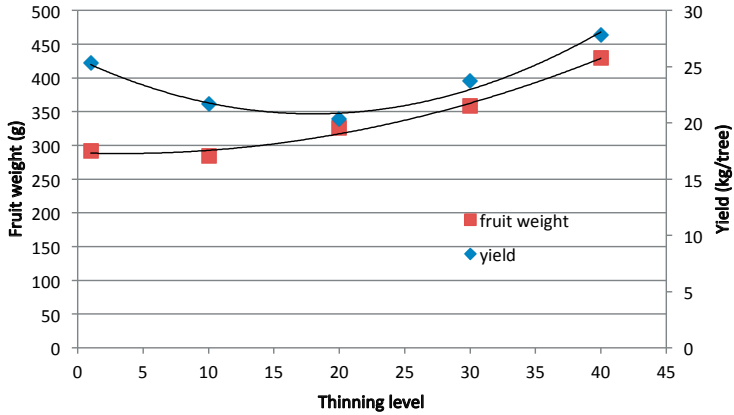

Fig. 1. The relationship between yield and hand thinning level ($y = 0.0151x^2 - 0.5435x + 25.7$; $r^2 = 0.9738$, $P \leq 0.05$) and between fruit weight and hand thinning level of 'Malase Torshe Saveh' pomegranate ($y = 0.1047x^2 - 0.6935x + 289.05$; $r^2 = 0.987$, $P \leq 0.05$).

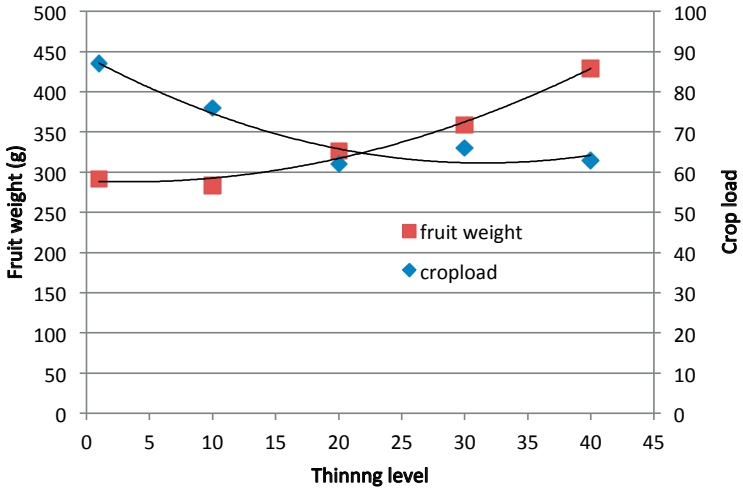

Fig. 2. The relationship between crop load (number of fruit per tree) and hand thinning level ($y = 0.0271x^2 - 1.6815x + 88.914$; $r^2 = 0.6582$, $P \leq 0.05$) and between fruit weight and hand thinning level of 'Malase Torshe Saveh' pomegranate ($y = 0.1048x^2 - 0.6944x + 289.05$; $r^2 = 0.7581$, $P \leq 0.05$).

tributes (Link, 2000). Depending on market demand, a grower can create an optimum balance between yield and fruit size and adjust the fruit number according to a particular market strategy. In our study, polynomial regressions between the level of hand thinning and either yield per tree in kg or fruit weight are shown in Fig.1, resulting in r^2 (coefficient determination) values of 0.974 and 0.987, respectively. Also, polynomial regressions between the level of hand thinning and either number of fruit per tree (crop load) or fruit weight are presented in Fig. 2, resulting in r^2 values of 0.6582 and 0.7581, respectively. The regression equations in Figs. 1 and 2 can be used as a useful tool to estimate production (number of fruit per tree) and requirements for crop load adjustment to achieve a particular fruit size. According to Figs. 1 and 2, 30% hand thinning of fruit is an ap-

Table 2. Effects of hand thinning on fruit weight, length, and diameter in 'Malase Torshe Saveh' pomegranate in 2011 and 2012.

Thinning treatment	Fruit weight (g)			Fruit length (mm)			Fruit diameter (mm)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Control	265.4 c	317.7 c	291.4 c	99.5 b	107.3 b	103.4 b	81.9 bc	90.3 bc	86.1 c
Hand thin. 10%	282.5 bc	306.3 c	294.4 c	98.3 b	105.3 b	101.8 b	79.1 c	87.6 c	83.4 c
Hand thin. 20%	329 ab	323.1 bc	326.1 bc	106.4 ab	105.1 b	105.8 b	89.1 ab	92.2 bc	90.7 b
Hand thin. 30%	336 ab	381.8 b	358.9 b	107.1 ab	118.5 a	112.8 a	87.7 ab	94.9 b	91.3 b
Hand thin. 40%	374.4 a	484.0 a	429.2 a	113.6 a	119.7 a	116.7 a	90.3 a	103.2 a	96.8 a

Values within each column followed by the same letter are not significantly different at 5% level, using Fisher's Protected Least Significant Difference (LSD) test.

proximately optimum level of thinning for the tree size/age and production conditions used in this study. Pomegranate growers who are not accustomed to thinning practices will find this study a useful tool to use in producing larger fruit with higher prices. This level produced about 66 fruit per tree with an average weight of 359 g. Untreated control trees bore 87 fruit with an average weight of 292 g (Table 2). Comparing production figures in the untreated control with those in the 30% hand thinning treatment revealed that thinning at this level decreased fruit number by 19 fruit (87 - 66) and increased average fruit weight by 23.7 g (about 19%). Although fruit yield, expressed as kg/tree, was slightly reduced in the 30% hand thinning treatment (average of 23.3 kg per tree in 30% hand thinning vs. 25.2 kg. in control, Table 1), the likely economic value for the crop increased in the 30% hand thinned fruit because, in countries such as US, consumers mostly buy pomegranates on a number rather than fruit weight basis and are willing to pay a higher price for larger fruit. A simple analysis in the current Iranian market reveals that the price for 1 kg of pomegranate fruits with an average weight of 250-290 g (about the range in the un-treated control in our study) is about $US1.20 while that with an average weight of 350 g (about the size in the 30% thinned treatment) is about $US3.44. In trees receiving 40% hand thinning, yield/tree also increased while fruit size (weight) increased. The cost of hand thinning does not justify any level higher than 30% as this cost is increasing worldwide.

In apple production and international trade, there is generally more demand for larger fruit size (Dennis, 2000). Although total fruit number and weight per tree are typically reduced by fruit thinning, high returns for large fruit usually improve orchard profitability (Marini and Sowers, 1994). Stover et al. (2001) reported that growers concentrate on fruit weight without considering the cost in yield and the overall economic impact of achieving that increased fruit size. This is an important factor that should be kept in mind when planning for fruit thinning as a routine strategy in any fruit operation.

The impact of thinning on fruit size in this study is in agreement with similar thinning studies in apple (De Salvador et al., 2006; Fallahi et al., 2006a; Palmer et al., 1997), peach and nectarine (Fallahi et al., 2006b), and apricot (Levent, 2004).

Fruit size increased with every incremental increase in the level of hand thinning (Table 2). In this study, increasing hand thinning rates from 20% to 40% increased fruit length, diameter and volume. Fruit from trees that received 40% thinning were longest and those from un-thinned control were shortest. Compared to the un-treated control, the average fruit diameter was significantly increased by an increased severity of hand thinning from 20% to 40% (Table 2).

Fruit thinning increased average fruit volume from 277.5 cm^3 in 10% hand thinning

Table 3. Effects of hand thinning on fruit volume, soluble solids concentration (SSC), and SSC/titratable acidity ratio in 'Malase Torshe Saveh' in 2011 and 2012.

Thinning treatment	Fruit volume (cm^3)			SSC (ºBrix)			SSC/TA		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Control	269.3 bc	326.1 c	297.7 cd	19.2 c	17.7 a	18.5 b	13.4 a	14.3 a	13.9 ab
Hand thin. 10%	258.1 c	297.0 c	277.5 d	19.5 bc	18.3 a	18.9 a	13.4 a	14.0 ab	13.7 ab
Hand thin. 20%	348.6 a	334.0 bc	341.3 cb	19.6 ab	18.1 a	18.9 a	12.1 a	12.3 b	12.2 b
Hand thin. 30%	337.5 ab	398.6 b	368.1 b	19.9 a	17.0 a	18.9 a	15.3 a	15.0 a	15.2 a
Hand thin. 40%	371.8 a	505.9 a	438.8 a	19.7 ab	17.7 a	18.7 ab	14.8 a	15.6 a	15.2 a

Values within each column followed by the same letter are not significantly different at 5% level, using Fisher's Protected Least Significant Difference (LSD) test.

to 438.8 cm^3 in the 40% hand thinning treatment (Table 3). The best results for mean fruit weight and fruit size (fruit length, fruit diameter and fruit volume) were obtained when the 40% hand thinning treatment was used but such thinning to 40% of crop load cannot be justified economically.

These results are in agreement with those in other cultivars of pomegranate (Padmavathamma and Hulamani, 1996; Singh, 2001) and with those using other methods of thinning such as mechanical de-blossoming (Sharma and Singh, 2000).

Effects on SSC and SSC/TA. In general, any level of thinning increased SSC as compared to control, although differences overall were small and not always significant (Table 3). The relationship between yield in kg/tree, fruit number per tree and SSC deserves further study.

Although SSC was slightly lower, the SSC/TA was often higher in 2012, perhaps due to a lower levels of TA and more favorable weather conditions in 2012 (data not shown). Our results are in general agreement with previous reports where hand thinning increased SSC by 2-3% in apples (Link, 2000). However, some researchers found a greater SSC increase in hand-thinned apricot trees (Chira, 1999; Levent, 2004). Levent (2004) found that both increasing hand thinning rates from 50 to 70% and increasing NAA dose concentration from 10 to 30 ppm had a similar effects by increasing fruit weight and SSC in apricots. Some researchers noted that SSC of 'Stanley' plum negatively correlated with increasing fruit load (Wells and Bukovac, 1978). In contrast, De Salvador et al. (2006) found that SSC was higher in fruit from heavy-cropping apple trees. However, Link (2000) reported no apparent correlation between SSC and fruit size in apples and reported that SSC was essentially the same in both large and small fruits.

Trees receiving 30% or 40% hand thinning tended to have higher SSC/TA ratio, although differences were not always significant. This trend is consistent with those in other pomegranate cultivars (Padmavathamma and Hulamani, 1996).

Effects on fruit color. It has been reported that 'Malase Torshe Saveh' is dark-red in the fruit peel as well as in the aril (Varasteh and Arzani, 2009). In the present research, the a* factor value of 40% hand thinning treatment was typically higher than un-treated control, although differences were not always significant (Table 4). Increasing fruit color with heavy hand thinning in our study is in agreement with results in loquat (Agusti et al., 2000), apples (Fallahi et al., 2006a), stone fruit (Fallahi et al., 2006b), persimmons (Chi et al., 2010), and plums (Wells and Bukovac, 1978), perhaps due to the increased leaf-to-fruit ratio. No significant differences were

Table 4. Effects of hand thinning on aril color of 'Malase Torshe Saveh' pomegranate in 2011 and 2012.

Thinning treatment	Redness (a^*)			Yellowness (b^*)		
	2011	2012	Mean	2011	2012	Mean
Control	24.6 b	27.5 a	26.0 b	15.8 a	12.7 a	14.2 a
Hand thin. 10%	24.6 b	26.2 a	25.4 b	12.7 ab	13.4 a	13.1 a
Hand thin. 20%	27.3 a	24.9 a	26.1 ab	10.5 ab	13.7 a	12.1 a
Hand thin. 30%	28.0 a	25.7 a	26.8 ab	9.7 b	14.4 a	12.1 a
Hand thin. 40%	28.0 a	28.0 a	27.0 a	10.8 ab	13.0 a	11.9 a

Values within each column followed by the same letter are not significantly different at 5% level, using Fisher's Protected Least Significant Difference (LSD) test.

found among various treatments for either the a* or b* values in 2012 (Table 4).

Conclusions

A major difficulty of thinning is to find the optimal thinning intensity. Improving fruit size is best achieved through proper crop load adjustment. Generally, hand thinning improved fruit size and some other quality attributes. Due to the increased consumption of pomegranate and its implied health benefits, the detailed economic impacts of various levels of hand thinning deserve further investigation.

Acknowledgements

We thank Tarbiat Modares University (TMU) for providing facilities and financial support. The assistance of Saveh Pomegranate Research Centre and Saveh Department of Agriculture for managing a commercial pomegranate orchard in the region is acknowledged. Also, we thank Eng. Tavakoli in the Pomology Lab., TMU for his technical assistance.

Literature Cited

Afaq, F., M. Saleem, and H. Mukhtar. 2003. Pomegranate fruit extract is a novel agent for cancer chemoprevention. Studies in mouse skin, p. 135-142. In: Proc. 2nd Annual American Association for Cancer Research International Conference on Frontiers in Cancer Prevention, Phoenix, Az.

Al-Maiman, S.A., and D. Ahmad. 2002. Changes in physical and chemical properties during pomegranate (*Punica granatum* L.) fruit maturation. FoodChem.76:437–441.

Anonymous. 2005. Statistical Book of Agricultural of Iran. Iranian Statistical Centre. Tehran, Iran.

Agusti, M., M. Juan, V. Almela, and N. Gariglio. 2000. Loquat fruit size is increased through the thinning effect of naphthalene acetic acid. Plant Growth Reg. 31:167–171.

Chira, A., L. Chira, and V. Balan. 1999. Studies regarding the influence of thinning and productivity and quality of apricot fruits. Acta Hort. 488:511-514.

Choi, S.T., D.S. Park, S.M. Kang, and Y.C. Cho. 2010. Effect of fruit-load on the growth, absorption, and partitioning of inorganic nutrients in young 'Fuyu' persimmon trees. Scientia Hort. 126:408-412.

Dennis, F.G.Jr. 2000. The history of fruit thinning. Plant Growth Reg. 31:1–16.

De Salvador, F.R., M. Fisichella, and M. Fontanari. 2006. Correlations between fruit size and fruit quality in apple trees with high and standard crop load levels. J. Fruit Ornam. Plant Res. 14:113-122.

El Sese, A.M. 1988. Physiological studies on flowering and fruiting habits of some pomegranate cultivars under Assiut conditions. Assiut University J. Agric. Sci. 19:320–336.

Fallahi, E., C.R. Rom, and B. Fallahi. 2006a. Effects of hydrogen cyanamide, ammonium thiosulfate, endothalic acid, and sulfcarbamide on blossom thinning, fruit quality, and yield of apples. J. Amer.Pomol. Soc. 60:198-204.

Fallahi, E., B. Fallahi, J.R. McFerson, R.E., Byers, R.C. Ebel, R.T. Boozer, J. Pitts, and B.S. Wilkins. 2006b. Tergitol-TMN-6 surfactant is an effective blossom thinner for stone fruits. HortSci. 41:1243-1248.

Gil, M.I., F.A. Tomas-Barberan, B. Hess-Pierce, D.M. Holcroft, and A.A. Kader. 2000. Antioxidant activ-

ity of pomegranate juice and its relationship with phenolic composition and processing. J. Agric. Food Chem. 48:4581–4589.

Hussein, M.A., A.M. El-Sese, T.K. El-Mahdy, and B. Abd-El-Sabour. 1994. Physiological studies on thinning effects on the yield and fruit quality of 'Manfalouty' pomegranate. B - Sevin, NAA and hand thinning influences on some fruit physical and chemical properties. Assiut University J. Agric. Sci. 25:41-50.

Kulkarni, A.P., S.M. Aradhya, and S. Divakar. 2004. Isolation and identification of a radical scavenging antioxidant–punicalagin from pith and capillary membrane of pomegranate fruit. Food Chem. 87:551–557.

Levent, S. 2004. Effects of hand and chemical thinning on fruit size and quality of'Priana' and 'Beliana' apricot (*Prunus armeniaca*) cultivars. N. Z. J. Crop Hort. Sci. 32:331-335.

Link, H. 2000. Significance of flower and fruit thinning on fruit quality. Plant Growth Reg. 31:17–26.

Mansouri, Y.S., J. Khazaei, S.R. Hassan Beygi, and S.S Mohtasebi. 2010. Statistical modeling of pomegranate (*Punica granatum* L.) fruit with some physical attributes. J. Food Process Technol. 1:1-4.

Mars, M. 2000. Pomegranate plant material: genetic resources and breeding, overview. Opt. Mediterr. Ser. A Semin. Mediterr. 42:55–62.

Marini, R.P. and D.L. Sowers. 1994. Peach fruit weight is influenced by crop density and fruiting shoot length but not position on the shoot. J. Amer. Soc. Hort. Sci. 119:180–184.

Melgarejo, P., D.M. Salazar, and F. Artes. 2000. Organic acids and sugar composition of harvested pomegranate fruits. Euro. J. Food Res. Technol. 211:185-190.

Padmavathamma, A.S. and N.C. Hulamani. 1996. Effect of fruit thinning on yield, weight, physical and chemical parameters of pomegranate (*Punica granatum* L.) cv. Jyoti. Journal of Acharya N. G. Ranga Agricultural University Research (ANGRAU). 24:73-76.

Palmer, J.W., R. Giuliani, and H.M. Adams. 1997. Effect of crop load on fruiting and leaf photosynthesis of 'Braeburn'/M.26 apple trees. Tree Physiol. 17:741-746.

Ranganna, S. 1979. Manual of analysis of fruit and vegetable products, 2nd ed. McGraw-Hill Publishing Company Ltd, New Delhi.

Sharma, K.K. and N.P. Singh. 2000. Effect of mechanical de-blossoming on yield and quality of pomegranate (*Punica granatum* L.). J. Res., Punjab Agric. Univ. 37(3/4):203-205.

Shulman, Y., L. Fainberstein, and S. Lavee. 1984. Pomegranate fruit development and maturation. J. Hort. Sci. 59:265–274.

Singh, R. 2001. Crop regulation in tropical and subtropical fruits. Indian J. Hort. 58:33-40.

Stover, E. and E.W. Mercure. 2007. The pomegranate: a new look at the fruit of paradise. HortScience 42:1088-1092.

Stover, E., F. Wirth, and T. Robinson. 2001. A method for assessing the relationship between crop load and crop value following fruit thinning. HortScience 36:157-161.

Varasteh F. and K. Arzani. 2009. Classification of some Iranian pomegranate (*Punica granatum*) cultivars by pollen morphology using scanning electron microscopy. Hort. Environ. Biotechnol. 50(1):24-30.

Varasteh, F., K. Arzani, Z. Zamani, and A. Mohseni. 2009. Evaluation of the most important fruit characteristics of some commercial pomegranate (*Punica granatum* L.) cultivars grown in Iran. Acta Hort. 818:103-108.

Varasteh, F., K. Arzani, M. Barzegar and Z. Zamani. 2012. Changes in anthocyanins in arils of chitosan-coated pomegranate (*Punica granatum* L. cv. Rabbab-e-Neyriz) fruit during cold storage. Food Chem. 130: 267–272.

Webster, A.D. and J.E.Spencer. 2000. Fruit thinning plums and apricots. Plant Growth Reg. 31:101-112.

Wells, J.M. and M.J. Bukovac. 1978. Effect of fruit thinning on size and quality of 'Stanley plum' (*Prunus domestica* L.). J. Amer. Soc. Hort. Sci. 103:612–616.

Yawadio, R. and N. Morita. 2007. Color enhancing effect of carboxylic acids on anthocyanins. Food Chem. 105:421–427.