Comparison of Bag and Raised Bed Treatments for Strawberry Production under Unheated Greenhouse Conditions

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Bag and raised bed treatments for strawberry production were compared in an unheated greenhouse for two growing seasons using 'Camarosa', 'Sweet Charlie' and 'Selva'. Freshly rooted runners in pots were planted in early August in both years. The bag culture had higher early yield than raised bed treatments in both seasons. Yield/plant was also higher in bag culture than raised bed treatments. The fruit quality variables (e.g. average fruit weight, soluble solids, acidity, pH, and firmness) were not consistently affected by cultural system. 'Sweet Charlie' had the highest early yield/plant in both years. 'Sweet Charlie' and 'Camarosa' were the most productive cultivars. 'Sweet Charlie' had the highest soluble solids and the lowest acidity. 'Camarosa' had the highest fruit weight. Fruit firmness was also highest in 'Camarosa'. The bag cultural system should be the production method of choice because of higher early and total yield than raised bed culture; and, there were no negative impacts on fruit quality associated with bag cultural system.

Introduction

Strawberry production in Turkey has rapidly increased and recently reached 130,000 t (1). The production is concentrated in the country's Mediterranean, Aegean, and Marmara Regions (Figure 1). The Mediterranean Region produces about half of Turkey's total strawberry production. Most of this production is in Ýçel province. Although Hatay province also has a great potential for early strawberry production, the current total production in this province is negligible (12 t). Hatay has several advantages for strawberry production such as its unique climate and proximity to Middle Eastern markets. These advantages suggest that strawberry culture could be expanded in this region, especially with cultural systems designed to encourage early production.

Early winter strawberry production in December-January in Turkey would be a great advantage because of higher prices (11). Earliness can be achieved in Ýçel by combination of protected (plastic houses and high tunnels) and planting systems, as well as by using early cultivars (12). In raised beds, cold-stored plants (dormant plants stored for several months at - 2 °C) are planted as summer plantings (in July and August) on black-plastic-covered-soil (6). The fresh runners rooted in pots (plugs) were found to be the earliest planting system in Mediterranean climates (12). 'Sweet Charlie' was found to be the earliest cultivar in the Mediterranean Region (10, 13).

Continuous production in a greenhouse has the advantage of producing early fruit, but a monoculture over several years can result in problems such as diseases, salinity, and degradation of soil structure. These problems eventually contribute to yield reductions (15). The soil-borne pathogens (e.g., *Phytophtora* spp.), one of the most

important problems in strawberry production, are more frequent and detrimental under such conditions. The most common way to avoid these problems is to utilize bag culture, which has been practiced for 20 years and is increasing in popularity in Belgium and the Netherlands (8). Bag culture has other advantages over raised bed treatments such as enabling growers to more carefully control plant nutritional balance (16). Since the most important barrier to increased strawberry production in Hatay province is the poor soil condition, we designed a study to investigate the possible advantages of bag culture over raised bed treatments in an unheated greenhouse in Hatay.

Materials and Methods

The experiments were carried out during 2001-2002 and 2002-2003 at the Department of Horticulture, Faculty of Agriculture, Mustafa Kemal University, Antakya, Hatay. The bag and raised bed treatments were compared using freshly rooted runner plants of 'Camarosa', 'Sweet Charlie' and 'Selva', chosen because they were previously selected as promising ones for the region (13).

The raised bed treatments consisted of beds (70 cm width and 25 cm height) with two rows of plants set at 30 x 35 cm spacing.

The beds were fertilized with farmyard manure (40 tons/ha), and then solarized during June and July (7). After solarization, NPK (15:15:15) at 500 kg ha^{-1} was incorporated into the beds and then covered with black polyethylene mulch. The bags were 75 cm long, 45 cm wide, and 15 cm deep filled with peat: sand (2:1 ratio). There were 6 plants per bag and each replication consisted of three bags. In these planting systems, bag culture had ~100,000 plant/ha, while raised bed treatments had ~ 60,000 plant/ha.

To produce freshly rooted plants, runner tips were harvested from a nursery at the end of June and placed in pots (7 x 10 cm diameter) under mist for a month (10). These plants were transplanted in the greenhouse at the beginning of August for both growing seasons. The greenhouse was covered with clear plastic at the beginning of winter. Low tunnels (40 cm height) were constructed within the plastic house to protect plants against frost damage. In addition to base dressing, a total dose of 120 kg ha^{-1} N was provided during the growing season by drip irrigation as needed to both cultural systems.

The berries were harvested twice a week; early yield/plant, total yield/plant and fruit weight were recorded. Early yield/plant was determined as the cumulative yield harvested before the end of January. Average fruit weight was determined by dividing total fruit

Figure 1. Provinces with important strawberry production in Turkey.

yield per plot by total fruit number per plot. Twenty berries were harvested from every plot for each treatment for three times during the fruiting season to analyze the soluble solids, acidity, pH and fruit firmness. Soluble solids were determined with a hand held refractometer. Acidity was determined by titration with 0.1 N NaOH to pH 8.1 and calculated as citric acid (5). Berry firmness was measured with penetrometer with a standard 5 mm probe and expressed in kg (15).

The experiment was designed as a split plot, consisting of 4 replicates, where the cultural systems were whole plots and the cultivars were sub-plots. The means were calculated and Analysis of Variance (ANOVA) tables were constructed using

Generalized Linear Model (GLM) procedure of SAS (17). The mean separation was evaluated using least significant difference (LSD) at the 5% level.

Results and Discussion

Bag culture had higher early yield than raised bed treatments in both seasons and higher yield/plant than raised bed treatments in 2002-2003 (Tables 1 and 2). The differences between cultural systems in early and total yield/plant would be even more profound when we considered the yields on per area basis since there were more plants per area in bag culture than raised bed. Bag culture had higher average fruit weights in 2001-2002, while the average fruit weight was

Table 1. Mean squares, significance and mean values of several horticulturally important traits for strawberry cultivars grown in bag and raised bed treatments in 2001-2002 in Antakya, Hatay, Turkey.

Souce	df	Early yield (g/plant)	Yield (g/plant)	Fruit weight (g)	Soluble solids (%)	Acidity (%)	pH	Firmness (kg)
Analysis of variance								
Culture	1	487**	50735	7.0*	2.3	0.009*	0.075	0.001
Sub-plot error	4	26	10693	0.9	0.4*	0.001	0.014	0.001
Cultivar	2	1173**	22183	27.2**	1.5**	0.046**	0.042*	0.098**
Culture × Cultivar	2	429*	503	0.7	0.0	0.009*	0.009	0.001
Error	8	2	9249	1.7	0.1	0.002	0.005	0.001
Main effect - treatment								
Bag culture		15.1	666	11.7	8.4	0.74	3.42	0.48
Raised bed		4.8	560	9.3	9.1	0.69	3.55	0.50
Main effect - cultivar								
'Camarosa'		0.0b	683a	11.6a	8.4b	0.74a	3.39b	0.63a
'Selva'		4.0b	584a	10.4ab	8.5b	0.79a	3.50a	0.38c
'Sweet Charlie'		26.0a	572a	9.5b	9.3a	0.62b	3.56a	0.46b
LSD (5%)		6.7	128	1.8	0.42	0.07	0.09	0.05

*,**Significant at 5%, and 1%, respectively.

higher in raised bed treatments in 2002-2003. These results indicate that bag culture has a positive effect on fruit weight, yield and earliness. The earliness in bag culture is thought to be as a result of warmer soil/substrate temperature caused by mulch effect of plastic bag, while higher yield may be due to better soil/substrate management (3, 9, 11).

While the differences among cultivars were significant for many of the traits tested; no significant differences were found for yield/plant in 2001-2002 and fruit weight and soluble solids in 2002-2003 (Tables 1 and 2). Culture × cultivar interactions were not significant in general; they were significant

for early yield/plant and acidity in 2001-2002 and early yield/plant and pH in 2002-2003. Therefore, main effect means are presented.

Among the fruit quality variables the differences in cultural systems were significant only for acidity in 2001-2002 and pH in 2002-2003 (Tables 1 and 2). Paraskevopoulou-Paroussi et al. (15) did not find significant differences on fruit quality caused by production systems.

'Sweet Charlie' had the highest early yield/plant in both seasons (Tables 1 and 2). Some early yield was also recorded from 'Selva', while 'Camarosa' had no early yield. 'Sweet Charlie' also had the highest yield/plant in 2002-2003; and there were no significant

Table 2. Mean squares, significance and mean values of several horticulturally important traits for strawberry cultivars grown in bag and raised bed treatments in 2002-2003 in Antakya, Hatay, Turkey

Souce	df	Early yield (g/plant)	Yield (g/plant)	Fruit weight (g)	Soluble solids (%)	Acidity (%)	pH	Firmness (kg)
Analysis of variance								
Culture	1	1568*	44243**	0.6*	50734	2.347	0.009*	0.075
Sub-plot error	4	219	5094	2.8	10693	0.404*	0.001*	0.014
			50315**	0.8				
Cultivar	2	2578**			22183	1.452**	0.046*	0.042*
Culture × Cultivar	2	1772**	1335	5.2	503	0.037*	0.009*	0.009
Error	8	204	2308	2.8	9249	0.100	0.002	0.005
Main effect - treatment								
Bag culture		20.0	703	11.0	7.7	0.9	3.24	0.56
Raised bed		3.7	612	12.5	7.5	0.9	3.31	0.52
Main effect - cultivar								
'Camarosa'		0.0 b	644 b	12.1 a	7.4 b	1.0 a	3.24 b	0.64 a
'Selva'		2.9 b	591 b	12.2 a	7.2 b	0.9 b	3.27 ab	0.53 b
'Sweet Charlie'		32.4 a	738 a	10.9 a	8.1 a	0.8 c	3.32 a	0.45 c
LSD (5%)		15.6	54.3	2.1	0.42	0.1	0.05	0.05

*,**Significant at 5%, and 1%, respectively.

differences among cultivars in yield/plant in 2001-2002. These results are in agreement with the previous studies as the earliness in 'Sweet Charlie' is well known (10, 13).

The average fruit weight was the highest in 'Camarosa' in 2001-2002; and all cultivars had similar fruit weights in the second season (Tables 1 and 2). 'Camarosa' is known to have high average fruit weight (10). Similar to other studies, the highest soluble solids in both seasons was recorded in 'Sweet Charlie' (2, 13). 'Camarosa' had the high acidity while 'Sweet Charlie' had the high pH. The firmest berries were recorded to 'Camarosa' in both seasons. 'Camarosa' was found to have the firmest berries (4, 14).

This is the first report of a comparison of bag and raised bed cultures in greenhouse in the Mediterranean Region. The results indicate that when compared to raised bed, bag culture is more productive and it induces earliness. In addition, the fruit quality parameters were similar in both treatments. Therefore, we recommend utilization of bag culture in the protected strawberry culture in regions with mild climate such as Hatay province. For example, Mediterranean coastal region of Turkey has areas with warm winter temperatures and good sunlight. However, the area has a narrow strip of sand dunes followed by a narrow arable land finalized by rocky land. In this rocky land, cultivation is restricted by availability of soil and water. Early strawberry production can be enhanced by utilizing bag culture, especially when it is combined with greenhouses, early cultivars and plug plants. Occasional heating may be necessary to avoid rare freezing temperature damage.

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