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Growth, Yield, and Quality of Sweet Potato (*Ipomoea batatas* (L.) Lam.) Cultivars in the Southeastern Anatolian and East Mediterranean Regions of Turkey

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Abstract: The study was carried out to determine the adaptation potential of sweet potato crops to different regions of Turkey. The study included 9 introduced genotypes of diverse origin and 2 local genotypes that were tested in 4 locations (Diyarbakır and Şanlıurfa representing the southeastern Anatolia region, and Adana and Hatay representing the Mediterranean region) in 2000 and 2001. Haulm and storage root growth of the cultivars were monitored at monthly intervals. Total and graded storage root yield, and some quality parameters were determined at the final harvest. Although haulm and storage growth varied according to location and year, all cultivars showed rapid growth from the 90th to 120th day after planting (DAP), at all locations. Storage root formation started between the 30th and 60th DAP at all locations. Total storage root yield, according to cultivar, location, and year, varied from 6.72 to 112.60 t ha^{-1}, and the introduced genotypes produced higher yields than the local genotypes. Cultivars showed significant diversity in quality traits, such as dry matter content, alcohol insoluble solids content, protein content, and total carotenoid content. This study revealed that sweet potato could be adapted to both the Mediterranean and southeastern Anatolia regions of Turkey, and that high yield values could be achieved in these areas.

Key Words: Sweet potato, yield, adaptation, growth, Mediterranean, southeastern Anatolia

Tatlıpatates Çeşitlerinin (*Ipomoea batatas* (L.) Lam.) Türkiye'de Güneydoğu Anadolu ve Doğu Akdeniz Bölgelerindeki Büyüme, Verim ve Kaliteleri

Özet: Bu çalışma, tatlıpatates bitkisinin Türkiye'nin farklı bölgelerine adaptasyon potansiyelinin belirlenmesi amacıyla 2000 ve 2001 yıllarında yürütülmüştür. Çalışmada farklı kökene sahip dokuz introdüksiyon çeşidi ve iki yerel çeşit, ülkemizin Güneydoğu Anadolu bölgesini temsil eden Diyarbakır ve Şanlıurfa illeri ile Akdeniz bölgesini temsil eden Adana ve Hatay illeri olmak üzere dört farklı lokasyonda denemeye alınmışlardır. Çeşitlerin pir ve depo-kök büyümeleri yetişme dönemi boyunca aylık aralıklarla takip edilmiştir. Yetişme dönemi sonunda yapılan hasatta ise farklı irilik sınıfları ve toplam depo-kök verimleri ile bazı kalite özellikleri tespit edilmiştir. Çeşitlerin pir ve depo kök büyümeleri lokasyon ve yıllara göre değişiklik göstermekle birlikte, tüm çeşitler bütün lokasyonlarda dikimden sonraki 90 ile 120. günler arasında hızlı bir büyüme göstermişlerdir. Çeşitlerde depo-kök oluşumu tüm lokasyonlarda dikimden sonraki 30 ile 60. günler arasında olmuştur. Toplam depo-kök verimi çeşitlere, lokasyonlara ve yıllara bağlı olarak 6.72 ile 112.60 t ha^{-1} arasında değişim göstermiş ve introdüksiyon çeşitleri yerel çeşitlere göre daha yüksek verim vermişlerdir. Denemeye alınan çeşitler, tüm lokasyonlarda kuru madde oranı, alkolde çözülemeyen katılar oranı, protein oranı ve toplam karotenoid içeriği gibi kalite özellikleri açısından önemli farklılıklar göstermişlerdir. Sonuç olarak bu çalışma, tatlıpatatesin Türkiye'nin Güneydoğu Anadolu ve Akdeniz bölgelerine adapte olabileceğini ve bu bölgelerde yüksek verim değerleri elde edilebileceğini göstermiştir.

Anahtar Sözcükler: Tatlıpatates, adaptasyon, büyüme, verim, Akdeniz, Güneydoğu Anadolu

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Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam.) is grown in more than 100 countries in tropical, subtropical, and temperate climates. It ranks as the world's seventh most important crop, with an estimated annual production of approximately 122 million metric tons (FAO, 2006). Sweet potato is a major staple food in Africa, Asia, the Caribbean, and South America, where they are important sources of carbohydrates, vitamins A and C, fiber, iron, potassium, and protein (Woolfe, 1992). In developing countries, sweet potato is especially valued because it is highly adaptable, and tolerates high temperatures, low fertility soil, and drought (Yencho et al., 2002). Sweet potato is also used as animal feed, which has been a by-product of crops grown for human consumption. Increasing recognition of the great potential of the sweet potato crop as a nutritious food for humans and animals has resulted in intensified research efforts to enhance production and consumption in recent decades (Woolfe, 1992; Yamakawa and Yoshimoto, 2002).

Sweet potato is currently grown only in a limited area in Hatay province, located in the East Mediterranean region of Turkey. Two different genotypes, which probably came from Cyprus in the early 1900s, are grown in the region. Storage roots of these old genotypes are relatively fibrous and irregularly shaped, as well as having low yield potential compared to commercial varieties. Until now, studies on the adaptation of sweet potato in Turkey have been neglected, although suitable agro-ecological regions exist throughout the Mediterranean region and southeastern Anatolia. Though both the Mediterranean and southeastern Anatolia regions have hot and dry summers, the day-night temperature difference is greater and relative humidity is lower in the southeastern Anatolia region. Therefore, sweet potato can perform better in the southeastern Anatolia region. To the best of our knowledge there are no previous studies on the adaptability of sweet potato to the southeastern Anatolia region.

Current acceptability of the crop by both growers and consumers suggests that sweet potato crops could also be accepted in other parts of the country if better genotypes, with respect to both yield and quality, were available. Genotype × environment interaction has a significant effect on yield and yield components of sweet potato (Bacusmo et al., 1988; Abidin et al., 2005; Grüneberg et al., 2005; Caliskan et al., 2007); therefore, determination of the most suitable cultivar for a certain location is as important as determination of the adaptability of crops to different locations. Knowledge of the growth and development processes of a crop, from planting to harvest, is also very important for understanding the physiological behavior of the crop. It would allow better interpretation of the results, within the context of processes and resource exploitation, and how production practices should be manipulated. Furthermore, knowledge of the physiological components of yield in a certain environment could be useful in breeding programs aimed at yield improvement. The objective of this study was to determine the growth and development processes, and yield and quality traits of sweet potato cultivars in grown in the southeastern Anatolia and Mediterranean regions of Turkey.

Materials and Methods

The study included 9 sweet potato cultivars of diverse origin [Regal, NC-262, NC-1508, and Kafr El Zayat No. 1 (USA); Yan Shu-1 and Fongsu No. 1 (China); Tamayukata, Kyukei No. 63, and Satsumahikari (Japan)] obtained from The International Potato Center, Peru, and 2 local cultivars (Hatay Kırmızı and Hatay Beyaz), which were tested at 4 locations during 2 years. The 4 locations (Hatay, Adana, Diyarbakır, and Şanlıurfa) were chosen to represent the Mediterranean and southeastern Anatolian regions, both considered suitable areas in Turkey for sweet potato cultivation, with respect to climate. Location descriptions are given in Table 1.

The experiments were laid out as randomized complete block designs with 3 replications at each location. Each plot consisted of 4 rows spaced 75 cm apart and 7 m in length. Vine cuttings containing 5-6 nodes were hand-planted 35 cm apart in the crests of the ridges in each row and immediately furrow-irrigated. Fertilizer in composed form (15-15-15 NPK) was applied at the rate of 75 kg ha^{-1} for each of N, P, and K, before ridging, and an additional 52 kg ha^{-1} of nitrogen in urea form was side dressed at each experimental site. Weeds were controlled by hand and plots were furrow-irrigated at approximately 10-day intervals during the summer period. Final harvests were delayed due to autumn rainfall and, consequently, chilling injury occurred on vines at Hatay and Adana in 2001.

Table 1. Description of experimental locations.

		Adana	Hatay	Şanlıurfa	Diyarbakır
Region		East Mediterranean	East Mediterranean	Southeast Anatolia	Southeast Anatolia
Coordinates		36° 59′N, 35° 18′E	36° 39′N, 36° 40′E	37° 08′N, 38° 46′E	37° 54′N, 40° 14′E
Altitude		23 m	83 m	375 m	630 m
Soil characteristics		Entisol, clay loam, slightly alkaline, low in organic matter, medium in P_2O_5, and high in K_2O	Entisol, clay loam, slightly alkaline, low in organic matter, medium in P_2O_5, and high in K_2O	Aridisol, alluvial, clay, slightly alkaline, low in organic matter medium in P_2O_5, and high in K_2O	Aridisol, alluvial, clay loam, slightly alkaline, low in organic matter medium in P_2O_5, and high in K_2O
Climate type		Mediterranean	Mediterranean	Dry semi-arid	Dry semi-arid
Annual rainfall		647 mm	1100 mm	473 mm	496 mm
Temperature (°C)	Max.	28.1 (August)	29.5 (August)	31.5 (July)	31.0 (July)
	Min.	9.3 (January)	5.0 (January)	4.9 (January)	1.7 (February)
	Mean	18.9	18.0	18.0	15.8
Planting dates	2000	May 23	June 2	May 12	May 13
		June 5	June 8	May 25	May 29
		November 23	November 30	November 9	November 7
	2001	November 24	December 20	November 12	November 11
Harvest dates	2000				
	2001				

Five plants per plot were harvested at approximately 30-day intervals throughout the growing period. Plants were separated to the haulms and storage roots, and the weight of each part was determined. Haulm dry weight was determined after drying at 70 °C for 48 h in a forced air oven. Changes in storage root and haulm dry weight of the cultivars during the growing period are illustrated in Figures 1-8. At final harvest, storage roots were graded as No. 1 roots (diameter of 4.4 cm ≤ 8.9 cm and length of 7.6 cm ≤ 22.9 cm), canner roots (diameter of 2.5 cm ≤ 4.4 cm), jumbo roots (diameter > 8.9 cm), and cull roots (malformed or distorted roots), according to the US Department of Agricultural Marketing Service (1981). Average number of storage roots per plant was also determined by dividing the storage total number by the number of plants harvested. Five storage roots per plot were randomly sampled at the final harvest for quality analysis and immediately cured for 7 days at 30 ºC and 85%-90% relative humidity (Picha, 1985). The quality analysis could not be performed in 2000 due to the lack of adequate laboratory facilities.

Dry weight was determined by drying 10.00 g of fresh tissue at 70 ºC for 48 h in a forced air oven and was expressed as a percentage (Picha, 1985). The dried tissues were also ground and analyzed for protein content by the Kjeldahl method (Picha, 1985). To determine alcohol insoluble solids (AIS), exactly 10.00 g of tissue was homogenized in 50 ml of 80% ethanol using a homogenizer at low speed with a 10 mm shaft. The resulting slurry was immediately boiled until the volume of sample decreased to 50 ml, and was then cooled and filtered through Whatman no. 4 paper. The residue and original container were washed with additional 80% ethanol. The ethanol-insoluble residue left on the top of the filter paper was weighed after 24-h drying at 30 ºC to determine AIS percent content (Picha, 1987).

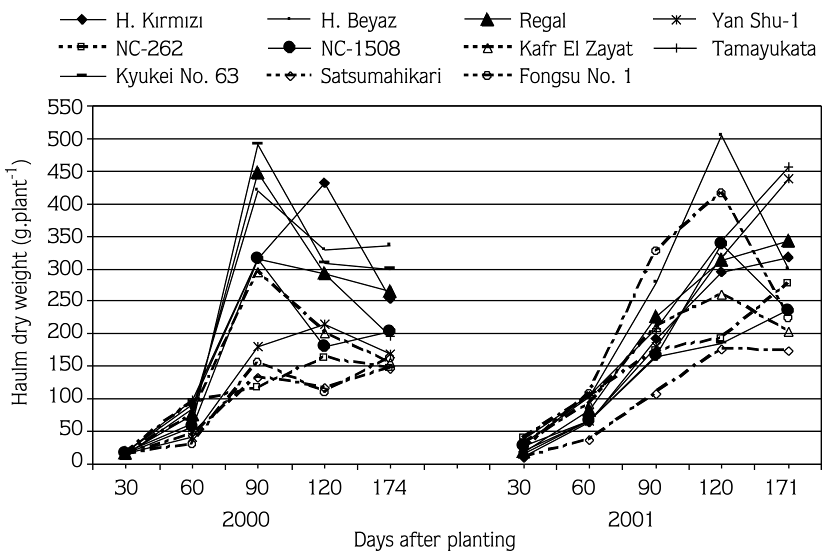

Figure 1. Haulm growth of sweet potato cultivars throughout the 2 growing periods in Diyarbakır.

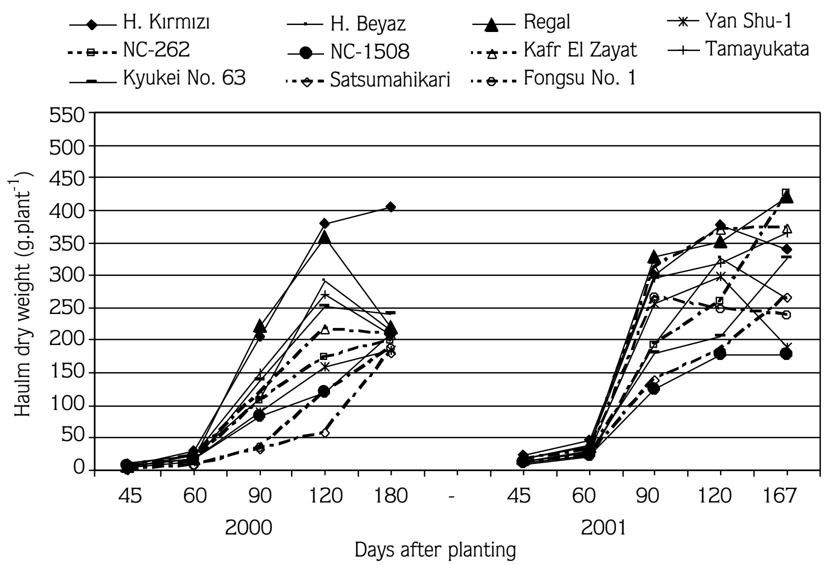

Figure 2. Haulm growth of sweet potato cultivars throughout the 2 growing periods in Şanlıurfa.

Total carotenoids were determined spectrophotometrically according to the procedure described by Picha (1985). Exactly 1 g of tissue was extracted until colorless with 10 ml of HPLC grade hexane, using a homogenizer. The sample was then filtered through Whatman no. 1 paper into a 50-ml bottle and a final volume of 50 ml was made with additional hexane. The absorbance of 3 ml of sample was read at 440 nm. The concentration of β-carotene was calculated from a β-carotene standard curve and expressed as mg 100 g^{-1} fresh weight. The content of total carotenoid was measured in terms of β-carotene because it is the main carotenoid of sweet potato, accounting for 86% to 90% of the carotenes present (Picha, 1985).

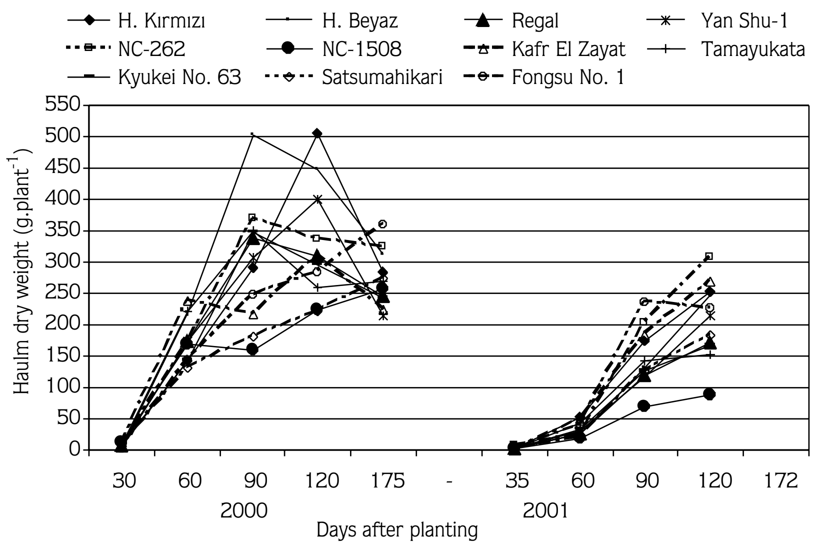

Figure 3. Haulm growth of sweet potato cultivars throughout the 2 growing periods in Adana.

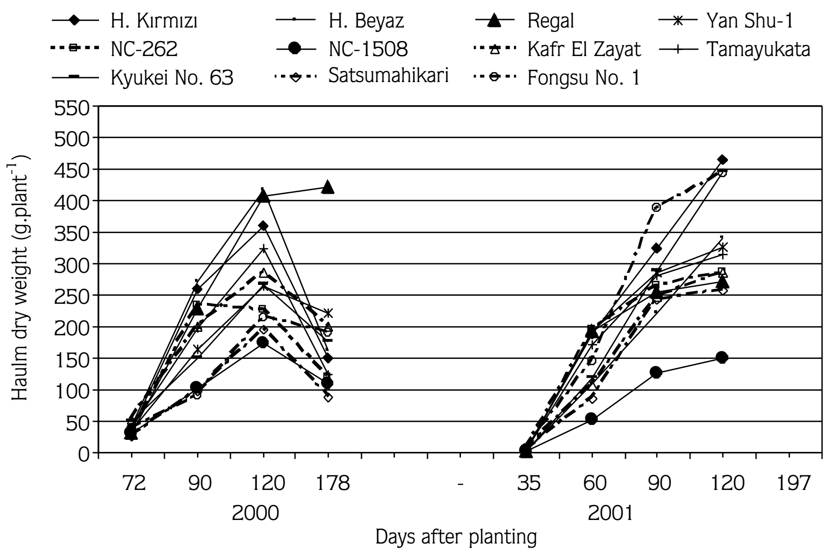

Figure 4. Haulm growth of sweet potato cultivars throughout the 2 growing periods in Hatay.

Data for each location, cultivar, and year were analyzed in a completely randomized block design by ANOVA with SAS software (SAS Institute; Cary, NC, USA). The least significant differences (LSD) test was used for the comparison of means.

Results

Haulm growth

Changes in the haulm dry weight per plant (HDW) during the growth period at different locations are shown in Figures 1-4. HDW of all the cultivars in Diyarbakır increased until the 90th day after planting (DAP), while

HDW of most of the cultivars tended to decrease after the 90th DAP in 2000. HDW of Kyukei No. 63 and Regal peaked on the 90th DAP, but their HDW values dramatically decreased after that date. At final harvest, HDW of all the cultivars ranged from 146 to 335 g $plant^{-1}$. Haulm growth of the cultivars continued until the 120th DAP in 2001. Hatay Beyaz and Fongsu No. 1 reached their highest HDW level on the 120th DAP, but they decreased considerably after that. Haulm growth of Yan Shu-1 and Tamayukata continued until final harvest, and they produced the highest HDW at the final harvest.

In Şanlıurfa, haulm growth of the cultivars increased until the 120th DAP in 2000 (Figure 2). The highest value was obtained from Hatay Kırmızı (379 g $plant^{-1}$), followed by Regal (359 g $plant^{-1}$) on the 120th DAP in 2000. Then, HDW of some cultivars (Regal, Hatay Beyaz, Tamayukata, Kyukei No. 63, and Kafr El Zayat No. 1) decreased, while HDW of the other cultivars continued to increase. Hatay Kırmızı reached an HDW of 404 g $plant^{-1}$ at the final harvest. In 2001, HDW of all the cultivars increased rapidly until the 90th DAP, then the rate of increase declined, except for Fongsu No. 1. Most of the cultivars had a decreasing trend in HDW after the 120th DAP, whereas Regal, NC-262, Tamayukata, and Satsumahikari had increasing trends in HDW until final harvest.

HDW values increased until the 90th and 120th DAP, according to cultivar, in Adana in 2000 (Figure 3). Hatay Beyaz (503 g $plant^{-1}$) and Hatay Kırmızı (505 g $plant^{-1}$) had the highest HDW on the 90th and 120th DAP, respectively. HDW could not be measured due to frost injury at the end of the 2001 growing period. Haulm growth of all cultivars showed an increasing trend until the 120th DAP, except Tamayukata and Fongsu No. 1, in 2001.

At the Hatay location all the cultivars showed strong haulm growth in the first 120 days in 2000, except NC-262 (Figure 4). Haulm growth of most of the cultivars dramatically decreased after the 120th DAP, whereas haulm growth of Regal increased until final harvest. HDW could not be measured due to frost injury at the end of the 2001 growing season in Hatay. HDW in all cultivars increased until the 120th DAP in 2001, and Hatay Kırmızı (465 g $plant^{-1}$), Kyukei No. 63 (445 g $plant^{-1}$), and Fongsu No. 1 (444 g $plant^{-1}$) had higher HDW on the 120th DAP.

Storage root growth

Storage root formation started between the 60th and 90th DAP in Diyarbakır in 2000 (Figure 5). The Yan Shu-1 and Kafr El Zayat No. 1 cultivars produced the highest storage root weight per plant (SRW), from root formation until final harvest, although some reductions in their SRW

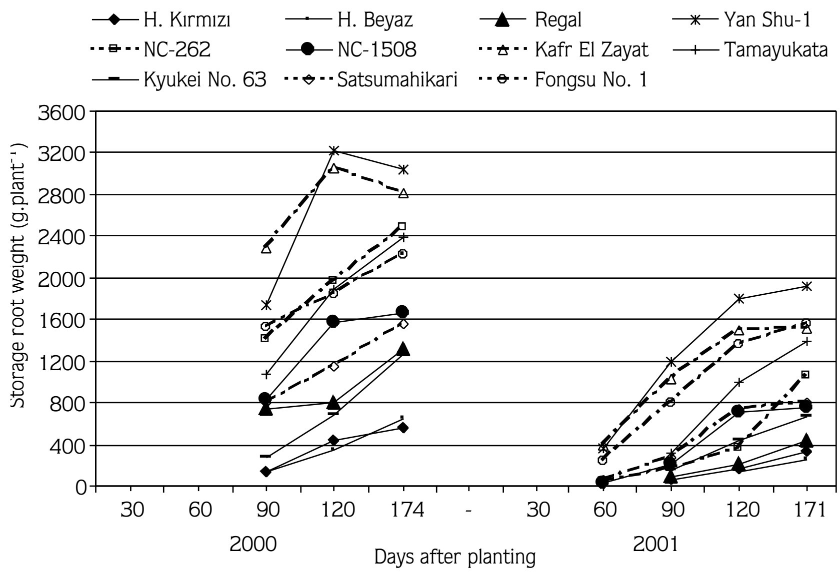

Figure 5. Storage root growth of sweet potato cultivars throughout the 2 growing periods in Diyarbakır.

were recorded after the 120th DAP. SRW of the other cultivars continued to increase at different rates until final harvest. In the 2001, lower SRW values were recorded in all the cultivars, while storage root formation in some cultivars (Kafr El Zayat No. 1, Yan Shu-1, Satsumahikari, Fongsu No. 1, NC-1508, and NC-262) started earlier (before the 60th DAP) compared to 2000. The increase in SRW of the cultivars was the highest between the 90th and 120th DAP, but continued until final harvest. Yan Shu-1, Kafr El Zayat No. 1, and Fongsu No. 1 had the highest SRW, while the 2 local cultivars and Regal had the lowest SRW throughout the growing period.

SRW of the cultivars in Şanlıurfa are given in Figure 6. In 2000, SRW was first recorded on the 75th DAP. SRW increased until final harvest, except for Satsumahikari and Tamayukata. Kafr El Zayat No. 1 and Yan Shu-1 had the highest SRW on the 120th DAP, 2246 g plant^{-1} and 2087 g plant^{-1}, respectively. SRW of these cultivars was still the highest at final harvest. Fongsu No. 1 and NC-262 showed continuously increasing SRW during the growing period. SRW of all cultivars in 2001 was lower than in 2000; however, some cultivars (Yan Shu-1, Kafr El Zayat No. 1, and Satsumahikari) initiated storage root formation earlier (before the 60th DAP) in 2001. Generally, the cultivars showed rapid storage root growth until the 120th DAP, and then the growth rate decreased. Fongsu No. 1, Yan Shu-1, and Kafr El Zayat No. 1 had the highest SRW on the 120th DAP and final harvest. The storage root growth of Regal was slow early in the season and accelerated toward to the end of the season in both years.

At the Adana location in 2000, storage root formation started before the 60th DAP in most cultivars, while it started later in Hatay Kırmızı, Hatay Beyaz, Regal, and Kyukei No. 63 (Figure 7). Kafr El Zayat No. 1 and Yan Shu-1 had the highest SRW on the 60th DAP. These cultivars showed very rapid root growth between the 90th and 120th DAP, and reached an SRW of 2449 g plant^{-1} and 1988 g plant^{-1}, respectively, on the 120th DAP; however, SRW of Kafr El Zayat No. 1 decreased after the 120th DAP. Storage root growth of Fongsu No. 1 accelerated after the 120th DAP and had the highest SRW together with Kafr El Zayat No. 1 and Yan Shu-1 at final harvest. In 2001, 4 cultivars (Fongsu No. 1, Yan Shu-1, Kafr El Zayat No. 1, and Satsumahikari) initiated storage root formation before the 66th DAP, while the initiation occurred between the 66th and 90th DAP in the other cultivars. Fongsu No. 1, Kafr El Zayat No. 1, and Yan Shu-1 performed rapid storage root growth during the growing period and had the highest SRW at final harvest. Other cultivars also showed an increasing trend in SRW until final harvest. The 2 local cultivars and Regal had the lowest SRW in both years.

In Hatay in 2000, all the cultivars, except for Hatay Kırmızı and Regal, initiated storage root formation before the 72nd DAP (Figure 8). SRW increased at a different rate in all the cultivars until final harvest, except

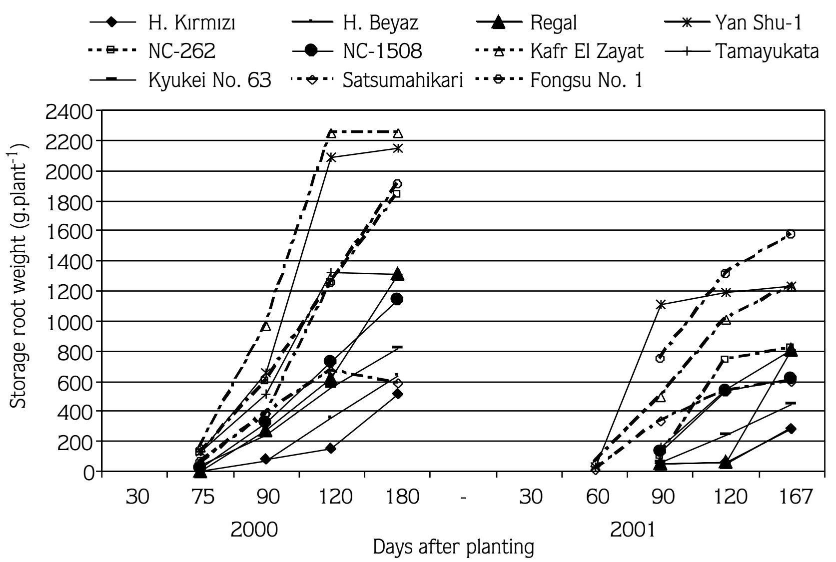

Figure 6. Storage root growth of sweet potato cultivars throughout the 2 growing periods in Şanlıurfa.

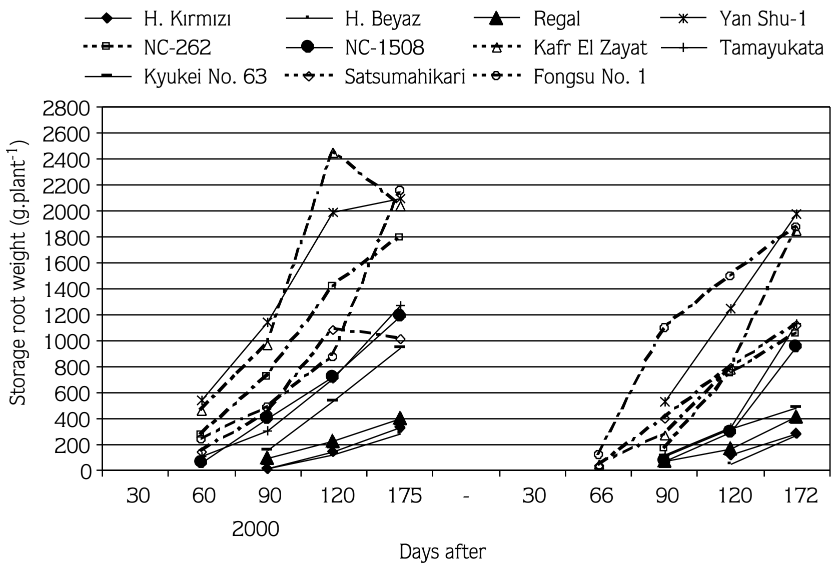

Figure 7. Storage root growth of sweet potato cultivars throughout the 2 growing periods in Adana.

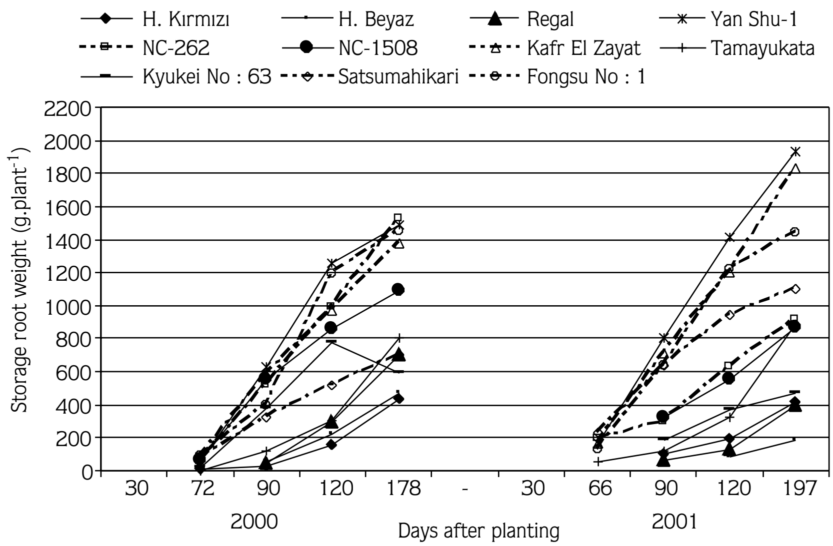

Figure 8. Storage root growth of sweet potato cultivars throughout the 2 growing periods in Hatay.

in Kyukei No. 63, the SRW of which decreased after the 120th DAP. The NC-262, Yan Shu-1, Fongsu No. 1, and Kafr El Zayat No. 1 cultivars had higher SRW from the earlier stages of growth until final harvest. In 2001, storage root formation started before the 66th DAP in most of the cultivars, while it started later (between the 66th and 90th DAP) in 4 of the cultivars (Hatay Kırmızı, Hatay Beyaz, Regal, and Kyukei No. 63), as illustrated in Figure 8. Although the increase in SRW continued throughout the growing period, the rate of increase declined after the 120th DAP in all the cultivars. Yan Shu-1 and Kafr El Zayat No. 1 had higher SRW, while the local cultivars and Regal had lower SRW.

Table 2. Average number of storage roots per plant of sweet potato cultivars at final harvest at different environments.

Cultivars	Diyarbakır		Şanlıurfa		Hatay		Adana	
	2000	2001	2000	2001	2000	2001	2000	2001
Hatay Kırmızı	3.0	3.0	2.1	2.9	2.4	3.5	3.1	2.4
Hatay Beyaz	5.2	2.8	3.2	3.2	2.6	1.9	2.2	2.3
Regal	5.8	4.6	5.1	6.4	4.9	3.4	2.8	4.5
Yan Shu-1	5.7	4.7	5.5	5.1	5.0	5.1	4.7	5.4
NC-262	4.0	5.0	4.8	3.7	4.8	4.0	3.4	3.4
Kafr El Zayat No. 1	4.8	5.7	5.5	4.7	6.9	5.9	3.4	4.3
NC-1508	4.8	6.3	3.4	4.8	4.8	3.5	3.8	6.0
Tamayukata	4.8	5.4	3.2	3.8	2.3	2.6	2.9	3.2
Kyukei No. 63	3.7	2.7	2.2	2.9	2.1	2.2	2.7	1.6
Satsumahikari	4.4	2.6	2.3	3.2	4.2	3.6	3.7	3.5
Fongsu No. 1	5.3	3.7	5.6	5.2	6.0	4.9	3.1	5.1
Mean	4.7	4.2	4.2	4.2	4.2	3.7	3.2	3.8
LSD* (0.05)	0.5	0.6	0.3	0.6	0.7	0.6	0.7	0.5

*Least significant difference.

Table 3. Storage root yields (t ha^{-1}) of cultivars tested in Diyarbakır.

Cultivars	2000					2001				
	US No. 1	Canner	Jumbo	Cull	Total	US No. 1	Canner	Jumbo	Cull	Total
Hatay Kırmızı	10.28	9.32	0.00	2.21	21.81	4.92	5.02	0.00	2.14	12.08
Hatay Beyaz	14.30	10.78	0.00	2.63	27.71	3.94	3.55	0.00	1.71	9.20
Regal	41.16	6.93	0.47	1.89	49.98	8.89	5.54	0.00	1.77	16.18
Yan Shu-1	69.71	5.59	35.81	1.44	112.60	40.22	6.66	23.12	0.92	70.22
NC-262	56.21	4.13	32.53	1.05	94.33	21.39	7.72	7.31	2.57	39.00
NC-1508	60.04	3.42	39.78	0.80	104.00	17.81	6.21	1.86	2.17	28.06
Kafr El Zayat No. 1	43.83	5.65	11.31	1.30	62.09	34.57	12.06	7.65	1.79	56.07
Tamayukata	58.79	3.04	21.17	1.25	84.25	36.86	7.58	6.02	0.84	51.29
Kyukei No. 63	31.84	5.78	7.27	2.10	46.99	13.22	4.17	4.98	2.12	24.49
Satsumahikari	51.87	3.34	1.43	0.73	57.36	21.32	3.51	3.74	0.92	29.49
Fongsu No. 1	48.73	5.85	25.77	1.88	82.22	33.58	4.11	19.09	0.90	57.68
Mean	44.25	5.80	16.00	1.57	67.57	21.52	6.01	6.70	1.62	35.80
LSD* (0.05)	2.76	1.16	3.03	0.57	5.22	2.94	1.25	1.36	0.70	3.91

*Least significant difference.

Average number of storage root per plant

The average number of storage roots per plant (ANSR) at final harvest differed significantly by cultivar in all locations in both years (Table 2). In Diyarbakır, the highest ANSR was obtained from Regal (5.8 storage roots $plant^{-1}$) and Yan Shu-1 (5.7 storage roots $plant^{-1}$) in 2000, and from NC-1508 (6.3 storage roots $plant^{-1}$) in

Table 4. Storage root yields (t ha^{-1}) of cultivars tested in Şanlıurfa.

Cultivars	2000					2001				
	US No. 1	Canner	Jumbo	Cull	Total	US No. 1	Canner	Jumbo	Cull	Total
Hatay Kırmızı	14.21	3.08	0.90	1.21	19.39	3.25	6.30	0.00	0.75	10.30
Hatay Beyaz	14.52	7.67	0.00	1.94	24.13	2.96	6.10	0.00	1.59	10.65
Regal	38.68	10.14	3.52	2.61	49.95	12.99	12.25	0.00	4.78	30.02
Yan Shu-1	60.20	6.65	13.77	1.11	81.72	26.86	8.92	7.80	1.92	45.50
NC-262	51.85	6.90	9.79	1.09	69.62	16.87	6.35	5.34	1.54	30.09
NC-1508	25.81	5.50	10.80	1.00	85.60	14.89	6.48	0.00	1.29	22.66
Kafr El Zayat No. 1	61.70	7.50	15.29	1.11	43.11	28.59	7.44	7.65	1.79	45.47
Tamayukata	32.87	3.97	12.11	0.79	49.73	18.75	5.52	4.96	0.50	29.73
Kyukei No. 63	20.48	4.95	4.83	0.77	31.02	8.33	6.59	0.00	1.61	16.64
Satsumahikari	15.81	4.85	0.68	0.69	22.02	16.13	3.83	1.14	0.92	22.03
Fongsu No. 1	39.55	28.74	0.00	4.00	72.30	35.44	8.73	12.30	1.90	58.37
Mean	33.70	8.18	6.52	1.48	49.87	16.82	7.14	3.56	1.69	29.22
LSD* (0.05)	1.94	1.04	1.41	0.29	2.18	2.49	1.47	1.14	0.37	3.71

*Least significant difference.

Table 5. Storage root yields (t ha^{-1}) of cultivars tested in Adana.

Cultivars	2000					2001				
	US No. 1	Canner	Jumbo	Cull	Total	US No. 1	Canner	Jumbo	Cull	Total
Hatay Kırmızı	4.36	6.29	0.00	1.49	12.14	4.73	4.95	0.00	0.56	10.23
Hatay Beyaz	4.25	8.74	0.00	0.00	12.99	2.43	6.40	0.00	1.14	9.97
Regal	7.24	7.01	0.00	0.79	15.04	3.51	9.16	0.00	2.55	15.21
Yan Shu-1	42.34	7.63	28.50	1.25	79.72	34.60	16.36	20.99	1.58	73.53
NC-262	33.58	5.27	21.35	1.03	61.23	18.59	6.00	12.98	1.41	38.98
NC-1508	35.88	7.16	1.43	0.58	45.06	20.71	13.19	0.00	1.17	35.07
Kafr El Zayat No. 1	34.09	6.18	33.10	0.52	73.89	24.18	13.26	29.64	1.30	68.38
Tamayukata	35.51	4.85	7.50	0.28	48.13	21.04	8.84	11.34	0.46	41.68
Kyukei No. 63	23.65	6.96	4.45	0.64	35.70	8.89	4.76	3.73	0.63	18.01
Satsumahikari	22.48	9.64	5.34	1.17	38.63	26.20	7.53	6.86	0.58	41.17
Fongsu No. 1	40.83	7.62	36.74	0.86	86.06	35.14	11.02	21.45	1.55	69.17
Mean	25.84	7.03	12.58	0.78	46.24	18.19	9.23	9.73	1.18	38.31
LSD* (0.05)	3.61	1.96	3.03	0.44	5.55	2.74	1.16	1.35	0.18	4.33

*Least significant difference.

2001. In 2000, Hatay Kırmızı and Hatay Beyaz had lower ANSR than the other cultivars, while Kyukei No. 63 and Satsumahikari had lower ANSR in 2001.

ANSR values varied from 2.1 to 5.6 storage roots plant^{-1} in 2000, and from 2.9 to 6.4 in 2001, in Şanlıurfa (Table 2). The highest ANSR was obtained from Fongsu and Regal in 2000 and 2001, respectively. Hatay Kırmızı and Kyukei No. 63 produced the lowest ANSR in both years.

In Adana, Yan Shu-1 (4.7 storage roots plant^{-1}) and NC-1508 (6.0 storage roots plant^{-1}) had the highest ANSR in 2000 and 2001, respectively (Table 2). In 2000 Hatay, Beyaz, Regal, and Kyukei No. 63 had low ANSR, and in 2001 Hatay Kırmızı and Hatay Beyaz had low ANSR.

The highest ANSR in 2000 and 2001 (6.9 and 5.9 storage roots plant^{-1}) was obtained from Kafr El Zayat No. 1 in Hatay, while in 2000 the lowest ANSR was obtained from Hatay Kırmızı, Hatay Beyaz, Tamayukata, and Kyukei No. 63, and in 2001 from Hatay Beyaz and Kyukei No. 63.

Storage root yield

Total and graded storage root yields significantly differed depending on cultivar, location, and year (Tables 3-6). The highest US No. 1 grade yields (69.71 t ha^{-1} in 2000 and 40.22 t ha^{-1} in 2001) were obtained from Yan Shu-1, while the 2 local cultivars produced the lowest US No. 1 grade yields in both years, in Diyarbakır (Table 3). Canner grade yield varied from 3.04 t ha^{-1} (Tamayukata) to 10.78 t ha^{-1} (Hatay Beyaz) in 2000 and from 3.51 t ha^{-1} (Satsumahikari) to 12.06 t ha^{-1} (Kafr El Zayat No. 1) in 2001. The highest jumbo grade yields were obtained from Kafr El Zayat No. 1 (39.78 t ha^{-1}) in 2000 and from Yan Shu-1 (23.12 t ha^{-1}) in 2001. Local cultivars did not produce jumbo roots in either year. Yan Shu-1 and NC-262 in 2000, and Fongsu No. 1 and NC-262 in 2001 had significantly higher jumbo grade yields. The total storage root yields of the introduced cultivars were significantly higher than those of the local cultivars. In 2000 Yan Shu-1 (112.60 t ha^{-1}) and Kafr El Zayat No. 1 (104.00 t ha^{-1}) produced over 100 t ha^{-1} of storage roots. In 2001, the highest total storage root yield was obtained from Yan Shu-1 (70.22 t ha^{-1}), followed by Fongsu No. 1 (57.68 t ha^{-1}), and Kafr El Zayat No. 1 (56.07 t ha^{-1}).

In Şanlıurfa, US No. 1 grade yield varied from 14.21 t ha^{-1} (Hatay Kırmızı) to 61.70 t ha^{-1} (Kafr El Zayat No. 1) in 2000 and from 2.96 t ha^{-1} (Hatay Beyaz) to 35.44 t ha^{-1} (Fongsu No. 1) in 2001 (Table 4). Local cultivars Hatay Kırmızı and Hatay Beyaz produced relatively high US No. 1 grade yields in the first year, but were still low yielding cultivars in both years. Canner grade yield varied from 3.08 t ha^{-1} (Hatay Kırmızı) to 28.74 t ha^{-1} (Fongsu No. 1) in 2000 and from 3.83 t ha^{-1} (Satsumahikari) to 12.25 t ha^{-1} (Regal) in 2001. The highest jumbo grade yields were obtained from Kafr El Zayat No. 1 (15.29 t ha^{-1}) in 2000 and from Fongsu No. 1 (12.30 t ha^{-1}) in 2001. Yan Shu-1, NC-262, and Tamayukata also produced significantly higher jumbo grade yield. The total storage root yields of the introduced cultivars were significantly higher than those of the local cultivars. The highest total storage root yields were obtained from Kafr El Zayat No. 1 (85.60 t ha^{-1}) in 2000 and from Fongsu No. 1 (58.37 t ha^{-1}) in 2001.

Higher No. 1 grade yields were obtained from Yan Shu-1 (42.34 t ha^{-1} in 2000 and 34.60 t ha^{-1} in 2001) and Fongsu No. 1 (40.83 t ha^{-1} in 2000 and 35.14 t ha^{-1} in 2001) at the Adana location (Table 5). Hatay Kırmızı, Hatay Beyaz, and Regal resulted in the lowest No. 1 grade yield in both years (Table 5). Canner grade yield varied from 4.85 t ha^{-1} (Tamayukata) to 9.64 t ha^{-1} (Satsumahikari) in 2000 and from 4.76 t ha^{-1} (Kyukei No. 63) to 16.36 t ha^{-1} (Yan Shu-1) in 2001. The highest jumbo grade yields were obtained from Fongsu No. 1 (36.74 t ha^{-1}) in 2000 and from Kafr El Zayat No. 1 (29.64 t ha^{-1}) in 2001. The local cultivars and Regal did not produce jumbo roots in either year. Early maturing cultivars showed a tendency to produce jumbo roots in cases of delayed harvest. The highest total storage root yields were obtained from Fongsu No. 1 (86.06 t ha^{-1}) in 2000 and from Yan Shu-1 (71.55 t ha^{-1}) in 2001. Kafr El Zayat also had a relatively high total storage root yield. Local cultivars and Regal had the lowest total storage root yields in 2000 and 2001.

In Hatay, No. 1 grade yield varied from 0.90 t ha^{-1} (Hatay Beyaz) to 40.89 t ha^{-1} (Fongsu No. 1) in 2000 and from 2.49 t ha^{-1} (Hatay Beyaz) to 46.50 t ha^{-1} (Kafr El Zayat No. 1) in 2001 (Table 6). Canner yield varied from 4.90 t ha^{-1} (Kyukei No. 63) to 18.30 t ha^{-1} (Kafr El Zayat No. 1) in 2000 and from 3.20 t ha^{-1} (Kyukei No. 63) to 8.89 t ha^{-1} (Kafr El Zayat No. 1) in 2001. The highest jumbo grade yields were obtained from NC-262 (10.31 t ha^{-1}) in 2000 and from Yan Shu-1 (18.72 t ha^{-1}) in 2001. The local cultivars did not produce jumbo roots in either year. The highest total storage root yield was obtained

Table 6. Storage root yields (t ha^{-1}) of cultivars tested in Hatay.

Cultivars	2000					2001				
	US No. 1	Canner	Jumbo	Cull	Total	US No. 1	Canner	Jumbo	Cull	Total
Hatay Kırmızı	5.63	9.26	0.00	1.43	16.33	7.64	6.55	0.00	1.35	15.43
Hatay Beyaz	0.90	13.56	0.00	3.51	17.96	2.49	3.38	0.00	0.80	6.72
Regal	10.55	9.88	1.43	5.16	27.02	7.82	6.16	0.00	0.65	14.70
Yan Shu-1	34.85	12.00	7.77	1.80	56.43	44.74	7.64	18.72	0.44	71.55
NC-262	38.36	8.05	10.31	1.34	58.05	20.48	6.22	6.37	0.57	33.88
NC-1508	29.01	9.36	2.40	1.08	41.85	23.92	4.01	3.91	0.23	32.25
Kafr El Zayat No. 1	33.87	18.30	6.21	2.80	61.16	46.50	8.89	11.52	0.64	67.61
Tamayukata	16.35	4.91	9.07	0.35	30.67	21.47	4.85	6.08	0.41	37.06
Kyukei No. 63	12.32	4.90	4.42	0.84	22.48	12.02	3.20	1.46	0.75	17.50
Satsumahikari	12.26	12.11	0.00	2.19	26.56	31.41	5.92	3.10	0.29	43.40
Fongsu No. 1	40.89	11.03	0.96	2.14	55.02	32.87	8.76	10.72	0.90	53.27
Mean	21.36	10.30	3.87	2.06	37.59	22.85	5.96	9.73	0.64	35.76
LSD* (0.05)	2.10	1.44	0.95	0.79	2.45	3.30	1.47	1.35	0.18	5.26

*Least significant difference.

from Kafr El Zayat No. 1 (61.16 t ha^{-1}) in 2000. In 2001, Yan Shu-1 and Kafr El Zayat No. 1 produced the highest total storage root yields, 71.55 t ha^{-1} and 67.61 t ha^{-1}, respectively. NC-262 and Fongsu No. 1 also had high total storage root yields. Hatay Kırmızı and Hatay Beyaz produced 16.33 t ha^{-1} and 17.96 t ha^{-}1, respectively, in 2000, and 15.43 t ha^{-1} and 6.72 t ha^{-1}, respectively in 2001. The local cultivars had poor yield performance, even at the Hatay location where these cultivars are commercially grown.

Quality characteristics

Mean values for DM and AIS content are presented in Table 7, and protein and total carotenoid content are presented in Table 8. DM content of the cultivars showed great diversity, from 20% to 40%, depending on location. Kyukei No. 63 was an outstanding cultivar with the highest DM content at all locations (40.6%, 37.9%, 40.8%, and 36.9%, in Diyarbakır, Şanlıurfa, Adana, and Hatay, respectively). Satsumahikari and the local cultivars Hatay Kırmızı and Hatay Beyaz also had considerably high DM content at all locations. The cultivars Yan Shu-1, Regal, and Kafr El Zayat No. 1 had the lowest DM content in all locations. Location means for DM content was 28.4%, 28.0%, 30.0%, and 26.9%, for Diyarbakır, Şanlıurfa, Adana, and Hatay, respectively.

AIS content of the cultivars showed ranking patterns similar to DM content. The highest AIS content was obtained from Kyukei No. 63 at all locations, whereas Regal, Yan Shu-1, Kafr El Zayat No. 1, and Fongsu No. 1 were determined to be low AIS content cultivars at all locations (Table 7). Location means for AIS content were 23.0%, 23.4%, 24.9%, and 18.7%, for Diyarbakır, Şanlıurfa, Adana, and Hatay, respectively.

Cultivars differed in their protein content, depending on location (Table 8). Protein content of the cultivars ranged from 3.50% to 5.52% in Diyarbakır, from 6.31% to 9.60% in Şanlıurfa, from 3.13% to 6.09% in Adana, and 5.55% to 8.90% in Hatay. Kyukei No. 63 had the highest protein content at 3 of the 4 locations (Şanliurfa, Adana, and Hatay), whereas the highest protein content was obtained from Regal in Diyarbakır. The lowest mean protein content was obtained from the Adana location, where the highest DM and AIS content were also obtained (Table 7).

Total carotenoid content of the cultivars significantly varied depending on location (Table 8). Regal was distinguished with the highest total carotenoid content at all 4 locations (7.76, 6.55, 7.95, and 7.45 mg 100 g fresh weight^{-1} in Diyarbakır, Şanlıurfa, Adana, and Hatay, respectively); however, all the other cultivars

Table 7. Dry matter and alcohol insoluble solid contents of sweet potato cultivars tested at 4 different locations.

Cultivars	Dry matter content (%)				AIS content (%)			
	Diyarbakır	Şanlıurfa	Adana	Hatay	Diyarbakır	Şanlıurfa	Adana	Hatay
Hatay Kırmızı	32.4	31.6	33.8	27.2	27.7	28.2	29.9	18.0
Hatay Beyaz	31.9	32.0	31.6	29.1	27.2	26.8	25.7	20.9
Regal	23.6	24.9	23.1	20.3	16.3	19.6	16.8	12.0
Yan Shu-1	21.5	23.6	26.2	24.2	15.1	18.5	21.5	16.0
NC-262	24.3	24.1	25.8	25.8	18.7	20.3	20.7	16.9
Kafr El Zayat No. 1	23.7	23.4	27.1	23.6	17.7	18.3	21.2	15.3
NC-1508	28.7	26.0	26.6	26.7	23.9	22.1	21.2	18.5
Tamayukata	29.9	29.7	32.6	25.0	25.5	25.8	28.8	17.2
Kyukei No. 63	40.6	37.9	40.8	36.9	36.7	33.4	36.5	30.9
Satsumahikari	30.5	30.6	34.9	32.3	25.0	26.8	29.8	23.9
Fongsu No. 1	25.2	23.7	28.0	25.1	19.2	18.1	22.3	15.7
Mean	28.4	28.0	30.0	26.9	23.0	23.4	24.9	18.7
LSD (0.05)	2.4	3.6	3.1	3.4	2.7	3.9	3.3	4.4

Table 8. Protein and total carotenoid content of sweet potato cultivars tested at 4 different locations.

Cultivars	Protein content (%)				Total carotenoid content (mg 100 g fresh weight^{-1})			
	Diyarbakır	Şanlıurfa	Adana	Hatay	Diyarbakır	Şanlıurfa	Adana	Hatay
Hatay Kırmızı	5.41	8.64	4.74	6.75	2.33	0.87	1.37	3.07
Hatay Beyaz	4.38	7.14	5.30	8.54	2.10	0.63	0.98	0.53
Regal	5.52	7.56	5.33	8.06	7.76	6.55	7.95	7.45
Yan Shu-1	4.49	6.31	3.67	5.55	1.91	0.61	0.75	0.53
NC-262	4.36	9.16	3.95	7.24	2.59	0.83	1.33	2.36
Kafr El Zayat No. 1	4.33	7.02	3.39	8.77	1.88	0.65	0.90	0.65
NC-1508	4.80	7.67	3.52	5.57	2.39	0.78	1.10	0.74
Tamayukata	3.50	7.66	4.25	8.38	2.14	0.66	0.99	0.83
Kyukei No. 63	5.13	9.60	6.09	8.90	2.08	0.73	1.31	2.99
Satsumahikari	5.48	7.59	4.47	6.71	2.30	0.91	1.53	0.81
Fongsu No. 1	4.49	6.48	3.13	5.92	1.91	0.61	0.71	0.92
Mean	4.72	7.71	4.37	7.31	2.67	0.23	1.7	1.90
LSD (0.05)	0.51	0.50	0.52	0.61	0.34	0.87	0.26	1.10

could be considered as having low total carotenoid content since they contained less than 3.00 mg 100 g fresh weight^{-1}.

Discussion

Although haulm growth of the cultivars varied according to location and year, all the cultivars showed rapid haulm growth until the 90th or 120th DAP, at all locations. The increase in HDW of the cultivars was more dramatic after the 60th DAP and HDW started to decrease on the 120th DAP in most cultivars. The slow haulm growth in earlier stages could be attributed to transplanting stress since seedlings tried to maintain water balance and establish root systems in the first period after transplanting. Sweet potato continues to grow and branch as long as environmental conditions are favorable, due to its perennial habit, but the leaves form earlier in the growing season start to fall and the total number of leaves and leaf area decrease toward to the end of the growing season (Somda and Kays, 1990a, 1990b). Bhagsari (1990) reported that sweet potato cultivars maintained leaf area index to intercept a major portion of sunlight until harvest, and leaf area growth significantly differed depending on cultivar. Stem elongation and leaf formation decreased due to cooler temperatures in the last phase of the growing season in all locations, and HDW considerably decreased since young leaves did not compensate for weight loss due to defoliation of old leaves during this period. Sweet potato is primarily produced for its storage roots, but its leaves and stems can be used for human and animal consumption (Woolfe, 1992). Haulm can be harvested several times during the growing period in some countries, but this results in a considerable decrease in storage root yield (Dahniya et al., 1985; Nwinyi, 1992). Haulm harvesting just before storage root harvesting provides a considerable amount of animal feed without causing any reduction in storage root yield.

Generally, storage root formation started between the 30th and 60th DAP at all locations. Accumulation of dry matter in storage roots linearly increased until the 120th DAP. Both rapid storage root and haulm growth during this period suggest that efficient plant growth of the sweet potato cultivars in all locations occurred between the 60th and 120th DAP. The existence of a long growing period (from May to November) along with high temperature during the majority of the growing period in both regions provided a favorable environment for sweet potato growth and productivity. However, continuous storage root growth resulted in excessively high mean SRW, and the percentage of jumbo roots, which are undesirable for marketing, increased. The local cultivars and Regal generally tended to have later storage root formation, and their storage roots rarely reached jumbo size. Of course, genetic constituents of the cultivars are also important in respect to storage root size. In contrast, SRW of early maturing cultivars decreased with an extended growing period of more than 120 DAP. Similarly, decreasing storage root dry weight towards harvest was reported by Bhagsari and Ashley (1990). This could be attributed to the reallocation of carbohydrates that were stored in the roots to the haulms or other plant parts in the late growth period. We concluded that extension of the growing period to more than 120-130 DAP was unnecessary for storage root and haulm yield, although growth could continue until the 170th-180th DAP in both regions.

The world average for storage root yield in sweet potato is about 15 t ha^{-1} (FAO, 2006). Bacusmo et al. (1988) reported that storage root yield ranged from 9.46 to 25.56 t ha^{-1}, in sweet potato cultivars tested at 4 locations in the USA. The highest mean storage root yield obtained from 15 sweet potato cultivars in Georgia, USA, was about 60 t ha^{-1} (Bhagsari and Ashley, 1990). Our 2-year data on storage root yield obtained from 4 locations clearly indicated that Adana and Hatay, with Mediterranean climates, and Diyarbakır and Şanlıurfa, with dry semiarid climates, were all suitable locations for sweet potato cultivation. Although there were significant differences among the locations, 60-70 t ha^{-1} of storage root yield can be obtained by choosing high-yielding cultivars.

Sweet potato cultivars showed different growth and yield performance in different environments. The significant genotype × environment interaction between the evaluated cultivars and locations was previously reported by Caliskan et al. (2007). These findings indicated the importance of the selection of superior sweet potato genotypes for evaluated locations. Our study clearly revealed that the old local cultivars should be replaced by high-yielding new cultivars since all introduced cultivars produced higher yield values than the local cultivars. Among the introduced genotypes, Yan Shu-1, Fongsu No. 1 and Kafr El Zayat were distinguished by their higher total storage root yield; however, apart from fresh storage root yield, other traits such as β-carotene content, sweetness, and flavor, have to be considered when nominating a sweet potato genotype as potentially useful (Abidin et al., 2005; Grüneberg et al., 2005). Therefore, studies on the acceptability of new cultivars should be performed via sensory analysis.

Sweet potato is not a staple food in Turkey, and Turkish consumers mostly prefer dessert types. Dessert types of sweet potato generally have cream colored to orange flesh, dry weight content ranging from 17.7% to 26.3%, and starch content ranging from about 13.0% to 22.0% (Picha, 1987). AIS, which consists of 95% starch, is a good indicator of starch content of sweet potato storage roots, and it is well correlated with the DM content (Picha, 1985; LaBonte et al., 2000). In the present study, cultivars tested at 4 locations had dry matter ranging from low (~20%) to high (~40%). Sweet potato is also a good source of carotenoid (precursor of vitamin A), depending on the cultivar. Dark orange flesh roots are rich sources of β-carotene, the most active provitamin A carotenoid, while yellow/orange roots supply moderate amounts of β-carotene (Woolfe, 1992). K'osambo et al. (1998) and Teow et al. (2007) reported significant variations in respect to b-carotene content among sweet potato genotypes, and orange flesh had higher b-carotene content than white flesh. K'osambo et al. (1998) also indicated that total carotenoid content of sweet potato cultivars significantly changed depending on growing location. Vitamin A nutritional value calculations assume an 8% loss of carotenoid during baking and 90% of total carotenoid is composed of b-carotene (Picha, 1985). In our study, Regal had the highest total carotenoid content, but it was a very low-yielding cultivar at all locations. Among the genotypes tested, NC 262 would be considered as useful since it was the most preferred ones in respect to taste by the testers during the experiments. However, it had considerably unstable yield performance, whereas it ranked among the high-yielding cultivars in some locations. Therefore, further adaptation studies with new genotypes should be conducted in these locations to determine which genotypes are more acceptable and yield stable.

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