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Yield, Quality and Nutritional Status of Organically and Conventionally-Grown Strawberry Cultivars

İdris Macit, Aysen Koç, Semiha Güler and İlyas Deligöz
Black Sea Agricultural Research Institute, 55001, Samsun, Turkey

Abstract: In this study, five short-day strawberry (*Fragaria* × *ananassa* Duch) cultivars including Sweet Charlie, Redlans Hope, Kabarla, Festival and Camarosa were grown to evaluate their yield, quality and nutritional status under organic and conventional growing conditions in 2004-2005 seasons. In the conventional system, plants had early flowering and fruit development and produced higher yield when compared to the organic system. According to total yield of two years, there were significant differences between two growing systems, ranging from 21 (Camarosa) to 29% (Sweet Charlie). There were also significant differences in average fruit weight among cultivars in organic and conventional system. However, difference between growing systems in terms of fruit weight of each cultivar was not significant. Redlans Hope had the highest average fruit weight under conventional and organic system, followed by Camarosa and Kabarla. Total Soluble Solid (TSS) content and Titretable Acidity (TA) of fruit differed among the cultivars. Sweet Charlie and Festival cultivars had the highest TSS content under conventional system. Titretable acidity of fruit was strongly affected by fertilizer management and it was lower under organic growing conditions when compared to the conventional system. Cultivars differed significantly in Chlorophyll (CHL) and leaf N contents, Kabarla and Redlans Hope had the highest values. It was found that there was significant correlation between CHL and leaf N ($r = 0.551$, $p<0.001$). Kabarla and Camarosa were the cultivars yielded higher not only in conventional system but also in organic system.

Key words: Yield, fruit quality, chlorophyll, leaf nitrogen, strawberry (*Fragaria* × *ananassa* Duch)

INTRODUCTION

Strawberry cultivars have been selected under conventional growing conditions where their nutrient requirements are provided by inorganic fertilizers. However, usage of inorganic fertilizers was prohibited in organic agriculture via regulations (Anonymous, 1991). In organic production, nutrient requirements of plants can be supplied through organic fertilizers such as animal manure, green manure and compost which release the nutrients slowly and mineralization process is highly dependent on the soil moisture and temperature. Also, some rather soluble but expensive organic fertilizers such as hair meal pellets, molasses, horn and legume meals can be used as fertilizer. In addition some plant residues can be used to improve physical and chemical properties of soil.

Nutritional status of strawberry is influenced not only by many external factors such as soil, temperature, humidity, fertilization, growing management, but also by cultivars used (Ames *et al.*, 2003). Daugaard (2001), working with seven strawberry cultivars under organic conditions stated that nutrient level is a cultivar-specific property and this must be taken into account in evaluating the nutrient demands of strawberries. Hence, strawberry cultivars selected under conventional growing conditions should also be evaluated under organic conditions.

Nitrogen as a plant nutrient is of greater importance owing to have substantial effects on quality and yield of strawberry which is a nitrogen-sensitive crop. Nitrogen deficiency reduces leaf area, root mass and fruit size (Johanson and Walker, 1963; Ulrich *et al.*, 1980) and excessive amount leads soft fruit, delays ripening, decreases yield, increases powdery mildew and mite pressure (Voth *et al.*, 1967; May and Pritts, 1990; Miner *et al.*, 1997). Therefore, fertilizer management in organic agriculture is crucial for higher quality yield of strawberry. This study was planned to investigate the performance of 5 short-day strawberry cultivars by evaluating their yield, quality and nutrition under organic and conventional growing conditions.

Corresponding Author: Semiha Güler, Black Sea Agricultural Research Institute, 55001, Samsun, Turkey
Tel: +90 362 2560515 Fax: +90 362 2560516

Table 1: Physical and chemical analysis of the soils before and after experiment

Growing system	Texture	Total salinity (%)	pH	$CaCO_3$ (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})	Organic matter (%)
Before experiment							
Organic	Clay loam	0.11	7.65	6.55	6.20	100	4.07
Conventional	Clay loam	0.07	7.85	5.85	5.30	108	3.58
After experiment							
Organic	Clay loam	0.05	7.80	6.44	11.70	82	3.73
Conventional	Clay loam	0.07	7.80	6.52	8.80	61	4.17

Table 2: Chemical properties of farmyard manure, poultry manure and wood ash

Fertilizer	N (%)	P (%)	K (%)	pH	EC (dS m^{-1})
Farmyard manure	0.84	0.17	0.30	-	2.94
Poultry manure	1.19	2.31	4.55	6.98	3.27
Wood ash	0.03	1.65	7.72	-	-

MATERIALS AND METHODS

Five short-day strawberry (*Fragaria x ananassa* Duch) cultivars (Sweet Charlie, Redlans Hope, Kabarla, Festival and Camarosa) were grown in a raised bed on clay-loam soil in 2004-2005 growing season in the research field of The Black Sea Agricultural Research Institute, Samsun, Turkey (41° 21' N Latitude, 36° 15' E Longitude, 4 m elevation). Chemical and physical properties of the experimental soils are given in Table 1. Experimental design was randomized complete block with four replications. All plots received 40 t ha^{-1} farmyard manure prior to the planting.

In organic system, based on its chemical composition, wood ash was incorporated into the soil at a rate of equal to 150 kg P ha^{-1}. Green manure (*Vicia sativa* L.) sown in 2002 autumn was incorporated into the soil at the flowering stage in the spring of 2003. Straw was used as mulch material. After planting, aqueous solution of poultry manure was applied with irrigation water via trickle irrigation at once per week, terminating at the end of September in 2004 and 2005 growing seasons. Chemical composition of poultry manure and wood ash are given in Table 2.

In conventional system, prior to the planting 150 kg P ha^{-1} as triple superphosphate (42% P_2O_5) and 200 kg K ha^{-1} as potassium sulphate (50% K_2O) were applied as basal dressings. After planting, total of 139.1 kg N ha^{-1} (200 mg L^{-1}) as ammonium nitrate (33% N) was supplied with irrigation water through drip irrigation system once in a week from April to the end of September in 2004 and 2005 growing seasons. Black plastic mulch was used in this growing system.

Daughter plants were sown on a raised bed on July 18, 2003. Each plot had 20 plants at 30×32 cm inter row and plant spacing. Leaf samples were taken for determination of total N and CHL reading on June 01, 2004. The leaf chlorophyll was measured using Minolta SPAD-502 chlorophyll-meter, total of 30 chlorophyll meter readings were recorded on ten leaves of each plot and 3 readings on each leaf. Readings were taken from the same point/position of the leaves as much as possible. The same leaves were dried at 70°C for 48 h and prepared for chemical analysis. Leaf N was determined by micro-kjeldahl method (Chapman and Pratt, 1961).

RESULTS AND DISCUSSION

Flowering and harvest dates: In conventional system, strawberry cultivars flowered a few days earlier than those of organic system (Table 3). First harvest was two to seven days earlier depending on cultivars in conventional system in both years. Harvest duration was one (Kabarla) or two weeks (Camarosa) longer in conventional than organic system in 2004. Whereas in 2005 the last harvest was made on the same day (30 June) for all cultivars except for Redlans Hope which ended 10 days before (20 June). Early flowering resulted in early fruit set in conventional system which was attributed to higher solubility and easy availability of inorganic fertilizer used, especially nitrogen, in this system. Organic fertilizers used in organic system need time to be available to the plants. This is one of the most important challenges for organic agriculture (Muramoto *et al*., 2004; Finckh *et al*., 2006). Another reason for early flowering and early fruit setting may be utilization of plastic mulch in conventional system. Findings of Kaikas and Luik (2002) and Sing *et al*. (2007) support this assumption. There have been many studies reporting positive effects of plastic mulch on the nutrients availability and nutrient uptake of the plant through increasing soil water and temperature (Birkeland *et al*., 2002; Sharma and Sharma, 2003; Sonsteby *et al*., 2004; Singh *et al*., 2005; Berglund *et al*., 2006).

Fruit weight, total soluble solid and titretable acidity: There were significant differences among cultivars on average fruit weight in organic and conventional system in both years (Table 4). Redlans Hope had the highest mean fruit weight under conventional and organic system in both years, followed by Camarosa and Kabarla. When taken into account the mean values of two years, Redlans Hope was the cultivar having the highest mean fruit

Table 3: First flowering, first and last harvest dates of cultivars in 2004 and 2005

	First flowering		First harvest		Last harvest	
Cultivar	2004	2005	2004	2005	2004	2005
Organic system						
Kabarla	05 April	08 April	15 May	20 May	02 July	30 June
Festival	30 March	10 April	10 May	18 May	02 July	30 June
Sweet charlie	01 April	06 April	08 May	14 May	02 July	30 June
Camarosa	01 April	06 April	12 May	16 May	25 June	30 June
Redlans hope	02 April	08 April	17 May	21 May	09 July	20 June
Conventional system						
Kabarla	30 March	06 April	10 May	16 May	15 July	30 June
Festival	28 March	07 April	08 May	14 May	02 July	30 June
Sweet charlie	27 March	06 April	05 May	12 May	29 June	30 June
Camarosa	27 March	05 April	08 May	14 May	02 July	30 June
Redlans hope	28 March	06 April	10 May	18 May	15 July	30 June

Table 4: Mean fruit weight, total soluble solid and titretable acidity of strawberry cultivars grown organically and conventionally

	2004		2005		Mean		
Cultivars	Org.	Conv.	Org.	Conv.	Org.	Conv.	Difference (%)
Mean fruit weight (g)							
Kabarla	12.43b**	11.68ab**	7.45b*	6.85ab**	8.24b**	9.27ab**	-12 NS
Festival	9.79c	10.25bc	7.70b	6.42ab	7.62c	8.33bc	-9 NS
Sweet charlie	8.75c	9.06c	9.75a	5.80b	7.14c	7.43c	-4 NS
Camarosa	11.80b	12.39a	8.15b	7.50a	9.46b	9.95a	-5 NS
Redlans hope	14.22a	12.70a	8.70b	7.47a	10.45a	10.09a	+3 NS
CV (%)	8.71	10.79	10.25	13.60	6.98	7.84	
Total soluble solid content (%)							
Kabarla	5.77c**	6.12b**	5.25b**	7.30b**	6.61c**	6.71c**	-2 NS
Festival	7.50a	7.85a	5.47b	8.80ab	7.60b	7.92ab	+4 NS
Sweet charlie	7.35a	7.90a	5.52b	8.75a	8.55a	8.32a	+1 NS
Camarosa	6.85b	7.47a	7.12a	7.65ab	7.50b	7.56abc	-1 NS
Redlans hope	6.40c	7.35a	6.67a	7.05b	7.55b	7.20bc	+1 NS
CV (%)	8.02	7.92	10.36	10.13	5.45	7.00	
Titretable acidity (g 100 g^{-1})							
Kabarla	0.29ab	0.34	0.28bc	0.28b	0.28ab	0.31	-10 NS
Festival	0.30a	0.34	0.30a	0.33ab	0.30a	0.34	-12 NS
Sweet charlie	0.26b	0.34	0.25c	0.38a	0.26c	0.36	-28**
Camarosa	0.27ab	0.36	0.28ab	0.37a	0.28bc	0.37	-24**
Redlans hope	0.29ab	0.41	0.27bc	0.38a	0.29ab	0.40	-27**
CV (%)	7.63	20.35	5.13	11.42	4.55	13.28	

*: $p<0.05$, **: $p<0.01$, NS: Non significant, + and - in difference column indicate high and low values of the means, respectively, in organic plot when compared to conventional, Values with the same letter(s) are not significantly different at the 5% level

weight under both growing conditions, followed by Camarosa and Kabarla. According to t-test, the difference between growing systems in terms of mean fruit weight of each cultivar was not significant.

There were significant differences in TSS content of fruit among cultivars grown organically or conventionally (Table 4). Sweet Charlie and Festival cultivars had the highest TSS content under conventional system in both years. Under organic system, TSS content of Sweet Charlie and Festival cultivars showed variability, namely the values were lower in the second year when compared to the first year. This might be resulted from susceptibility of these cultivars to nutritional differences in the soil. According to mean values, although there were significant differences in TSS content among cultivars under two growing conditions, differences between systems in relation to this trait of each cultivar was not significant. TSS content is a cultivar-specific character. While some cultivars had higher TSS, the others had the lower TSS under the same growing conditions.

Titretable acidity of cultivars was significantly influenced by growing system (Table 4). It can be concluded from that TA was significantly affected by fertilizer management. TA of the cultivars under organic system was lower when compared to the conventional system. This was attributed to differences in nutritional power of the soil under organic and conventional system. Although the same amounts of fertilizers were supplied with different fertilizer sources for organic and conventional systems, differences in fertilizer solubility resulted in different concentrations in soil. Of all the fertilizer, potassium has the most important effect on fruit quality, especially TA of fruit (Locascio *et al*., 1990; Güler, 1997). In present study, potassium was supplied by farm yard manure (0.30% K), poultry manure (4.55% K) and wood ash (7.22%) in organic system (Table 2), however lower availability of K derived from these sources might lead to lower TA of strawberry fruit. Plastic mulch might be another factor influencing TA through positive effect on soil humidity and temperature which have crucial

Table 5: Yield of strawberry cultivars grown organic and conventional system in 2004 and 2005 (g plant^{-1})

	2004			2005		
Cultivars	Organic	Conventional	Difference (%)	Organic	Conventional	Difference (%)
Kabarla	403.99a**	501.41a**	-21**	157.57b**	251.54	-37NS
Festival	253.62b	260.99c	-3NS	147.19b	295.38	-50**
Sweet charlie	159.82c	260.63c	-39**	268.83a	341.94	-22NS
Camarosa	299.31b	373.95b	-20*	270.35a	344.96	-22NS
Redlans hope	136.32c	186.62d	-17NS	135.67b	202.74	-33NS
CV (%)	16.14	11.21		24.96	32.64	

**: p<0.01, NS: Non significant, - in the last column indicates difference of means between organic and conventional system according to t-test, Values with the same letter(s) are not significantly different at the 5% level

Table 6: Monthly yield of strawberry cultivars grown under organic and conventional system in 2004 and 2005 (g plant^{-1})

	2004						2005			
	Organic			Conventional			Organic		Conventional	
Cultivar	May	June	July	May	June	July	May	June	May	June
Kabarla	241.0a	158.9a	2.7b	361.2a	130.6a	9.5ab	112.0b	44.8b	167.2b	84.4b
Festival	203.9a	47.0c	2.8b	215.3b	40.0b	5.7bc	97.3b	49.9b	222.2ab	73.2b
Sweet charlie	132.3b	24.7d	2.9b	200.9b	58.1b	1.6c	224.7a	44.1b	286.2a	37.1b
Camarosa	205.7a	92.3b	1.0b	324.0a	45.1b	4.8c	157.1b	113.3a	188.9ab	173.9a
Redlans hope	85.6b	40.1cd	10.6a	118.3c	55.7b	12.6a	97.7b	36.7b	148.6b	53.8b
CV (%)	18.21	17.46	60.9	10.14	28.86	42.42	27.87	23.75	36.69	52.64

Values with the same letter(s) are not significantly different at the 5% level

influence on many soil factors and plant nutrient uptake mechanism (Singh *et al*., 2007). According to the mean values, TA of Sweet Charlie, Camarosa and Redlans Hope grown organically were significantly different than those of grown conventionally.

Yield: In both years, strawberry yield was higher in conventional than organic system (Table 5). Most of the fruits from both growing systems were picked in May during the experiment (Table 6). Differences between the growing systems in terms of yield were significant for Kabarla, Sweet Charlie and Camarosa. In the first year, of all the cultivars Kabarla and Camarosa gave the highest yield, while differences were significant for only Festival in the second year. In the first year yield, differences varied from 3% (Festival) to 39% (Sweet Charlie). Whereas, in the second year differences in yield varied from 22% (Sweet Charlie and Camarosa) to 50% (Festival). Small differences in yield in the first year might be explained by differences in soil nutrient level of each year (Table 1). According to total yield of two years, there were significant differences between two growing systems, ranging from 21% (Camarosa) to 29% (Sweet Charlie) (Table 7). This finding is in agreement with the result of Gliessman *et al*. (1996) who reported that organic system yields of strawberry California were depressed relative to conventional system yields by 39% in the first, 30% in the second and 28% in the third year. Although each cultivar showed different performance in present study, Kabarla and Camarosa were the less depressed cultivars. Working with seven strawberry cultivars, Daugaard (2001) reported that nutrient level is a cultivar-specific property and this must be taken into account in evaluating the nutrient demands of strawberries. Bull *et al*. (2001) tested twelve commercial strawberry cultivars in California and found that Aromas, Pacific and Seascape were the best performed cultivars under organic growing conditions. Black plastic mulch might be another factor leading to higher yield in conventional system. This result is compatible with the results of Kaikas and Luik (2002) and Singh *et al*. (2007).

Table 7: Total yield of strawberry cultivars (g plant^{-1})

Cultivar	Organic	Conventional	Difference (%)
Kabarla	561.56a**	752.95a**	-25**
Festival	400.82b	556.37c	-28**
Sweet Charlie	428.64b	602.58bc	-29**
Camarosa	569.65a	718.91ab	-21*
Redlans hope	271.99c	389.36d	-28*
CV (%)	14.60	14.67	

**: p<0.01, in the last column indicates difference, *: p<0.05, **: p<0.01, in the yield of the same cultivar grown organically and conventionally according to t-test, Values with the same letter(s) are not significantly different at the 5% level

Leaf nitrogen and chlorophyll: There were significant differences in leaf CHL reading values and leaf N among cultivars tested (Table 8). Kabarla and Redlans Hope had the highest CHL reading values and leaf N under both growing systems. Significant growing system by cultivar interaction for leaf CHL reading value indicated that cultivars had different response under different growing systems. Muramoto *et al*. (2003) tested five strawberry cultivars under organic system and found that there were significant differences in leaf N and petiole NO_3-N among

Table 8: Leaf CHL reading value and leaf N (%) of five strawberry cultivars under organic and conventional system conditions

	CHL reading			Leaf N (%)		
Cultivars	Organic	Conventional	Mean	Organic	Conventional	Mean
Sweet charlie	29.03c**	29.30c	29.16b**	1.58	1.68	1.63d**
Redlans hope	32.20ab	31.65b	31.93a	2.31	2.18	2.24ab
Kabarla	32.30ab	33.90a	33.10a	2.42	2.46	2.44a
Festival	29.05c	31.05bc	30.05b	1.88	1.93	1.91c
Camarosa	26.73d	30.25bc	28.49b	2.24	2.11	2.17b
Mean	29.86	31.23	30.55	2.09	2.07	2.08
CV (%)	3.72			7.22		

Cultivar × growing system interaction for chlorophyll $p<0.01$, for leaf nitrogen $p>0.05$, **: $p<0.01$, Values with the same letter(s) are not significantly different at the 5% level

cultivars. Among the cultivars Aromas and Seascape had the highest leaf N and petiole NO_3-N and had significant correlation between total leaf N and total fruit yield ($p<0.001$) and stated that total nitrogen in leaf blade may provide a better indicator for N status in organic strawberries. We found significant correlation between leaf CHL and leaf N ($r = 0.551$, $p<0.001$). Leaf N level has significant effect on yield and fruit quality. Therefore, leaf N should be monitored frequently in order to maintain it above or near to the sufficiency (2.8% N) level (Ulrich *et al*., 1980). Leaf N can be estimated by using leaf CHL reading values measured by SPAD chlorophyll meter (Leaf N = -0.32 + 0.079 CHL).

Diseases and pests: During the experiment plants were observed in relation to diseases and pests especially for *Tetranychus* sp. and grey mould (*Botrytis cinerea* pers). *Tetranychus* sp. population was under the economic threshold value (15 numbers per leaf) in both of growing systems, so no chemicals were used. We encountered some predators during observation. The low level of *Tetranychus* sp. population might be attributed to these predators.

In the first year, intensive grey mould was seen in both growing systems due to heavy rain continuing nine days without interval. No chemical was used against grey mould (*Botrytis cinerea* pers), it was controlled by cultural method, ie removing infected plants from the experimental area. In the second year, grey mould was not a serious problem under both growing systems.

CONCLUSIONS

This study revealed that Kabarla and Camarosa performed well not only under conventional but also organic conditions. These cultivars can successfully be grown organically under the same conditions of this study. Slow release of the nutrients from organic fertilizer is the main cause of lower yield of organically grown strawberry. Titretable acidity of fruit was strongly affected by fertilizer management and it was lower under organic growing conditions when compared to the conventional system. High correlation between leaf N and CHL indicated that leaf N can be monitored by measuring leaf CHL throughout the growing season.

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