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Effects of winter green manuring on organic cucumber production in unheated greenhouse conditions

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Abstract: The effects of winter green manure crops on organic cucumber production were determined in unheated greenhouse conditions in order to integrate soil building and conservation practices, which are critically important in greenhouse production without crop rotation. The study was conducted between 2006 and 2008 to compare (1) pea (*Pisum sativum* L.), (2) Italian rye-grass (*Lolium multiflorum* L.), and (3) common vetch (*Vicia sativa* L.) as winter green manure plants. These treatments were compared with a control without green manuring (4). All of the plots were divided into halves, and poultry manure was applied as 0 (–PM) and 0.75 kg m^{-2} (+PM) to each. Cucumber (*Cucumis sativus* 'Sardes') was grown as a spring cycle production after winter green manure plants were incorporated into the soil. Treatments were evaluated in terms of yield, fruit quality parameters such as electrical conductivity, pH, titratable acidity, total soluble solids, and dry weight. Soil fertility and pest/disease incidence were also determined. It was found that cucumber yield varied between 9.7 and 16.3 kg m^{-2} and between 10.0 and 13.6 kg m^{-2} in the first and second spring growing seasons, respectively. Green manuring improved the organic matter and nitrogen contents of the soils. Other available nutrients in the soil were also analyzed and found to be sufficient. Additionally, the nutrient status of the cucumber plants was found to be sufficient. Pea and vetch proved to be efficient as winter green manure crops for vegetable production in greenhouses. Poultry manure also produced positive effects, in particular on soil total N content. Therefore, it could be used with green manure crops according to the N content of the soil.

Key words: Common vetch, *Cucumis sativus*, Italian rye-grass, pea, poultry manure

1. Introduction

Protected cultivation in the Mediterranean region has gained importance, and the region currently represents one of the most unique areas in the world due to the mild winter climatic conditions and the possibility of utilizing very simple protective shelters for plant production. Total covered area in the region has reached 351,141 ha in recent years, out of which 211,556 ha are devoted to greenhouses and 138,854 ha to low tunnels (Tüzel and Leonardi 2009). Protected cultivation in the region is practically synonymous with cultivation under plastic (FAO 1990a). Although technological improvements in plastic covering materials and greenhouse structures have been recorded, low-tech and low-cost structures characterize the protected cultivation in most of the Mediterranean region (Tüzel and Leonardi 2009). Growers use only limited energy to partially control greenhouse temperatures during cold seasons (Baille 1999, 2001), resulting in poor climatic conditions and low yield and fruit quality. Pesticide and fertilizer use are also high in the region due to continuous cropping and lack of rotation (Hanafi and Papasolomontos 1999; Tüzel et al. 2007). Therefore, the use of environmentally friendly systems has a special importance for sustaining agricultural practices in an economically feasible way and maintaining a balance between agricultural land and the environment (Tüzel et al. 2005).

In recent decades consumer buying inclination has focused on food safety and quality (Gruda 2005). The traceability of produce has become an essential element of production in order to provide the customer with information about production inputs. This consumer demand could be met through production methods that are environmentally, economically, and socially sustainable

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(Van Uffelen et al. 2000). Sustainable and controllable production processes are 2 main issues that will guide future developments in protected cultivation.

Organic farming is one of several approaches to sustainable agriculture. Organic agricultural area worldwide has reached 37 × 10^6 ha. The global market for organic products in 2010 was estimated at 44.5 billion euros, and compared to 2009, the market trends have increased by roughly 8% in Europe and the United States (IFOAM/FIBL 2011). The demand for organic vegetables is significant and growing steadily, and the majority of organic production comes from open fields. In this regard, organic greenhouse vegetable production has promising potential as a niche market for the production of out-of-season produce (Tüzel et al. 2001). The total acreage of European Union organic greenhouse horticulture is 3700 ha and has increased 5% per year (Van der Lans et al. 2011). However, it is still limited compared to conventional greenhouse production due to the high investment requirement for infrastructure (i.e. greenhouses and climate control), the need to grow high cash crops, and the difficulty of rotating crops using a limited number of crops, which results in lower yields (up to 55%) (Tüzel et al. 2005).

Organic greenhouse growers have a limited number of tools for crop and soil fertility management, which are critically important for productivity. In organic production, growers rely heavily on crop rotations, crop remains, animal manures, legumes, green manures, organic wastes, and mineral-bearing rocks to feed the soil and supply plant nutrients. Pests, weeds, and diseases are managed by mechanical cultivation and cultural and biological methods (Greer and Diver 2000). Green manuring is one of the tools for improving soil productivity (Watson et al. 2002) and is considered the backbone of organic cropping systems (Sullivan 2003).

Green manuring is the plowing of cover crops while they are green or soon after they flower. Green manuring improves soil quality by increasing the organic matter content of soils (Doran and Smith 1987; Duyar 2007), acting as a source of nutrients (Drinkwater et al. 1998; Staver and Brinsfield 1998; Dinnes et al. 2002), improving soil structure (Gallandt et al. 1999; Sullivan 2003), restricting growth of weeds (Teasdale 1998), helping in soil-borne disease control in suppressive soils (McGuire 2003; Sullivan 2003; Crow and Dunn 2010), and increasing biological activity in the soil (Tu 1990; Urzua et al. 2001). Green manure crops are grown either before or along with the main crop in winter or summer.

Green manuring is not common in protected cultivation due to the time required for adequate development of the green manure crop prior to the main crop. However, in low-tech and low-cost structures, green manure crops can be grown during the winter months before the production of long-term high-value cash crops.

In the Aegean region, cucumber is widely grown during the spring/summer seasons in greenhouses located in the preservation area of a dam, which is the major drinking water source for İzmir, the third largest city in Turkey. Green manuring could be introduced to the region as a practice in order to improve soil fertility and reduce chemical fertilizer use. Therefore, in this study, cucumber was selected as the main crop and winter green manure plants were tested to compare the effects on cucumber yield and fruit quality, to determine nutrient uptake with or without poultry manure applications, and to evaluate the effect of green manuring on soil fertility.

2. Materials and methods

The experiment was conducted in a polyethylene (PE) covered double span greenhouse (12 × 44 m) with galvanized construction, side and roof ventilation, and an insect net from 2006 to 2008 in Bornova (38°27′16.5″N, 27°13′16.8″E), İzmir, Turkey.

The experimental layout was a split-plot design with 3 replicates. The main plots were assigned to green manure crops (GMs) and the subplots to poultry manure (PM). The data related to the physical and chemical properties of the soil and the PM are given in Tables 1 and 2.

Table 1. Physical and chemical properties of the experimental soil.

pH	7.06	Available P (mg kg^{-1})	8.19
Soluble salts (%)	0.15	Available K (mg kg^{-1})	671.0
$CaCO_3$ (%)	2.87	Available Ca (mg kg^{-1})	3125.0
Sand (%)	61.28	Available Mg (mg kg^{-1})	232.0
Clay (%)	16.72	Available Mn (mg kg^{-1})	37.80
Loam (%)	22.00	Available Fe (mg kg^{-1})	7.28
Texture	Sandy loam	Available Cu (mg kg^{-1})	7.70
Organic matter (%)	2.43	Available Zn (mg kg^{-1})	4.70
Total N (%)	0.12		

Table 2. Physical and chemical properties of the poultry manure.

pH	6.40	Total Ca (%)	3.53
Soluble salts (dS m^{-1})	5.00	Total Mg (%)	0.73
Organic matter (%)	9.96	Total Fe (%)	0.15
Total N (%)	2.69	Total Mn (mg kg^{-1})	329.0
Total P (%)	2.15	Total Cu (mg kg^{-1})	36.0
Total K (%)	1.90	Total Zn (mg k^{-1})	140.0

The experimental soil was neutral in reaction, low in $CaCO_3$ and organic matter, and had a sandy loam texture. Macro- and microavailable plant nutrients in the soil were found to be sufficient (Table 1). PM was of organic origin in pellet form and provided by Org-E-Vit (ITM Turhol Company, Antalya, Turkey) (Table 2).

The 3 GMs, (1) pea (*P. sativum* L.), (2) Italian rye-grass (*L. multiflorum* L.), and (3) vetch (*V. sativa* L.), were compared to (4) the control (no green manure). PM was also tested for its effects on yield and soil fertility, according to the results obtained from previous studies (Karaçancı and Tüzel 2006; Okur et al. 2006). Therefore, each main plot was divided into 2 subplots for PM treatments. The green manure plant seeds, pea, Italian rye-grass, and vetch, were sown on 15 October 2006 and 25 October 2007 as 15.0, 3.0, and 10.0 g m^{-2}, respectively. Plants were incorporated into the soil during the 8th or 9th weeks (after the first flower appearance). PM was applied to each subplot (9 × 5 m) before transplanting the cucumber seedlings into the greenhouse as (1) 0 (–PM) and (2) 0.75 kg m^{-2} (+PM) on 8 March 2007 and 6 March 2008, respectively.

Cucumber (*C. sativus* L. 'Sardes') seedlings were planted on 16 March 2007; however, the seedlings were replaced on 21 April due to retarded growth. The second year of production started on 20 March 2008. In both growing cycles, plant density was 3.57 plants m^{-2} (90 × 50 × 40 cm). The cucumber cultivar Sardes, which is resistant to powdery mildew (PM), *Cucumber mosaic virus* (CMV), *Cucumber vein yellowing virus* (CVYV), and *Zucchini yellow mosaic virus* (ZYMV), was selected since it is the most common cultivar grown by local growers.

Pruning was done by removing the flowers and lateral shoots up to a height of 30 cm; subsequently, all lateral branches were pruned out leaving 1 fruit and 1 leaf per node until the main stem reached the overhead wire (Hochmuth 2008). Irrigation was based on Class A pan evaporation (Allen et al. 1998; Castilla 1999).

Greenhouse indoor climatic data were recorded with a HOBO U12 Temperature/Relative Humidity Data Logger (Onset Company, Bourne, MA, USA) and downloaded using HOBOware Pro Software. During the growing period, the average air temperatures were 17.35 °C and 15.41 °C, relative humidities were 31.90% and 39.53%, and soil temperatures were 18.20 °C and 16.87 °C in the first and second years, respectively.

Harvested fruits were weighed and counted to determine the fruit yield and the number of fruits from each plot. Yields were classified as total and unmarketable (misshaped and/or with any disorder) in each harvest and eventually calculated at the end of each growing season in kg m^{-2}.

Fruit samples were taken at 2 time intervals (5 June and 3 July in the first year; 15 May and 12 June in the second year) during the harvest period in order to determine some quality parameters such as electrical conductivity (EC), pH, titratable acidity (TA), total soluble solids (TSS) of fruit juice, and dry matter content (DMC) of fruits. Ten fruit samples were taken from each plot. Fruit juice was extracted using a kitchen juicer and filtered through qualitative paper. TSS values were measured by digital refractometer (Euromex RD 645, Arnhem, the Netherlands). TA was determined by titration with 0.1 N NaOH until pH 8.1 and expressed as mval 100 mL^{-1}. The dry matter content (expressed as percentage of fresh weight) was determined by drying samples in an oven at 65 °C until constant weight was obtained. The means of 2 sampling periods were used for statistical analysis.

To study and establish the current fertility status of the treatment plots during the growing season, soils were periodically sampled and analyzed before green manuring, at the time of incorporation of green manure plants, at 30 days after incorporation, at transplanting of cucumber seedlings, and at the middle and the end of the growing period. Soils were sampled and analyzed for their physical and chemical properties according to standard methods (Rauterberg and Kremkus 1951; US Soil Survey Staff 1951; Bouyoucos 1962; Bremner 1965; Schlichting and Blume 1966; Jackson 1967; Kacar 1995). To determine nutrient uptake of the plants, whole plants were harvested from the soil surface (above ground) at the end of growing cycles, dried at 65 °C, and analyzed for their macro- and microelement status (Kacar 1972, 1995).

During the growing period, observations were made once a week in order to determine the incidence of pests and diseases. Above-ground pests were monitored on 10 plants in each treatment. Sticky yellow traps, 1 trap

15 m^{-2}, were hung 10 cm above the plants to monitor pests and were changed at 2-week intervals. For pest and disease control, sulfur (80% wettable, Kumulus DF, BASF AgSolutions Inc., Canada) and potassium soap (Aka Chemistry, Bornova, İzmir, Turkey) were applied at 0.4% and 3.0%, respectively, as recommended.

According to the data obtained from the research, analysis of variance was carried out using a statistical analysis package program (TARİST) (Açıkgöz et al. 1994) and the least significant difference (LSD) test was conducted at 5% importance level in order to identify differences between means.

3. Results

3.1. Yield and total fruit number

Fruit harvest started on 17 May and continued until 23 July in the first year, and in the second year the fruit harvest continued from 1 May to 30 June. Yield varied between 9.7 and 16.3 kg m^{-2} in the first and between 10.0 and 13.6 kg m^{-2} in the second year of the experiment (Table 3).

The effects of green manures on total yield and total fruit number were significant in both years. The effect of PM on total yield and fruit number was also significant in the first year. With respect to interactions, in the first year pea green manuring and in the second year pea and vetch green manuring with or without PM gave higher yield and fruit numbers. Italian rye-grass and the control without PM gave the lowest yield in both years. Unmarketable yield was between 0.25 and 0.40 kg m^{-2} and between 0.31 and 0.42 kg m^{-2} in the first and second years, respectively (Table 3).

3.2. Fruit quality

The TSS, TA, and EC of fruit juices showed significant differences among green manure treatments in the first year. Fruit juice EC was the highest in vetch manuring and the control, and TSS was the highest in vetch manuring. No impact of green manuring was found in the second year in terms of fruit quality parameters excluding TA (Table 4). Regarding TA, results were contradictory in both years. The highest TA value was measured in the pea manuring

Table 3. Effect of treatments on total and unmarketable yield and fruit number.

Treatments		Total yield (kg m^{-2})		Total fruit number (no m^{-2})		Unmarketable yield (kg m^{-2})	
		First year	Second year	First year	Second year	First year	Second year
Main effects							
Green manure	Pea	16.0 a	13.5 a	110.3 a	72.2 a	0.35	0.32
	Italian grass	12.4 bc	10.9 b	92.2 ab	63.8 b	0.35	0.36
	Vetch	14.0 ab	13.5 a	104.6 ab	76.5 a	0.30	0.34
	Control	11.5 c	10.4 b	86.5 b	64.3 b	0.26	0.34
	LSD $_{(0.05)}$	2.43	1.26	18.97	4.65	Ns	ns
Poultry manure	+PM	14.4 a	12.4	104.3 a	71.2	0.33	0.37
	–PM	12.5 b	11.7	92.6 b	67.3	0.30	0.31
	LSD $_{(0.05)}$	1.04	ns	7.25	ns	ns	ns
Interaction effects							
Pea	+PM	16.3 a	13.6 a	113.7 a	74.9 ab	0.40	0.33
	–PM	15.6 ab	13.3 a	106.9 ab	69.6 ab	0.30	0.30
Italian grass	+PM	13.9 c	11.6 ab	101.1 ab	66.9 ab	0.36	0.42
	–PM	10.8 d	10.3 b	83.3 cd	60.8 b	0.35	0.30
Vetch	+PM	14.2 bc	13.8 a	107.0 ab	77.8 a	0.29	0.36
	–PM	13.9 c	13.2 a	102.3 ab	75.2 ab	0.31	0.32
Control	+PM	13.2 c	10.8 b	95.3 bc	65.1 ab	0.28	0.37
	–PM	9.7 d	10.0 b	77.7 d	63.6 ab	0.25	0.31
	LSD $_{(0.05)}$	2.074	2.24	14.51	14.53	ns	ns

Values shown with differing letters are significantly different. ns: nonsignificant.

Table 4. Effect of treatments on fruit quality parameters.

Treatments		EC (dS m^{-1})		pH		TA (mval 100 mL^{-1})		DW (%)		TSS (%)	
		First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
Main effects											
Green manure	Pea	4.69 b	4.70	5.73	5.46	1.90 a	1.76 b	5.06	5.63	3.03 b	2.04
	Italian grass	4.71 b	4.60	5.77	5.45	1.69 ab	1.97 a	5.58	5.70	3.13 ab	2.07
	Vetch	4.91 a	4.59	5.78	5.47	1.61 b	2.03 a	5.49	5.17	3.23 a	2.00
	Control	4.91 a	4.78	5.78	5.45	1.70 ab	2.06 a	4.84	5.43	3.21 ab	2.10
	LSD $_{(0.05)}$	0.149	ns	ns	ns	0.213	0.145	ns	ns	0.190	ns
Poultry manure	+PM	4.79	4.66	5.74 b	5.45	1.76	2.02 a	5.31	5.61	3.14	2.08
	–PM	4.82	4.67	5.77 a	5.46	1.69	1.89 b	5.18	5.36	3.16	2.03
	LSD $_{(0.05)}$	ns	ns	0.026	ns	ns	0.109	ns	ns	ns	ns
Interaction effects											
Pea	+PM	4.67 b	4.68	5.74 bc	5.46	1.95 a	1.94 a	4.79 c	5.91	2.95 b	2.14
	–PM	4.71 b	4.73	5.71 c	5.47	1.85 ab	1.59 b	5.33 ab	5.37	3.12 ab	1.94
Italian grass	+PM	4.71 b	4.53	5.70 c	5.42	1.67 bc	2.02 a	5.75 a	6.16	3.22 a	2.03
	–PM	4.71 b	4.68	5.77 b	5.47	1.72 abc	1.93 a	5.41 ab	5.25	3.05 ab	2.12
Vetch	+PM	4.83 ab	4.70	5.79 b	5.46	1.62 bc	2.04 a	5.64 a	5.26	3.28 a	2.00
	–PM	4.99 a	4.49	5.77 b	5.48	1.59 c	2.02 a	5.34 ab	5.09	3.18 ab	2.00
Control	+PM	4.96 a	4.74	5.73 c	5.46	1.81 abc	2.10 a	5.06 bc	5.12	3.12 ab	2.15
	–PM	4.86 ab	4.81	5.83 a	5.44	1.59 c	2.02 a	4.62 c	5.75	3.30 a	2.06
	LSD $_{(0.05)}$	0.240	ns	0.052	ns	0.226	0.218	0.452	ns	0.264	ns

Values shown with differing letters are significantly different. ns: nonsignificant.

treatment in the first year, whereas it was the lowest in the second year. The effect of PM on the pH of the fruit juice was significant in the first year. There was also a significant effect on TA in the second year.

Significant interactions were found between the treatments in the first year. DMC of the fruits was higher in the vetch and Italian rye-grass green manure plots with PM. The control without PM had the highest TSS. Fruit juice EC changed between 4.67 and 4.99. Among the treatments, control (–PM) and pea (+PM) had the highest pH and TA of fruit juice, respectively. In the second year, there were no significant differences, excluding TA, in green manuring. TA was the lowest in pea manuring without PM (Table 4).

3.3. Soil fertility and nutrient status of plants

The pH of the experimental soil changed from neutral to slightly alkaline. Organic matter (%), water soluble salts (%), and calcium carbonate (%) contents were 2.43, 0.15, and 2.87 in the first year (Table 1). In the second year, these specified soil properties ranged from 1.24% to 1.81%, 0.128% to 0.178%, and 1.24% to 2.65%, according to treatment, before the seed sowing of green manure plants in the second year.

In both years, results related to available plant nutrients in the soils showed variation with respect to sampling dates. In the first and second years, the changes were, respectively, 0.10%–0.21% and 0.09%–0.21% for nitrogen, 3.76–9.34 mg kg^{-1} and 5.34–7.82 mg kg^{-1} for phosphorus, and 320–671 mg kg^{-1} and 260–590 mg kg^{-1} for potassium (Tables 5a and 5b). In the first year of the experiment, when PM (+) was applied to green manured plots, average soil organic matter content increased by 19.61% at transplanting compared to the control treatment. If no PM (–) was applied, the increase was 11.35%. In the second year, the average organic matter content was 22.2% higher at the transplanting of cucumber seedlings when only green manuring (–PM) was practiced. The increases were slightly lower in the second year despite

Table 5a. Organic matter, N, P, and K content of the soils in the first year.

Treatments*		Pea		Vetch		Italian grass		Control	
		–PM	+PM	–PM	+PM	–PM	+PM	–PM	+PM
Organic matter (%)	1	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43
	2	1.23		1.34		1.79		1.67	
	3	1.34		1.73		2.56		1.45	
	4	1.25	1.56	1.78	1.56	1.25	1.46	1.34	1.23
	5	1.34	1.56	1.67	1.78	1.78	1.35	1.45	1.43
	6	1.78	2.65	2.70	2.23	2.44	1.49	1.56	1.45
	Mean	1.56	2.05	1.94	2.00	2.04	1.60	1.65	1.64
Total N (%)	1	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	2	0.10		0.12		0.15		0.14	
	3	0.12		0.10		0.21		0.12	
	4	0.10	0.11	0.15	0.10	0.10	0.11	0.12	0.13
	5	0.12	0.12	0.14	0.15	0.11	0.12	0.14	0.12
	6	0.15	0.15	0.13	0.19	0.11	0.15	0.13	0.11
	Mean	0.12	0.13	0.13	0.14	0.13	0.13	0.13	0.12
Available P (mg kg^{-1})	1	8.19	8.19	8.19	8.19	8.19	8.19	8.19	8.19
	2	5.19		6.19		4.67		4.34	
	3	4.69		3.76		6.30		3.76	
	4	9.15	8.67	6.45	6.57	6.78	7.83	6.18	6.57
	5	9.34	6.78	6.78	7.56	6.54	8.65	5.65	5.89
	6	7.65	6.54	7.65	5.67	7.56	6.87	7.54	7.47
	Mean	7.37	5.03	6.50	4.67	6.67	5.26	5.94	4.69
Available K (mg kg^{-1})	1	671	671	671	671	671	671	671	671
	2	380		320		380		380	
	3	380		420		480		440	
	4	390	450	430	450	430	450	460	430
	5	460	480	390	400	460	370	480	480
	6	450	460	420	460	480	410	450	320
	Mean	455.17	343.50	441.83	330.17	483.50	316.83	480.17	316.83

*1: before manuring (15.10.2006); 2: at incorporation (17.01.2007); 3: at 30 days after incorporation (17.02.2007); 4: at transplanting (08.03.2007); 5: at the midpoint (30.05.2007); 6: at the end (23.07.2007) of the growing period.

Table 5b. Organic matter, N, P, and K content of the soils in the second year.

Treatments*		Pea		Vetch		Italian grass		Control	
		–PM	+PM	–PM	+PM	–PM	+PM	–PM	+PM
Organic matter (%)	1	1.36	1.45	1.56	1.76	1.25	1.24	1.55	1.81
	2	1.40	1.34	1.87	2.34	1.36	1.78	1.70	1.24
	3	1.56	1.89	1.56	1.78	2.49	2.49	1.55	1.65
	4	1.56	1.36	1.78	1.54	1.24	1.56	1.19	1.50
	5	1.78	1.67	1.46	1.58	1.68	1.87	1.91	1.08
	6	1.56	1.80	1.75	1.56	1.72	1.52	1.55	1.54
	Mean	1.54	1.59	1.66	1.76	1.62	1.74	1.58	1.47
Total N (%)	1	0.09	0.11	0.13	0.15	0.10	0.13	0.13	0.15
	2	0.10	0.10	0.16	0.20	0.12	0.15	0.14	0.10
	3	0.10	0.12	0.14	0.15	0.15	0.21	0.13	0.14
	4	0.13	0.12	0.16	0.11	0.10	0.14	0.10	0.13
	5	0.10	0.12	0.12	0.13	0.14	0.14	0.10	0.16
	6	0.10	0.15	0.13	0.15	0.13	0.16	0.13	0.11
	Mean	0.10	0.12	0.14	0.15	0.12	0.16	0.12	013
Available P (mg kg^{-1})	1	5.37	5.40	6.78	6.34	6.78	7.56	7.54	6.78
	2	5.45	6.37	6.56	7.54	6.13	6.78	6.56	7.67
	3	5.78	6.78	5.34	6.46	6.47	7.56	6.12	7.14
	4	7.57	7.79	6.58	7.82	6.13	7.56	6.11	6.15
	5	7.32	7.56	8.24	7.56	7.24	7.13	7.76	7.56
	6	6.24	6.72	7.64	7.46	6.98	6.76	6.56	6.78
	Mean	6.29	6.77	6.86	7.20	6.62	7.23	6.78	7.01
Available K (mg kg^{-1})	1	410	420	480	520	480	450	260	480
	2	420	460	580	530	470	430	470	350
	3	430	420	520	530	540	570	350	450
	4	480	390	580	590	580	590	420	410
	5	400	480	480	500	370	450	410	470
	6	420	450	400	590	360	420	470	550
	Mean	426.67	436.67	506.67	543.33	466.67	485.00	396.67	451.67

*1: before manuring (25.10.2007); 2: at incorporation (03.01.2008); 3: at 30 days after incorporation; 4: at transplanting (06.03.2008); 5: at the midpoint (31.05.2008); 6: at the end (30.06.2008) of the growing period.

the PM application. Nutrient uptake in the cucumber plants changed according to treatment and experimental year (Table 6). In the first year, the effect of GMs on N, P, and K uptake was not significant. The green manure × PM interaction was significant for N and K uptake. N and K uptake in cucumber plants changed between 7.02 and 5.04 and between 6.74 and 4.40 mg kg^{-1}, respectively. In the second year, the effect of GMs on P uptake was found to be significant. The highest uptake was measured in pea manuring. There were also significant differences in P and K uptake among the treatments regarding green manure × PM interaction. The cucumber plants in the Italian grass treatment with or without PM had the lowest P and K uptakes.

3.4. Plant protection

Disease incidence was not observed in either growing cycle; however, pest problems, namely spider mites and thrips, were determined. For pest control, preparations permitted in organic agriculture (i.e. sulfur and potassium soap) were used when necessary.

4. Discussion

Average total yields were 13.5 and 12.1 kg m^{-2} in the first and second years, respectively. Crop yield is affected by the performance of the variety, the abiotic and biotic stress resistance/tolerance of the variety, climatic conditions, length of growing season, production system, and crop management (Tüzel and Gül 2008). The cucumber plants

Table 6. N, P, and K uptakes (mg kg^{-1}) of cucumber plants in different treatments (first and second years).

Treatments			N		P		K	
			First year	Second year	First year	Second year	First year	Second year
Main effects								
Green	Pea		5.90	5.53	1.09	1.25 a	5.98	13.65
manure	Italian grass		6.46	4.83	1.11	0.64 c	5.97	11.17
	Vetch		6.57	4.94	1.12	1.08 b	4.88	13.17
	Control		6.44	4.67	1.06	1.09 ab	5.45	13.31
		LSD $_{(0.05)}$	ns	ns	ns	0.16	ns	ns
Poultry	+PM		6.12	5.13	1.13	1.08	5.72	13.07
manure	–PM		6.57	4.85	1.06	0.95	5.43	12.58
		LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns
Interaction effects								
Pea	+PM		5.04 d	5.71	1.25	1.41 a	5.91 bc	14.83 a
	–PM		6.77 abc	5.36	0.93	1.10 abc	6.05 b	12.46 ab
Italian grass	+PM		7.02 a	5.12	1.26	0.59 d	6.74 a	10.90 b
	–PM		5.90 cd	4.54	0.97	0.68 cd	5.20 d	11.34 b
Vetch	+PM		6.42 abc	5.27	1.12	1.26 ab	4.40 e	14.23 a
	–PM		6.73 abc	4.60	1.13	0.90 bcd	5.37 cd	12.12 ab
Control	+PM		6.01 bc	4.42	0.91	1.04 abc	5.82 bc	12.32 ab
	–PM		6.88 ab	4.91	1.20	1.13 ab	5.09 d	14.31 a
		LSD $_{(0.05)}$	0.94	ns	ns	0.43	0.58	2.82

Values shown with differing letters are significantly different. ns: nonsignificant.

in conventional greenhouse production systems generally yield 10–20 kg m^{-2} in short-term production, while the yield can increase up to 45 kg m^{-2} in longer cycles (Engindeniz et al. 2007). Previous studies on organic greenhouse cucumber production showed variation from 13.7 to 21.65 kg m^{-2} (Tüzel et al. 2002, 2003) due to differences in the length of the growing period, number of plants, and/or pest and disease incidence. However, yield reductions in some vegetable crops in organic greenhouse production, when compared to conventional production and/or soilless culture, are also reported (Tüzel et al. 2005). In this regard, the yield results of the present study are in agreement with local average yield data (approximately 10 kg m^{-2}), and the highest treatments are reasonable in terms of return that could be profitable to the grower.

Among the examined green manure plants the leguminous crops, pea and vetch, provided higher yields, which might particularly be due to the increase in organic matter content and available N in the soil. It could also could be attributed to the several benefits of leguminous crops in terms of organic matter, soil structure, soil microbial activity, nutrient enhancement, rooting action, weed suppression, and soil and water conservation (Sullivan 2003; Duyar et al. 2007, 2012). The positive effects of green manuring in open-field vegetables are well documented (Beckmann 1977; Thorup-Kristensen and Van Den Boogaard 1999; Stirling and Stirling 2003; Chaves et al. 2004; Thorup-Kristensen 2006; de Góes et al. 2011).

The effects of treatments on fruit quality parameters were contradictory over the 2 years. Individual and/or interactive effects were significant in the first year, whereas there were no significant differences, excluding TA, in the second year. Similar contradictory results related to harvest dates were found in some previous studies on organic greenhouse cucumber production where different irrigation schedules with organic fertilizers (Tüzel et al. 2005) and organic manures (Karaçancı 2010) were tested. As these values were the means of 2 harvest dates, climatic conditions and lack of uniformity in the sampling could play a role in the observed differences (Hobson and Davies 1971; Karaçancı and Tüzel 2006).

Organic farming is based on building/maintaining soil fertility. It is important to achieve a balance between inputs and outputs of nutrients to ensure either short-term productivity or long-term sustainability (Watson et al. 2002). Plant nutrients provided from organic sources depend on mineralization, which is affected by moisture, temperature, pH, and the biological life of the soil. Organic materials are less predictable regarding nutrient content, nutrient release, and nutrient-use efficiency (Mitchell 2008), and acquiring the amounts needed may be difficult. Therefore, precise control of plant nutrition is not as easy as it is in conventional production. In this experiment the amount of available nutrients in the soil was found to be sufficient according to Bingham (1949), Lindsay and Norwell (1969), and the FAO (1990b). Plant N, P, and K contents were also found to be sufficient in both years (Jones 1983).

There was no incidence of disease in either year, and pest problems appeared in particular on plants that were close to the entrance. The preparations allowed in organic agriculture were satisfactory in terms of pest control (Başpınar et al. 2000; Madanlar et al. 2000, 2002).

The results of the present study showed that green manuring can improve organic matter and total N content of soils, increase yield, and supply nutrients to the sequential crop. Pea and vetch were efficient GMs under the conditions of the present study. PM also had positive effects, in particular on soil total N content. Therefore, it could be used with GMs according to the N content of the soil.

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