Growth, yield and fruit quality of three papaya cultivars grown under protected cultivation

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Abstract — Introduction. Papaya is grown mainly under tropical conditions due to its requirement of high temperatures year-round. With modern greenhouse technology and production systems, the Mediterranean countries are now able to produce many tropical crops such as banana and papaya. Such technology has also increased the yield and improved fruit quality in comparison with open field production systems. **Materials and methods**. Our study was conducted in an unheated greenhouse in the Mediterranean region of Turkey. Three papaya cultivars ('SS-45', 'BH-65' and 'Sel-42') were evaluated for their physical and physicochemical properties and yield. **Results**. There were no significant differences in chemical properties related to fruit cultivars. Conversely, certain features of the development cycle of these three cultivars varied: BH-65 flowered at only 65.4 cm compared with SS-45 (133.8 cm) and Sel-42 (135.1 cm). Fruit set was improved for Sel-42 (63.7 fruits) compared with SS-45 (49.3 fruits) and BH-65 (31.3 fruits). The corresponding yields for Sel-42, SS-45 and BH-65 were (28.3, 21.3 and 7.8) kg per plant, respectively. The Sel-42 cultivar presented the largest fruits (weight, 460.0 g; width, 11.7 cm; length, 16.7 cm), closely followed by those of SS-45 (433.3 g, 11.3 cm and 15.3 cm, respectively). In contrast, the cultivar BH-65 produced the smallest fruits (weight, 250.0 g; width, 9.7 cm; length, 13.3 cm). The physical and chemical characteristics did not vary among the cultivars. **Conclusion**. Our results allow us to recommend the cultivars Sel-42 and SS-45 for greenhouse cultivation under a Mediterranean climate in Turkey.

Turkey / *Carica papaya* / variety trials / protected cultivation / life cycle / yields / quality / fruits

Croissance, rendement et qualité des fruits de trois cultivars de papaye menés sous culture protégée.

Résumé — Introduction. Le papayer est principalement cultivé en conditions tropicales en raison de ses besoins en températures élevées toute l'année. Grâce à la technologie à effet de serre et aux systèmes modernes de production, les pays méditerranéens sont maintenant capables de produire de nombreuses cultures tropicales telles que bananiers et papayers. Une telle technologie a aussi augmenté le rendement et amélioré la qualité des fruits par rapport au système de production à l'air libre. **Matériel et méthodes**. Notre étude a été menée dans une serre non chauffée, en conditions méditerranéennes de Turquie. Trois cultivars de papaye (SS-45, BH-65, et Sel-42) ont été évalués pour leurs caractéristiques physiques et physico-chimiques et leurs rendements. **Résultats**. Il n'y a eu aucune différence significative des propriétés chimiques des fruits liée aux cultivars. A l'inverse, certaines caractéristiques du cycle de développement de ces trois cultivars ont varié ; BH-65 a fleuri à seulement 65,4 cm de hauteur par rapport à SS-45 (133,8 cm) et Sel-42 (135,1 cm) ; La nouaison a été améliorée pour Sel-42 (63,7 fruits) par rapport à SS-45 (49,3 fruits) et BH-65 (31,3 fruits). Les rendements en fruits correspondants pour les cultivars Sel-42, SS-45 et BH-65 ont été de (28,3, 21,3 et 7,8) kg par plante, respectivement. Le cultivar Sel-42 a présenté les fruits les plus gros (poids, 460,0 g ; largeur, 11,7 cm ; longueur, 16,7 cm), suivi de près par ceux de SS-45 (433,3 g, 11,3 cm et 15,3 cm, respectivement). En revanche le cultivar BH-65 a produit les fruits les plus petits (poids, 250,0 g ; largeur, 9,7 cm ; longueur, 13,3 cm). Les caractéristiques physico-chimiques n'ont pas varié entre les cultivars. **Conclusion**. Nos résultats nous permettent de recommander les cultivars Sel-42, puis SS-45, pour la culture sous serre sous climat méditerranéen de Turquie.

Turquie / *Carica papaya* / essai de variété / culture sous abri / cycle de développement / rendement / qualité / fruits

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1. Introduction

Tropical fruits are grown in very limited countries in Europe due to the climatic constraints. Therefore, tropical fruit demands in Europe are mainly supplied by tropical countries. However, some of them are grown due to a favorable climate on the Mediterranean coast and Atlantic Islands for local consumption [1]. Among the tropical crops, banana is the most important one grown under subtropical conditions on the Canary Islands (Spain), and in Morocco, Israel, the Algarve region of Portugal, Crete, Cyprus, Turkey, Tunisia, Italy (Sicily and Sardinia) and Argentina [2, 3]. In addition to banana, other tropical fruit species such as pineapple, loquat, papaya, mango, litchi, guava, carambola and cherimoya are cultivated on a small scale under net or protected cultivation in subtropical conditions [2].

Carica papaya L. (papaya), which belongs to the family *Caricaceae*, is grown worldwide under tropical climates [4] but also in mild subtropical climates [5, 6]. Nevertheless, under subtropical conditions, the cold temperature in the winter season affects fruit set, and fruit growth and production [5]. Therefore, protected cultivation provides a big advantage to prevent cold damage and to allow supply of fruits to market throughout the seasons. The ripe papaya fruits are commonly eaten fresh but green papaya fruit is used as a vegetable, usually after cooking or boiling [7]. Nutritionally, papaya is a good source of Ca and vitamins A and C [8–10]. It also contains small amounts of thiamin, riboflavin, iron, potassium, magnesium and sodium.

Papaya is cultivated under protected cultivation in subtropical countries such as the Canary Islands (Spain), Israel and Japan [6]. However, optimum growth and development occur during the hot summer months when 2.5 (average) new leaves appear every week even in subtropical conditions [5]. Nakasone and Paul [9] reported that environmental factors such as light, wind, edaphic soil characteristics, temperature, soil relative humidity, and biotic factors such as mycorrhizal fungi and genotype significantly affect the productivity and physiology of papaya [11]. Besides environmental factors, fruit chemical features are also affected by location and season [5, 12, 13], and maturity stage [14]. Temperatures below 20 °C have a very negative effect, causing among other problems, carpelloidy, sex changes, reduced pollen viability, and low sugar content of the fruit. Furthermore, at temperatures below 12–14 °C for several hours, growth and production are severely affected [9], particularly in dioecious cultivars. Under subtropical conditions, papaya growth ceases at temperatures below 11 °C [5, 15]; therefore, protected cultivation of papaya in a subtropical region may provide the optimal environment for its growth and productivity.

Although papaya is well known for its wide adaptability to tropical and subtropical environments, significant decline in the key physiological indices occurs when plants are exposed to high ambient temperature, photosynthetic photon flux density and soil water deficit, that directly affects plant growth and fruit yield [16]. Greenhouse cultivation simultaneously provides both adequate temperatures and exclusion of Papaya Ring Spot Virus (PRV) [6]. Growth and flowering benefit from the climate within greenhouses, resulting in improved yields, both in fruit quantity and quality, with the critical additional benefit of the exclusion of PRV [6]. Therefore, it is extremely important to determine yield and quality features of papaya under protected cultivation.

The objective of our study was to select suitable papaya cultivars and to compare yields and fruit quality parameters under unheated plastic-greenhouse cultivation in the Mediterranean region of southern Turkey.

2. Materials and methods

2.1. Plant material and environmental conditions

Seeds were provided by the Institute for Tropical Crops in South Africa (ARC). The plant material evaluated included seeds of the cultivars 'SS-45', 'BH-65' and 'Sel-42' (hermaphrodite line) which were bred in

that institute. The study was conducted in 2007 and 2008 in the experimental field of the Seed Research and Development Center of Akdeniz University in Antalya, Turkey (alt. 38 m, lat. 36° 54' N, long. 30° 38' E, temperatures given in *figure 1*). The average relative humidity was recorded above 60% during the vegetation period.

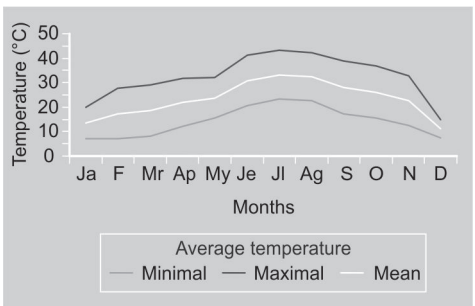

Figure 1.
Evaluation of the temperatures during the year under protected cultivation (Antalya, Turkey, 2007–2008).

The greenhouse structure was made of galvanized steel iron; it was 6-m high at the center and tapered down to 5 m at gutter level; it was covered with Low Density Polyethylene (LDPE) plastic (UV+IR and 150-µm thick, for 36 months). The greenhouse was ventilated from the sides to the top and was not heated during the two growing seasons. Soil pH at 0–60 cm was 7.0; organic matter content was 4%, and soil texture was a clay-loam. Plants were planted on April 2007, spacing was 3.0 m × 1.8 m (1850 plants·ha^{-1}) and a double-line drip irrigation system was installed for each row. Fertilization was applied to each plant during the vegetative phase with, for each plant: 350 g of nitrogen (NH_4SO_4), 225 g of phosphorous (MAP), 550 g of potassium (KNO_3), 25 g of magnesium ($MgSO_4$) and 5 g of calcium ($CaNO_3$).

2.2. Morphological features

Plant height (distance from soil level to growing point), stem circumference (at 20 cm above soil level), leaf number, height at first flowering, and days from planting to flowering and from first flowering to harvest were recorded. Fruit set (fruit number per plant) and yield (kg per plant) were also evaluated.

2.3. Fruit physical features

Fruit weight (g), length (cm) and width (cm) were measured using a top pan balance and a digital caliper. The fruits were harvested at a commercially ripe stage when the peel color approached 25% yellow. Fruit skin color was measured by using a Minolta (Japan) (CR-200) colorimeter and reported as L^*, a^* and b^*. This method gives numeric values of three chromatic scales (L, a, b). L^* is the brightness, ranging from no reflection for black (L = 0) to perfect diffuse reflection for white (L = 100). The value a^* is the redness, ranging from negative values for green to positive values for red. The value b^* is the yellowness, ranging from negative values for blue to positive values for yellow.

2.4. Physicochemical characteristics

The flesh firmness was determined on three sides of the fruit using a penetrometer (Effegi, 48011 Alfonsine, Italy) with a 1.5-cm diameter tip depressed 2 mm into the fruit after harvest. The juice extracted from the homogenized flesh of the fruits from each cultivar was used for monitoring Total Soluble Solids (TSS) using a handheld refractometer (Atago N1). Vitamin C content was measured by using the 2,6-dichlorophenolindophenol titration method. The titratable acidity measurements were made using 0.1 N NaOH solution. All physicochemical analyses were done on April-harvested fruits.

2.5. Experimental design and statistical analysis

The experiment was laid out in a completely randomized design with three replications. Six plants were sampled for plant growth, morphological characteristics and yield components. Five fruits were randomly selected for evaluating fruit features, fruit color and physicochemical characteristics of

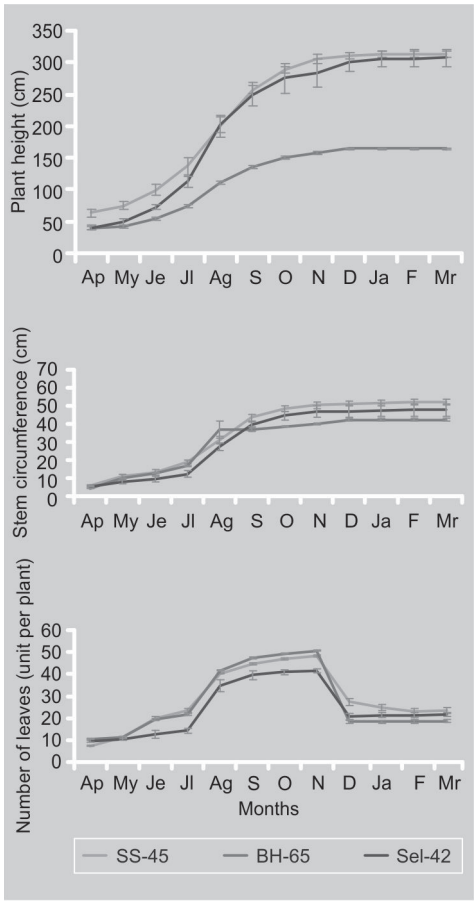

Figure 2.
Monthly plant height, stem circumference and number of leaves for the SS-45, BH-65 and Sel-42 papaya cultivars grown under protected cultivation (Antalya, Turkey).

Figure 3.
General view of papaya plants grown under protected cultivation.

each cultivar. The data were analyzed in a completely randomized design using analysis of variance (ANOVA). Means were separated by the LSD multiple range test at the 0.05 level of probability.

3. Results and discussion

The results for the three cultivars of papaya studied showed that plant height was similar during the early growing period (March-April) in all cultivars; it increased significantly in SS-45 and Sel-42, and attained its maximum height (308.3 cm and 300.3 cm, respectively) during the period August-September as compared with BH-65 (162.9 cm) (*figure 2*). A general view of the plants is given in *figure 3*. Data on stem circumference and number of leaves formed during the periods of growth demonstrated a similar trend to that of plant height, with maximum stem circumference attained in SS-45 (52.0 cm), followed by Sel-42 (47.8 cm), showing significant differences as compared with that for plants of BH-65 (42.4 cm) (*figure 2*). However, the total number of leaves produced did not show any significant differences in all the cultivars during the entire growth period (*figure 2*). Similar varietal differences in plant height, stem girth and leaf number per plant were also obtained by Jeyakumar *et al.* [16], and Galan Sauco and Rodriguez Pastor [6], who attributed phenological differences to genetic dissimilarity in growth responses among different cultivars. Furthermore, among the cultivar differences, cultivation systems affect growth and fruit quality. For instance, Galan Sauco and Rodriguez Pastor [6] reported that growing papaya under greenhouse conditions results in a more beneficial period of growth and fruit quality due to both higher temperatures and wind protection.

The morphological parameters recorded for the cultivars SS-45, BH-65 and Sel-42 (*figure 4*) varied significantly, except for the number of days to first flowering (119.7 days, 125.3 days and 124.7 days, respectively) and to final fruit harvesting (237.0 days, 235.7 days and 237.7 days, respectively) (*table I*). The cultivar BH-65

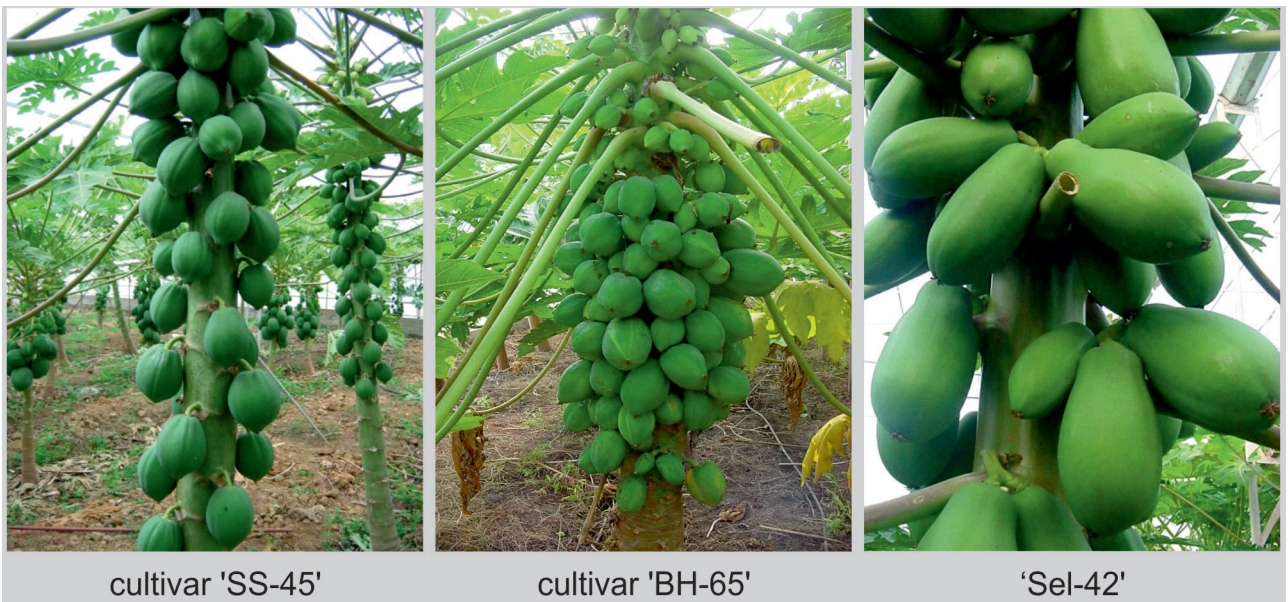

Figure 4.
General views of fruits on three papaya cultivars studied regarding their growth, yield and fruit quality under protected cultivation (Antalya, Turkey).

flowered at a plant height of 65.4 cm, which was significantly different from the other cultivars SS-45 (133.8 cm) and Sel-42 (135.1 cm). Annual fruit number was recorded; the highest was for Sel-42 (63.7 fruits); this number significantly differed from SS-45 (49.3 fruits) and BH-65 (31.3 fruits) along with their corresponding fruit yields (28.3 kg, 21.3 kg and 7.8 kg, respectively) harvested per plant, being exceptionally low for BH-65.

Fruit features recorded for the three papaya cultivars grown under a standard ventilated greenhouse indicated that fruits harvested from BH-65 differed significantly from those of SS-45 and Sel-42 with respect to their individual weight, width and length (*table II*). Maximum fruit weight (460.0 g); width (11.7 cm) and length (16.7 cm) were obtained in Sel-42 and followed by SS-45 (433.3 g, 11.3 cm and 15.3 cm, respectively). BH-65 produced the smallest fruits with lowest fruit weight (250.0 g), width (9.7 cm) and length (13.3 cm) as compared

Table I.
Morphological features, fruit set and yield in three papaya cultivars grown under protected cultivation (Antalya, Turkey).

Cultivar	First flowering height (cm)	Time from planting to flowering (day)	Time from first flowering to harvest (day)	Fruit set (number per plant)	Yield (kg per plant)
SS-45	133.8 a	119.7	237.0	49.3 b	21.3 b
BH-65	65.4 b	125.3	235.7	31.3 c	7.8 c
Sel-42	135.1 a	124. 7	237.7	63.7 a	28.3 a
$LSD_{0.05}$	10.18	Not significant	Not significant	8.10	3.65

Means followed by the same letter are not significantly different according to LSD, $P < 0.05$.

Table II.
Physical fruit features in three papaya cultivars grown under protected cultivation (Antalya, Turkey).

Cultivar	Fruit weight (g)	Fruit width (cm)	Fruit length (cm)
SS-45	433.3 a	11.3 ab	15.3 b
BH-65	250.0 b	9.7 b	13.3 c
Sel-42	460.0 a	11.7 a	16.7 a
$LSD_{0.05}$	81.30	1.77	0.76

Means followed by the same letter are not significantly different according to LSD, $P < 0.05$.

Table III.
Fruit skin color in three papaya cultivars grown under protected cultivation (Antalya, Turkey).

Cultivar	Fruit color		
	L*	a*	b*
SS-45	62.7 b	13.7	56.0
BH-65	63.0 ab	13.8	55.0
Sel-42	64.2 a	13.8	55.1
$LSD_{0.05}$	1.42	Not significant	Not significant

Means followed by the same letter are not significantly different according to LSD, $P < 0.05$.

Table IV.
Physicochemical characteristics of three papaya cultivars grown under protected cultivation (Antalya, Turkey).

Cultivars	Fruit firmness ($kg \cdot cm^{-2}$)	Soluble solid content (%)	Vitamin C ($mg \cdot 100\ g^{-1}$)	Titrable acidity (%)
SS-45	2.1	9.5	77.3	0.2
BH-65	2.1	9.6	77.0	0.2
Sel-42	2.1	10.0	77.3	0.2
$LSD_{0.05}$	Not significant	Not significant	Not significant	Not significant

with the other cultivars. Similar differences in postharvest fruit characteristics (weight, length, equatorial perimeter, shape and color) were recorded in hermaphrodite fruits by Delgado *et al.* [17]. These authors also demonstrated that these fruits were consumer-acceptable as indicated by their demand in the European markets. However, there were no significant differences among fruit cultivars with respect to their edible fraction, which averaged over 50%.

The harvested fruits of Sel-42 varied significantly in their skin color as compared with SS-45 but remained equal to those of BH-65 in terms of *L** values (64.2, 63.0 and 62.7, respectively) (*table III*). However, the skin color of the fruits did not show differences in *a** and *b** measurement levels within all cultivars. These results are in agreement with those reported by Delgado *et al.* [17]. The physicochemical characteristics of the fruits showed some variation among the cultivars with respect to fruit firmness, total soluble solid content, vitamin C and titrable acidity but the differences were not significant between the tall (SS-45 and Sel-42) and the dwarf (BH-65) cultivars. Therefore, dwarf papaya genotypes could be used to breed suitable cultivars for greenhouse cultivation to achieve a sustainable crop with an enhanced fruit yield and quality characters [18].

4. Conclusion

Our results allow us to recommend the cultivar Sel-42, followed by SS-45, for cultivation under greenhouse conditions in the Mediterranean region of Turkey.

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Crecimiento, rendimiento y calidad de los frutos de tres cultivares de papaya criados en cultivo protegido.

Resumen – Introducción. El papayo se cultiva principalmente en condiciones tropicales, dada su necesidad de temperaturas elevadas durante todo el año. Gracias a la tecnología de efecto invernadero y a los sistemas modernos de producción, los países mediterráneos ahora son capaces de producir numerosos cultivos tropicales, tales como bananos y papayos. Una tecnología semejante también aumentó el rendimiento y mejoró la calidad de los frutos, en comparación con el sistema de producción al aire libre. **Material y métodos**. Nuestro estudio se llevó a cabo en un invernadero no calentado, en condiciones mediterráneas de Turquía. Se evaluaron tres cultivares de papaya (SS-45, BH-65, y Sel-42) por sus características físicas y físico-químicas y por sus rendimientos. **Resultados**. No hubo ninguna diferencia significativa de las propiedades químicas de los frutos relacionadas con los cultivares. Al contrario, algunas características del ciclo de desarrollo de estos tres cultivares variaron; BH-65 floreció con tan sólo 65,4 cm de altitud, en relación con SS-45 (133,8 cm) y Sel-42 (135,1 cm). La fructificación se mejoró para Sel-42 (63,7 frutos), en relación con SS-45 (49,3 frutos) y BH-65 (31,3 frutos). Los rendimientos de frutos correspondientes en los cultivares Sel-42, SS-45 y BH-65 fueron de (28,3, 21,3 y 7,8) kg por planta, respectivamente. El cultivar Sel-42 presentó los frutos más grandes (peso, 460,0 g; anchura, 11,7 cm; longitud, 16,7 cm), seguido de cerca por los de SS-45 (433,3 g, 11,3 cm y 15,3 cm, respectivamente). En cambio, el cultivar BH-65 produjo los frutos más pequeños (peso, 250,0 g; anchura, 9,7 cm; longitud, 13,3 cm). Las características físico-químicas no variaron entre los cultivares. **Conclusión**. Nuestros resultados nos permiten recomendar los cultivares Sel-42, así como SS-45, para el cultivo en invernadero en clima mediterráneo de Turquía.

Turquía / *Carica papaya* / ensayos de variedades / cultivo protegido / ciclo vital / rendimiento / calidad / frutas