Organic or conventional agriculture? A Study on yield and nutritional status of sweet corn

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Abstract

Organic cultivation of field crops became popular in the last decades due to public awareness about the effects of residual chemicals used in conventional farming systems on human health. Thus, we aimed to compare yield and plant nutritional status of conventionally and organically grown sweet corn (*Zea mays saccharata* L., Jubilee F1 cultivar) under Isparta, Turkey, ecological conditions. The effects of organic fertilization with leonardite (L) at 3 Mg ha^{-1}, farmyard manure (FYM) at 30 Mg ha^{-1} and L + FYM application were compared with the conventional cultivation (CC). Two year field experiments in completely randomized block design in triplicates were set up in 2012 and 2013 growing seasons. Fresh kernel samples were taken at milky maturing stage to reveal nutritional status of sweet corn. The yield and yield components obtained for conventionally cultivated corn were significantly higher than the organically cultivated ones. As the yield and yield components considered, L+FYM treatment was the best performing of the organic treatments and it was comparable to CC for some traits. Nitrogen deficiency was the critical problem of the organic treatments whereas there were also milder deficiencies of other nutrient elements. It can be concluded that despite smaller amounts of yield, the organic farming may be considered for the healthier sweet corn.

Introduction

Turkey has total of 5.8 million tons per year corn production (TUIK 2018). Majority of this production is used as animal feed (65-70%) and in sugar, starch and oil industry (20%) (Ozcan 2009). Chemical characteristics of sweet corn kernels in milky mature stage are different than the other corn species, thus it is suitable for fresh consumption. Moreover, sweet corn may be consumed either canned or frozen food (Kara and Atar 2013).

Sweet corn cultivation have increased in especially Aegean and Marmara regions of Turkey in the last decades. Since significant portion of both dent corn and flint corn is consumed freshly, sweet corn cultivation has a significant production potential in the market.

The composition of sweet corn is different than the rest of corn species. It has significantly higher sucrose (60 g kg^{-1}), protein and fat concentrations than the other species as harvested at the milky maturing stage. It is also a rich natural source of carotenoids such as gluten and zeaxanthin (Coskun et al. 2006). Corncobs or kernels at milky maturing stage can be used for human nutrition after some simple food processing procedures in either personal or industrial scale. This enables it to be consumed practically not only in summer times but also in any time of the year.

Increasing fertilizer prices and relative decreases in agricultural subsidies, and food and environmental quality along with consumer preferences are the main obstacles of conventional agricultural management systems in Turkey. As a result, as in the world, organic agriculture became widespread with 500 000 ha total area and 0.8% share in agricultural lands (TUIK 2018) due to economical, environmental and health considerations. Thus, economically feasible and environmentally friendly agricultural practices, such as organic farming, increasing the availability of plant nutrients in indigenous soils or supplying plant nutrients beside chemical fertilizers to soils should be used for healthy food production. In order to attain such goals, the use of low-cost organic residues, farmyard manure, industrial by-products may be recycled-back either as a source of organic matter and plant nutrients or as a soil conditioner in agricultural soils (Delgado et al. 2002, Uygur and Karabatak 2009).

Previous studies have indicated that a high-quality organic input can be comparable to, or more effective than the conventional fertilization practices, at least for some plant nutrient such as phosphorus (Nziguheba et al. 1998, Kwabiah et al. 2003). Similarly, Russo and Taylor (2010) reported that annually applied 5 Mg ha^{-1} chicken manure resulted in better yield performance than either biannual manure treatment or conventional treatment for sweet corn. However, the effects of organic treatments on yield comparing to conventional agricultural practices are species and site dependent. For example, the yield gap between conventional and transition to organic farming was reported to become smaller or even similar in the subsequent years for different vegetables such as pepper and cucumber, whereas sweet corn yields for plants under conventional production were always higher in three consecutive years (Russo and Taylor 2006). In reduced tillage system green manure intercropped with sweet corn enabled the enhancement in root length density at the upper layer of the soils without any significant difference in ear yield (Cherr et al. 2006).

Chemical quality of soils may be enhanced by mass amount of organic fertilizer additions in short-term. For example, it was reported that soil organic C, total N, and available P increased 60%, 68%, and 225%, respectively, above the control with the application of 144 Mg ha^{-1} compost during the 3-year study, whereas the low rate of compost treatments (31 Mg ha^{-1}) did not affect soil C or N but enhanced soil physical conditions (Evanylo et al. 2008).

Besides such beneficial chemical effects, long-term application of organic residues also enhances physical quality of soils towards environmentally friendly and sustainable agriculture (Bender et al. 1998). Despite such beneficial effects organic farming, in general, suffer from the limited magnitude of organic fertilizer resources and lower yield induced by slower release of plant nutrients that may cause nutritional disorders at the fast growing stages.

Thus the aim of this study was to compare the effects of various organic treatments on yield and yield components to those of the conventional practices in sweet corn cultivation under Isparta, Turkey, ecological conditions.

Materials and Methods

Site description and experimentation

Two year field experiment was set up in completely randomized block design in triplicates to compare the effects of conventional cultivation and organic growing on mineral nutritional status of grain, yield and yield components of sweet corn (*Zea mays saccharata* L., Jubilee F1 cultivar). The experiments were carried out in 2012 and 2013 growing seasons in Isparta ecological conditions (37° 45' N latitude, 30° 33' E longitude and 1050 m altitude). A field left fallow for at least two years was selected for the experiment. The experimental soil had a slightly alkaline pH with 13.0 g $CaCO_3$ kg^{-1}, 11.8 kg NH_4+ ha^{-1} of exchangeable nitrogen, 6.61 kg P ha^{-1} and 405 kg K ha^{-1}.

The region shows typical continental climate with cold and snowy winters and dry and mild-temperate summer (Table 1) which is suitable for growing early to mid-early maturing corn cultivars.

Table 1 - Some climate data for the growing seasons and long-term averages

Climatic factors	Years	April	May	June	July	August	Total or Average
		Months					
Precipitation	2012	53.2	107.4	18.1	0.8	34.6	214.1
(mm)	2013	59.9	66.5	34.4	88.2	15.4	264.4
	Long Years	56.6	50.8	28.4	18.4	0.8	155.0
Average	2012	10.8	14.5	22.5	25.4	22.8	19.2
Temperature (°C)	2013	11.9	17.1	20.5	23.0	23.7	19.3
	Long Years	10.8	15.6	20.1	22.3	23.9	18.5
Relative humidity	2012	57.0	66.0	46.0	42.0	43.0	50.8
(%)	2013	58.0	52.0	50.0	44.0	41.0	49.0
	Long Years	64.2	50.3	53.0	45.8	44.5	51.5

* Data were obtained from the Regional Meteorology Station, Isparta

The treatments were: i) conventional cultivation (CC) with 200 kg N ha^{-1} as ammonium sulphate (21%), 100 kg P_2O_5 ha^{-1} from triple super phosphate (46%), and 100 kg K_2O ha^{-1} from potassium sulphate (50%) fertilizers. Nitrogen was applied in two equal portions at sowing and 35-40 cm height stages, respectively whereas the phosphorous and potassium fertilizations were made at the sowing; ii) farmyard manure application (FYM) at 30 Mg ha^{-1}; iii) leonardite treatment (L) at 3 Mg ha^{-1}; and iv) the combination of FYM and L treatments. The FYM and L treatments were practiced at typical ra-

Table 2 - The effects of agricultural managements on yield and some yield components of sweet corn

Managements/ years	Ear length (cm)		Ear diameter (mm)		Number of kernels per ear (grain)		Ear weight (g)	
	2012	2013	2012	2013	2012	2013	2012	2013
CC	18.1 a	18.3 a	43.2 a	43.3 a	554.7 a	559.7 a	224.7 a	241.0 a
L	13.1 b	14.1 b	35.9 b	36.2 c	381.4 b	403.7 c	132.7 c	132.1 c
FYM	13.3 b	14.7 b	36.5 b	37.9 bc	383.9 b	415.3 bc	135.7 c	139.3 bc
L + FYM	14.8 b	15.3 b	38.1 b	40.6 ab	404.6 b	445.6 b	147.3 b	155.7 b
Years	14.8 B	15.6 A	38.4	39.2	431.2 B	456.1 A	160.1 B	167.0 A
LSD	2.17	2.24	3.55	3.41	74.26	37.51	6.93	20.48
C.V. (%)	6.84	4.47	8.05	6.87	5.69	7.57	6.43	5.61
F^P values	$31.94^{0.0004}$	$16.44^{0.0027}$	$23.69^{0.0010}$	$29.21^{0.0006}$	$34.34^{0.0004}$	$82.23^{0.0001}$	$1082.1^{0.0001}$	$131.78^{0.0001}$

Managements/ years	Fresh ear number (cobs ha^{-1})		Fresh ear yield (kg ha^{-1})		Protein content (%)	
	2012	2013	2012	2013	2012	2013
CC	63719.0 a	63936.7 a	14327.3 a	14580. 0 a	11.6 a	11.7 a
L	25000.0 c	25263.3 c	6150.0 c	6183.3 c	7.6 d	7.7 d
FYM	25375.0 c	26000.0 c	6351.0 bc	6463.4 c	9.2 c	9.1 c
L + FYM	30428.7 b	32270.3 b	7182.0 b	7576.7 b	10.4 b	9.8 b
Years	36130.7 B	36867.5 A	8502.6 B	8700.8 A	9.7	9.6
LSD	1907.1	2789.4	1029.0	1036.2	0.867	0.652
C.V. (%)	10.74	8.25	13.99	11.39	2.94	2.18
F^P values	$2603.45^{0.0001}$	$848.19^{0.0001}$	$396.65^{0.0001}$	$370.31^{0.0001}$	$107.29^{0.0001}$	$111.48^{0.0001}$

*CC: Conventional management, L: Leonardite, FYM: Farm yard manure, LSD: Least significant difference, and C.V: Coefficient of variation. Different letters in the same column indicate statistically significant difference at p≤ 0.05.

tes applied by the farmers. The FYM was matured for at least 6 months. The properties of the leanordite were: organic matter content 250 g kg^{-1}, humic acid + fulvic acid content 400 g kg^{-1}, pH 6-8 and water content 250 mL L^{-1}. Following the addition of both FMY and L, the plots were tilled by means of rototiller to maintain homogenous distribution.

The spacing used was 0.70 x 0.20 m and the plot area was 25.2 m^2 with 6 rows. Seeds were sown at 5-6 cm depth using a dibbler on the 5^{th} and 9^{th} of May in the first and second growing years, respectively. Two successive sprinkler irrigations were performed to maintain uniform plant establishment. After the emergence of maize seedlings, drip irrigation was used to meet water requirement in week intervals. The weeds were hand-hoed as appeared.

During the vegetative periods (from April to end of August) in 2012 and in 2013, there was total precipitation of 214.1 and 264.4 mm, average temperature of 19.2 and 19.3°C and an average humidity of 50.8 and 49.0% (Table 1).

Yield components and nutrient element analysis

Fresh sweet corn seeds were taken at milky stage to reveal the nutritional status of plants. The samples were dried at 65°C and then homogenized by grinding with a mill to reduce particle size below 0.5 mm. A scoop of 0.25 g samples were digested in a microwave oven with HNO_3 and H_2O_2 mixture (5:2 v/v) and diluted (Kacar and Inal 2013). Then the K, Ca, Mg, P, Fe, Cu, Mn, Zn, and B concentrations of the digests were determined by means of Inductively Coupled Plasma Optical Emision Spectrometer (Perkin-Elmer, Optima 2100 DV ICP-OES). Nitrogen concentrations of the seed samples were determined by semi-micro Kjeldahl method. The protein concentration of the grain was calculated by multiplying the nitrogen content by 6.25 (Simonne et al. 1996).

When the kernel moisture was about 72% (milk stage) for fresh consumption (Olsen et al. 1990), ears from 4 rows in the center of each plot were manually harvested. Fresh ear yield and its components including ear length, ear diameter, number of kernels per ear, ear weight and number of fresh ear were determined as described by Gokmen et al. (2004).

Statistical analysis

Both the nutrient elements and yield and yield components data were subjected to ANOVA to reveal the effects of treatments on the parameters by SAS statistical package (SAS 1990). The mean separation between the treatments' averages was made by the LSD test (Least Significant Difference) (Steel and Torrie 1980).

Table 3 -Management-induced macro and micro nutrient concentrations of sweet corn kernel

Agricultural practices	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
CC	1.86 a	0.324 a	0.810 a	0.019 a	0.12 a
L	1.22 d	0.265 c	0.753 b	0.014 b	0.10 b
FYM	1.48 c	0.282 bc	0.663 c	0.013 b	0.10 b
L + FYM	1.66 b	0.300 ab	0.790 ab	0.016 ab	0.11 a
LSD	0.139	0.027	0.041	0.004	0.008
C.V. (%)	2.94	3.04	1.81	8.39	2.51
F^P values	$107.19^{0.0001}$	$24.02^{0.0010}$	$68.03^{0.0001}$	$13.00^{0.0049}$	$32.09^{0.0004}$
	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	B (mg kg^{-1})
CC	21.45 a	2.716	9.168	31.74	4.045 a
L	17.59 b	2.222	7.101	28.12	2.395 b
FYM	13.74 c	2.752	8.425	29.65	3.063 ab
L + FYM	19.01 ab	2.238	8.975	31.60	3.487 a
LSD	3.173	ns	ns	ns	1.077
C.V. (%)	5.83	14.49	9.09	4.82	10.96
F^P values	$28.42^{0.0006}$	$2.09^{0.2034}$	$4.45^{0.0571}$	$4.17^{0.0647}$	$11.47^{0.0068}$

* CC: Conventional management, L: Leonardite, FYM: Farm yard manure, LSD: Least significant difference, and C.V: Coefficient of variation. Different letters in the same column indicate statistically significant difference at $p \leq 0.05$.

Results and Discussion

Yield and yield components

The effects of treatments on yield and yield components in two growing seasons were given in Table 2. Despite the yield and yield components' parameters obtained for conventional cultivation were better than the ones obtained for organic treatments; some trait such as ear diameter was comparable. Beside protein content, the differences between two growing seasons for the investigated-traits were significant (Table 2). Such differences were possibly resulted from the inherited effects of the organic treatments on yield and yield components; those were comparatively higher in the second growing season. Considerably higher increases were recorded for yield components of organically grown sweet corns such as 3.38-10.5% for ear length, 3.84-8.36% for ear diameter, 5.85-10.1% for kernel number, and 0.45-5.70% for kernel weight whereas in conventional cultivation, beside kernel weight (7.25%), majority of the traits showed an increase about 1% in the subsequent growing season. This trend indicates that as the organic cultivation continues longer period or with higher organic residue application it might be possible to obtain further enhancements in yield and yield components. Similarly the use of green manure (vetch plant) grown both between and within corn rows in a reduced-tillage system on a sandy Florida soil benefited the season-long growth of sweet corn much more than final ear yields (Cherr et al. 2006). Erdal et al. (2011) reported 7700-12000 Mg ha^{-1} fresh ear yield range for different cultivars grown in Antalya and Sakarya ecologies which are comparable to those obtained in this study for FMY + L treatment and smaller than the one obtained for the CC treatment. They reported 20.4 cm ear length and 4.3 cm ear diameter values for Jubilee variety which are similar to present study. This study also proves the critical importance of nitrogen for better yield either in conventional or in organic managements. On the other hand, light textured soils with low organic matter content, as the experimental soil, may be inadequate to supply sufficient amount of plant nutrients such as Ca, K, P and N.

Mineral nutrient composition of fresh kernels

Chemical quality of soils may be enhanced by mass amount of organic fertilizer additions in short-term to obtain economically feasible yield in the transition stage from the conventional to organic farming management system in low input arid and semi-arid regions. For example, Evanylo et al. (2008) reported a substantial increase in soil organic C (60%), total N (68%), and available P (225%) comparing to the control with the application of 144 Mg ha^{-1} compost during the 3-year study, whereas the low rate of compost treatments (31 Mg ha^{-1}), as the current study, did not significantly improve nutrient availability and abundance but enhanced soil physical conditions. Such significant difference between conventional and organic management systems in protein concentration of kernels is corresponded well with the findings of Evanylo et al. (2008). Leonardite which has the ability to supply the minimum nitrogen produced the minimum protein concentration. Along with the higher nitrogen supply by FMY and FMY+L treatments the protein content significantly increased. Despite significant improvement, FMY+L treatment still suffer from the lack of sufficient nitrogen supply. In relation to lack of nitrogen supply, weight of cob, number of cobs, and yield were comparatively very small, as small as 39% of the conventional ones. Similarly, Eghball and Power (1999) reported lower grain yield comparing to commercial fertilizer treatment for compost and cattle manure applied by taking into consideration the N requirement of corn. Their data are also well corresponded to total N uptake of corn despite significant fluctuations in the experimental years depending on the environmental conditions. Organic nitrogen management is particularly challenging in high N consuming crops such as sweet corn because of the low N content and low N to phosphorus (P) ratios of organic soil amendments (Johnson et al. 2012). Many studies have shown that crop yields generally are similar between manure and synthetic fertilizers as the applied organic fertilizers meet crop N requirements (Eghball and Power 1999, Basso and Ritchie 2005, Tarkalson et al. 2006). Sneller and Laboski (2009) found no difference in corn yield between manure types and synthetic fertilizer. In the current study, the yield gap between conventional and the organic treatments was very high in favor of conventional treatment. In contrast, it was reported that the yield gap become smaller or even nil in the subsequent years for different vegetables such as pepper and cucumber, whereas sweet corn yields for plants under conventional production were always higher in three consecutive years (Russo and Taylor 2006). Thus, the obtained improvements in the yield components can be mainly due the conditioner effects of the organic treatments and to a lesser extent their nutrient elements sustenance.

Macro nutrient elements' concentrations of fresh sweet corn kernels were given in Table 3. The nitrogen (N) concentrations of each treatment were separated in different individual groups. Their descending order was recorded as CC (18.6 g kg^{-1}), L + FYM (16.6 g kg^{-1}), FYM (14.8 g kg^{-1}), and L (12.2 g kg^{-1}), respectively. This suggested that all of organic treatments suffer from the maintaining the required N for optimum growth. It was reported that different sweet corn cultivars showed an N concentration range between 21.6- 28.2 g kg^{-1} for mature kernels with 10% water content (Goldman and Tracy, 1994). On the other hand, Oktem et al. (2011) reported a range of N concentrations between 16.8-34.8 g kg^{-1} for fresh kernel which is comparatively higher than the organic treatments. Nitrogen concentrations obtained for CC and FYM +L treatments may be comparable with the literature values whereas the organic treatments resulted in very low values.

FYM + L and CC treatments resulted in comparable kernel phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) concentrations. The other organic treatments were not able to supply adequate amounts of these elements at their corresponding yields. On the other hand, the plants usually maximize the efficiency of nutrient through dilution effect to produce possible highest yield at the nutrient deficient environment (Jarrell and Beverly 1981). In such cases analysis of any plant tissue shows a severe deficiency for only one element. The second or even third element may be found inadequate concentrations in any plant tissue but, due to reduced growth induced by the primary nutrient deficiency, the other elements will accumulate to differing degree depending on the sustenance. The organic treatments in this study resulted in severe N deficiency. Thus, the severity of the other elements' deficiencies was milder despite their supplies were not sufficient. Mineralization of organic P and organic amendments-induced solubilization of indigenous soil P (Uygur and Karabatak 2009) and possibly other elements was not sufficient to fully meet P, Ca, Mg, and P requirements of sweet corn. Under this circumstance, the smaller number of main separation groups may indicate the milder deficiency for the respective nutrient elements at current growth environments.

There were no significant differences between the organic and conventional treatments for copper (Cu), manganese (Mn), and zinc (Zn) concentrations of fresh kernel whereas Fe and B concentration behaved differently (Table 3). Manganese and Fe concentrations found in this study were similar; whereas Cu was smaller and Zn was higher than those reported by Oktem et al. (2011). Bressani et al. (1989) reported higher Fe, Cu, and Zn concentrations than the ones obtained in this study.

It can be concluded that organic treatments, especially in low input arid and semi-arid regions and coarse textured soils, have limitation in the first couple of years and require much higher organic residue or fertilizer addition per ha in order to meet the nutrient requirements of voracious plants such as sweet corn. In short term, it was not possible to produce high fresh ear yield organically as 30 Mg ha^{-1} FYM and/or 3 Mg ha^{-1} leonardite, typically practiced rates, applied. Mineral elements concentrations of the fresh kernel suggested that nitrogen is the main limiting nutrient element for obtaining better performance in organic treatments. On the other hand, the enhancement of yield components from the first year to second year may indicate that the organic treatments may be promising management to produce environmentally friendly and healthy sweet corn, if applied at larger quantities.

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