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ORIGINAL RESEARCH

Effects of green manure and poultry manure on strawberry production and soil fertility

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Abstract

Purpose In this study, the effects of green manure and animal waste on economic of strawberry yield, fruit quality and soil fertility were investigated.

Method The experiment was set up with four replicates in a randomized complete block design. The treatments consisted of green manure parcels divided into two parts and green manure + poultry manure slurry were given to one part, and the other part was not applied complete. Seed planting was carried out in the first year of the experiment (2015) while strawberry plants were removed during the second year (2016) and the seeds of green manure plants were planted. *Soja hispida* [Soja] and *Vigna sinensis* [Cowpea] plants were mown and mixed into the soil when they were in bloom.

Results The results from the study shows that the yield realized from control plot during first year was between 10.68 and 22.33 t ha^{-1}, second year yield was between 8.81 and 23.39 t ha^{-1} and third year was 10.68 and 16.98 t ha^{-1}. After harvest, soil organic matter content increased by 12% in the first year and 5.10% in the second year in green manure + poultry manure slurry application, the total nitrogen content increased by 75% in the first year and 10% in the second year. In the fruit, it gave higher content of Vitamin C and nitrate level.

Conclusion From our findings, it was discovered that green manure and poultry manure slurry gave better results in terms of fruit yield, quality, soil fertility and economy.

Keywords Green manuring, Organic agriculture, *Soja hispida,* Strawberry, *Vigna sinensis*

Introduction

Organic agriculture includes sustainable production systems that restore the natural balance that has been upset as a result of improper practices in agricultural activities. It is an alternative form of agriculture that does not use synthetic chemical pesticides and fertilizers, which are environmentally hazardous agricultural production inputs, and enables achieving soil fertility through green manuring and crop rotation as an alternative (İlter and Altındişli 1996). Management of soil fertility in organic agriculture is one of the most important issues. Fertilization with natural and organic substances in this agricultural system has to be done. Moyin-Jesu (2015) in a study conducted on cabbage concluded that the use of poultry manure in cabbage production can achieve significant economic benefits, as well as increase soil fertility and ensure environmental sustainability. Products that are produced using organic fertilizers and do not contain pesticide applications in world markets attract great attention. These preferences suggest that the possibilities of using various organic materials in agriculture should be investigated in more detail. One of them is poultry manure, which is an organic fertilizer; it has been a good source of nutrients for plants, especially nitrogen and other plant nutrients, as well as improving the physical properties of the

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soil. Adeyemo et al. (2019) found a similar result in a study conducted in maize that the application of poultry manure at regular intervals significantly improved soil physical properties, organic matter and maize productivity while reducing the production cost. "Green manure" is one of the ways to improve soil structure, prevent soil erosion, preserve soil moisture and increase the amount of organic matter in the soil (Soyergin 2006). Also, green manuring prevents soil erosion and thereby ensures that the elements important in plant nutrition remain in the soil (Soyergin 2006). It also improves soil structure (Watson et al. 2002), increases the amount of organic matter in the soil (Sullivan 2003) and enhances the amount of nutritional element uptake (Dinnes et al. 2002; Sullivan 2003). Also, it helps weed control (Sullivan 2003), has a positive effect on the quantity and functions of microorganisms in the soil by providing a nutrient source for microorganisms in the soil (Açıkgöz 2001; Urzua et al. 2001). Fungal pathogens, especially in nematodes and roots suppressed and used in soil fumigation and the amount of toxic chemicals are reduced with green fertilization. Although a wide variety of plants are grown as green manure crops, legumes are always used more commonly since they bring more nitrogen to the soil compared to non-legume plants. When choosing green manure crops, it should be considered that they grow fast, have plenty of vegetative components and grow well even in infertile soils. Kacar and Katkat (1999) stated in their study that Soja and fodder beans are among the crops that are frequently grown as green manure crops. Studies have shown that the recommended nitrogen amount for the production of strawberries in the Mediterranean Region is 8-10 kg da^{-1} and the phosphorus dose is 5-7 kg da^{-1} (Kacar 1994). Thus, cowpea and Soja were preferred in the selection of green manure crops as they would be suitable during the strawberry growing period. In this study, determination of the effects of plant and animal wastes on fruit yield, quality, soil fertility [soil organic matter content, total nitrogen (N), available phosphorus (P), potassium (K)] in strawberry cultivation and its effects on economy were investigated.

Materials and methods

This research was conducted between 2015 and 2018 in Cukurova University Yumurtalık Vocational School Research and Application Site (36.75 north latitude, 35.71 East meridian). The green manure used are: soja (*Soja hispida*) and cowpea (*Vigna sinensis* L). Green manure plots were divided into two and some of them were given poultry manure slurry in addition to green manure (soja + PMS, cowpea + PMS and control + PMS); poultry manure slurry application was not done to the other part (soja, cowpea and control).

Green manure was not applied in the control parcel. Information on poultry manure slurry and soil properties are given in Table 1.

Table 1 Chemical properties of poultry manure slurry and trial area soil

Soil	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	OM* %
Manure slurry	0.36	0.09	1.60	0.15	0.03	5	15	23
2016	0.12	1.35	150	3198.0	563	1.86	0.85	1.94
2017	0.22	12.89	250	2523.6	325	25.36	3.86	2.15
2018	0.16	14.26	425	2159.0	212	28.25	2.12	2.02

*: Organic matter

The organic matter content of the poultry manure used in the study was 20.12%. Poultry manure slurry was applied after dilution ratio of 1/5 during production and compared to untreated control plot (Brinton et al. 2004). In the experiment, the treatments were arranged in a randomized complete block design with four replicates. Each plot consists of 30 plants per stand. Seed planting (green manure seed at the rate of 12 kg da^{-1}) was planted on 19th of May 2015 in the first year of the experiment. In the second year, the strawberry plants were removed, and the seeds of green manure plants were planted on 2nd of July 2016. Soja and cowpea plants were harvested and mixed into the soil when 75% flowering began (approximately 6-7 weeks after seed sowing; 5 weeks later in the second year). In the study, the strawberry variety used was Albion. Frigo seedlings were transplanted and the first year of transplanting was done on 10th of October 2015, the second year on 18th of October 2016 and the third year on 15th of October 2017. Plant was planted with spacing of 30 cm X 30 cm with an inter plot space of 100 cm. Drip irrigation was applied. In the study, weed control was done using a hand hoe and mulch (black polyethylene).

Prior to transplanting, soil samples were taken from 0 to 30 cm deep at random in the field for laboratory analysis. Organic matter was 33.11% (Rauterberg and Kremkus 1951), total N (Bremner 1965), available P (Bingham 1949) and K (Pratt 1965). After the fruits were harvested, they were weighed on a sensitive scale and the yield amount obtained was divided by the number of plants in the parcel, and the yield per plant was determined in grams. During the growing season, fruit weight, water soluble dry matter ratio (TSS), titratable acid ratio (TAA) and pH were determined from the harvested fruits four times a month. Samples were homogenized in 10 fruits obtained from each repetition plot, and the TSS value was determined by digital refractometer, as well as pH, vitamin C (mg 100 mL^{-1}, Pearson 1976), nitrate (Cataldo et al. 1975) and taste-aroma, values were determined. For TAA measurements, 10 mL of the juice obtained in each repetition was taken, 10 mL of pure water was added to it and the amount of nitrogen sodium hydroxide (NaOH) spent in titration with 0.1 NaOH until pH 8.1 was reached, and g malic acid was expressed as 100 mL^{-1}. The firmness of the flesh was measured with a penetrometer from the equatorial area of the fruit, bilaterally. On taste and aroma, the fruits randomly selected from each recurrence were determined by a jury of 20 people, giving scores between 1-5 (Erenoğlu et al. 1999). At the end of the experiment, a profitability analysis was performed to determine whether or not strawberry production with green manuring applications is economical (Aras 1988).

The findings obtained in the study were analysed using the SPSS 17.0 statistical program. The mean values were calculated, and analysis of variance and Duncan test ($P \leq 0.05$) were employed to determine if there was a significant difference among the treatments (Düzgüneş et al. 1993).

Results and discussion

Soil fertility

The results of soil analysis show that organic matter was 1.96% (Fig. 1), the total N amount 0.12% (Fig. 2), the amount of available P was 1.35 mg kg^{-1} (Fig. 3) and that of K was 312 mg kg^{-1} (Fig. 4). After green manuring

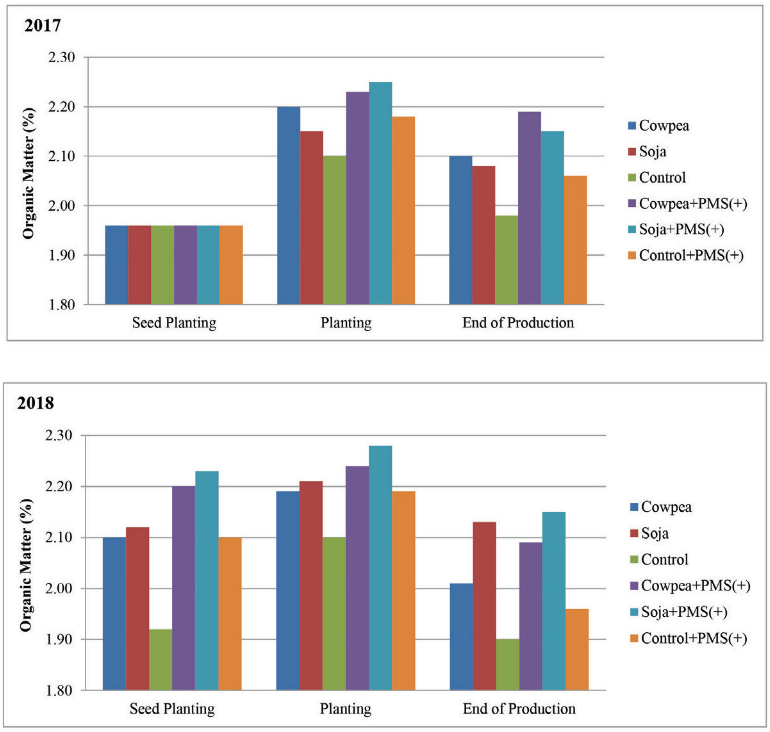

Fig. 1 Change of organic matter (%) in the soil according to green manure and poultry manure slurry application

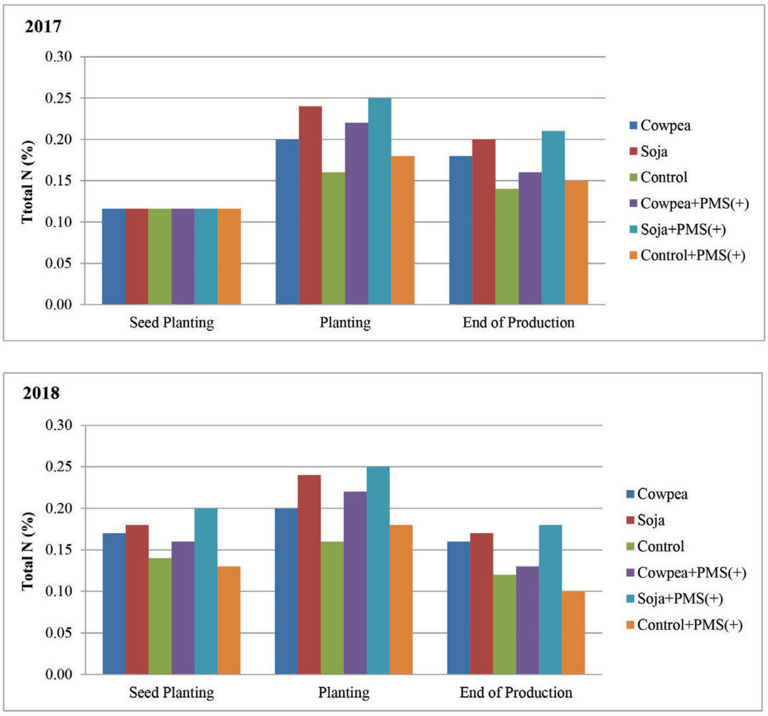

Fig. 2 Change in total N (%) in the soil as a function of green and poultry manures slurry

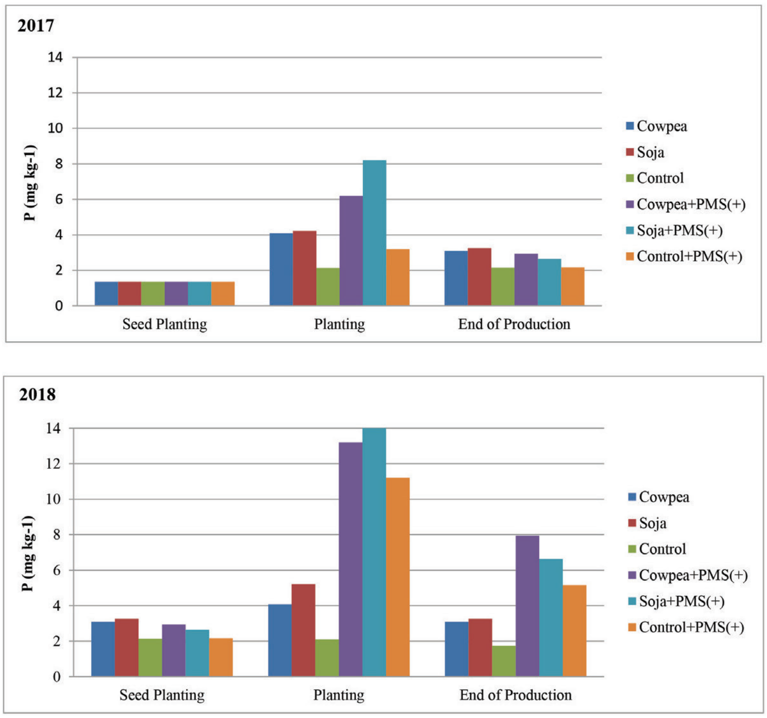

Fig. 3 Change in available P (mg kg^{-1}) in the soil as a function of green and poultry manures slurry

applications, the amount of organic matter in the soil before and after the strawberry transplanting ranged between 2.10-2.25% and 1.98-2.19 % in the first year and between 2.10-2.28% and 1.90-2.15%, respectively in the second year (Fig. 1).

Total Soil N content before and after seedling planting varied between 0.16-0.25% and 0.14-0.21% in the first year and between 0.14-0.20% and 0.12-0.18%, respectively in the second year (Fig. 2).

Before transplanting, the amount of available P in the soil varied between 2.13 mg kg^{-1} (control) and 8.2 mg kg^{-1} (soja + PMS) in the first year and between 2.13 mg kg^{-1} (control) - 14.20 mg kg^{-1} (soja +PMS), respectively in the second year. At the end of production, it was determined that these values varied between 2.14-7.94 mg kg^{-1} and 1.75–7.94 mg kg^{-1}, respectively (Fig. 3).

The K value in the soil ranged between 350-585 mg kg^{-1} and 442-496 mg kg^{-1}, respectively in the first year, 350-685 mg kg^{-1} and 542-696 mg kg^{-1}, respectively in the second year before planting and at the end of production (Fig. 4).

The sufficient amount of total N in the soil ranged between 0.090-0.170%; the amount of P ranged between 1.30-3.26 mg kg^{-1} and the amount of K uptake was between 140-370 mg kg^{-1} (Kacar and Inal 2010).

According to these analyses, the soil nutrient in terms of content was enough. With the accumulation of green manure plants, plant and animal residues in the soil, the amount of organic matter in the soil increased. On the other hand, legume plants fragmented rapidly and increased the amount of N available in the soil (Campiglia et al. 2010; Stagnari and Pisante 2010; Askegaard et al. 2011). Since poultry manure is richer in N content among farm manure (Sloan et al. 2003), the usable N in the soil increases after application.

Yield

Considering all applications, the yield per crop in the first year of the experiment varied between 10.68 – 22.33 t·ha^{-1} and the average fruit weight between 8.68 - 13.80 g. After green manuring, poultry manure slurry with green manure was effective on the yield values of grown strawberries (Table 2).

In 2016, the highest yield per plant was obtained from cowpea applications with and without the slurry obtained from poultry manure, and an increase of 24.80% and 59.16% was achieved, respectively compared to the control. In 2017, the highest yield per crop was obtained from Soja + PMS application (23.39 t·ha^{-1}) and a 42.53% higher yield was obtained compared to the control. In 2018, the highest yield per crop was obtained from Soja + PMS application (23.69 t·ha^{-1}) and 43.05% higher yield was obtained compared to the control. The change in this year originated especially from the difference in average fruit weight (Table 2).

Quality values

The pH, total soluble solids, titratable acidity, vitamin C, and nitrate values representing the quality parameters in strawberry fruit of different green manuring applications are presented in Table 3.

There was no effect of green manure and poultry manure slurry applications on fruit quality. Additionally, the pH was found to be close to the values stated by Gündüz and Özdemir (2008), total soluble solids dissolved in water to the values stated

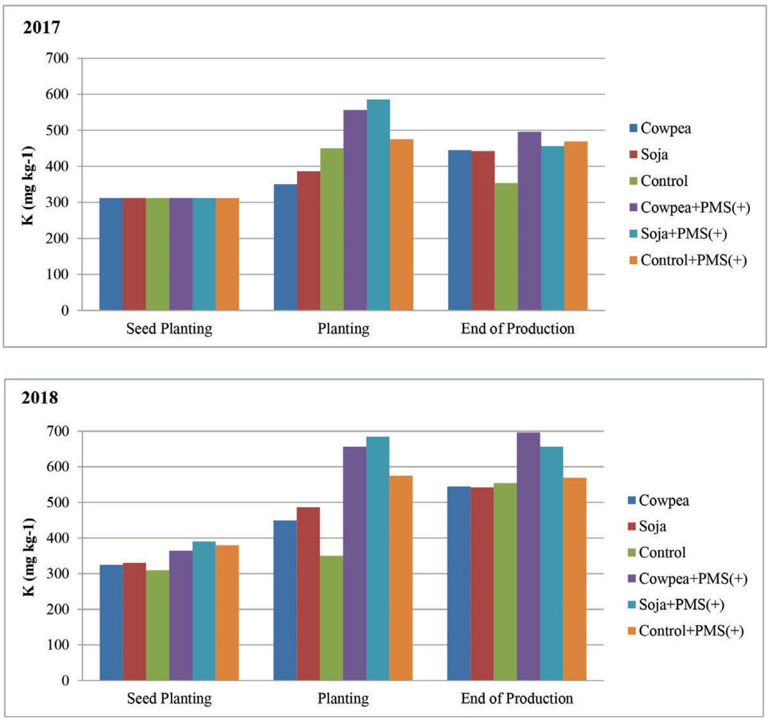

Fig. 4 Change in available K (mg kg^{-1}) in the soil as a function of green and poultry manures slurry

Table 2 The effect of green manure and poultry manure slurry applications on yield, fruit weight, fruit firmness and taste-aroma

Treatments			Yield (t·ha^{-1})	Fruit Weight (g)	Fruit Firmness (kg)	Taste-aroma (point)
2016	Cowpea	PMS (+)	22.33^{a}	13.80^{a}	0.54	3.78
	Soja		22.09^{a}	13.23^{ab}	0.60	3.71
	Control		17.89^{b}	12.32^{b}	0.66	3.59
	Cowpea	PMS (-)	16.99^{a}	11.19^{a}	0.59	3.65
	Soja		13.24^{b}	11.01^{a}	0.65	3.49
	Control		10.68^{c}	8.68^{b}	0.57	3.61
2017	Cowpea	PMS (+)	22.96^{a}	14.23^{a}	0.54	4.41
	Soja		23.39^{a}	13.54^{ab}	0.60	4.25
	Control		16.41^{b}	12.63^{b}	0.65	3.84
	Cowpea	PMS (-)	16.91^{a}	11.69^{a}	0.58	3.90
	Soja		16.88^{a}	11.57^{a}	0.64	3.74
	Control		8.81^{b}	8.98^{b}	0.56	3.86
2018	Cowpea	PMS (+)	23.26^{a}	14.61^{a}	0.58	4.66
	Soja		23.69^{a}	14.10^{ab}	0.63	4.50
	Control		16.56^{b}	12.88^{b}	0.64	3.59
	Cowpea	PMS (-)	16.98^{a}	12.12^{a}	0.61	3.65
	Soja		13.24^{b}	12.26^{a}	0.63	3.49
	Control		10.68^{c}	8.91^{b}	0.56	3.11
Cowpea			19.91	12.94	0.57	4.01
Soja			18.76	12.62	0.63	3.86
Control			13.50	10.73	0.61	3.60
	PMS(+)		20.96	13.48	0.60	4.04
	PMS(-)		18.99	12.63	0.62	3.61
		2016	17.20	11.71	0.60	3.67
		2017	17.31	11.78	0.60	4.00
		2018	17.53	11.83	0.60	3.83

The difference between the means (P≤0.05) shown with different letters is significant.

PMS(+): Poultry manure slurry application: Available

PMS(−): Poultry manure slurry application: None

by Galetta et al. (1995), and the vitamin C contents were found to be higher. Türemiş et al. (2000) stated that 100 grams of strawberries contain vitamin C that can rise to 100 mg. The nitrate content in the fruit was found to be significant in the application of soja green manure + poultry manure slurry and was 33.11% higher in 2016, 28.23% in 2017, and 47% in the 2018 compared to the control (Table 3). According to the amount of nitrate content, strawberry fruit is in the intermediate nitrate group (200-600 mg kg^{-1}) (Anoymous 2002). When the data obtained from the experiment were evaluated, these limits were not observed in any of the applications and all values were found to be in the low-nitrate class (0-200 mg kg^{-1}).

Financial analysis

The products obtained in the present study were sold at the price (5.00 ₤ on average) that emerged in the current market demand (Anonymous 2019). It was observed that there was high demand for the strawberry product. However, during the marketing of the products, problems including preservation, the convenient packaging materials and transportation to demanded markets were encountered. As in most agricultural products, since strawberries should be consumed in a short time after harvest, losses were observed in marketable products.

Resolving these problems will enhance the profit to be gained. In the study, production costs of strawberries

Table 3 The effect of green manure and poultry manure slurry applications on quality parameters

Treatments			pH (%)	TSS (%)	TAA (%)	Vitamin C (mg 100 mL^{-1})	Nitrate (mg kg^{-1})
2016	Cowpea	PMS (+)	3.36	7.14	0.62	35.38a	3.94a
	Soja		3.22	7.09	0.57	39.23a	3.83a
	Control		3.37	7.56	0.67	22.75b	2.96b
	Cowpea	PMS (-)	3.71	7.06	0.59	38.73a	3,43a
	Soja		3.56	6.73	0.66	39.72a	2.86a
	Control		3.63	7.40	0.59	25.75b	1.33b
2017	Cowpea	PMS (+)	3.68	7.06	0.61	37.25ab	3.77a
	Soja		3.62	7.38	0.60	42.98a	3.75a
	Control		3.61	7.37	0.63	31.50b	2.94b
	Cowpea	PMS (-)	3.65	6.80	0.62	39.48a	3.38a
	Soja		3.61	6.31	0.64	39.23a	3.70a
	Control		3.59	7.03	0.62	33.18b	2.07b
2018	Cowpea	PMS (+)	3.62	6.93	0.54	35.88ab	3.77a
	Soja		3.60	7.30	0.56	40.73a	3.55a
	Control		3.55	7.20	0.55	31.00b	2.68b
	Cowpea	PMS (-)	3.66	6.41	0.60	37.23a	3.27a
	Soja		3.59	6.54	0.58	37.00a	3.58a
	Control		3.62	6.80	0.56	29.95b	1.78b
Cowpea			3.61	6.90	0.60	37.33	3.59
Soja			3.53	6.89	0.60	39.82	3.55
Control			3.56	7.23	0.60	29.02	2.29
	PMS (+)		3.51	7.23	0.59	35.19	3.47
	PMS (-)		3.23	6.79	0.61	35.96	3.31
		2016	3.48	7.16	0.62	33.59	3.06
		2017	3.63	6.99	0.62	33.91	3.03
		2018	3.61	6.86	0.57	34.53	3.02

The difference between the means (P≤0.05) shown with different letters is significant.
PMS(+): Poultry manure slurry application: Available
PMS(−): Poultry manure slurry application: None

produced employing different green manure crops and poultry manure slurry were calculated. The calculation of the production costs of the applications was carried out in two stages. Firstly, the production costs of the application using poultry manure slurry in addition to green manure were calculated (Table 4a). Secondly, the production costs of only green manure applications were measured (Table 4b).

Considering the production input costs, the highest income was obtained from the Soja PMS (+) slot with 10614.38 ₤ in 2018, the lowest income from the Control PMS (-) slot with (315.27₤) in 2017. Since there were no machinery and seedling expenses in 2018, these expenses increased the revenue in this period. When the economic data of both tables were compared, it was seen that the production using poultry manure yielded more income by incurring a low cost.

Table 4a Profitability Account: Green manure poultry manure slurry in strawberry production

Budget	2016			2017			2018		
Annual Income	**Control PMS(+)**	**Soja PMS(+)**	**Cowpea PMS(+)**	**Control PMS(+)**	**Soja PMS(+)**	**Cowpea PMS(+)**	**Control PMS(+)**	**Soja PMS(+)**	**Cowpea PMS(+)**
I. Yield Per Plant, g	298.15	368.11	372.10	273.57	389.91	382.73	276.07	394.91	387.73
II. Total Production kg (Plant Yield * 6.000 pieces da^{-1}) / 1000 = 6000 Plants per Decare * Yield Per Plant	1788.90	2208.66	2232.60	1641.42	2339.46	2296.38	1656.42	2369.46	2326.38
III. Total Income = Total Efficiency * kg Price (5 £)	8944.50	11043.30	11163.00	8207.10	11697.30	11481.90	8282.10	11847.30	11631.90
Annual Production Expenses	**Control (+)PMS**	**Soja (+) PMS**	**Cowpea (+)PMS**	**Control (+)PMS**	**Soja (+) PMS**	**Cowpea (+)PMS**	**Control (+)PMS**	**Soja (+) PMS**	**Cowpea (+)PMS**
I. Tool Machine Rent (£ da^{-1})	400.00	400.00	400.00	447.88	447.88	447.88	0.00	0.00	0.00
II. Labor Costs (£ da^{-1})	630.00	630.00	630.00	693.00	693.00	693.00	777.00	777.00	777.00
III. Material Costs (£ da^{-1})	2956.00	2956.00	2956.00	3200.19	3200.19	3200.19	176.00	176.00	176.00
IV. Fixed Costs (£ da^{-1})	250.00	250.00	250.00	498.50	498.50	498.50	279.93	279.93	279.93
TOTAL EXPENSES (£ da^{-1})	**4236.00**	**4236.00**	**4236.00**	**4839.57**	**4839.57**	**4839.57**	**1232.93**	**1232.93**	**1232.93**
NET PROFIT (£ da^{-1})	**4708.50**	**6807.30**	**6927.00**	**3367.53**	**6857.73**	**6642.33**	**7049.18**	**10614.38**	**10398.98**

(£: Turkish Lira)

Table 4b Profitability Account: Green manure in strawberry production

Budget	2016			2017			2018		
Annual Income	**Control PMS(-)**	**Soja PMS(-)**	**Cowpea PMS(-)**	**Control PMS(-)**	**Soja PMS(-)**	**Cowpea PMS(-)**	**Control PMS(-)**	**Soja PMS(-)**	**Cowpea PMS(-)**
I. Yield Per Plant, g	177.93	220.65	283.20	146.81	281.35	281.89	144.31	286.35	284.34
II. Total Production kg (Plant Yield * 6.000 Pieces da^{-1}) / 1000 = 6000 Plants per Decare * Yield Per Plant	1067.58	1323.90	1699.20	880.86	1688.10	1691.34	865.86	1718.10	1706.04
III. Total Income = Total Efficiency * kg Price (5 £)	5337.90	6619.50	8496.00	4404.30	8440.50	8456.70	4329.30	8590.50	8530.20
Annual Production Expenses	**Control PMS(-)**	**Soja PMS(-)**	**Cowpea PMS(-)**	**Control PMS(-)**	**Soja PMS(-)**	**Cowpea PMS(-)**	**Control PMS(-)**	**Soja PMS(-)**	**Cowpea PMS(-)**
I. Tool Machine Rent (£ da^{-1})	400.00	400.00	400.00	447.88	447.88	447.88	0.00	0.00	0.00
II. Labor Costs (£ da^{-1})	630.00	630.00	630.00	693.00	693.00	693.00	777.00	777.00	777.00
III. Material Costs (£ da^{-1})	2836.00	2836.00	2836.00	3080.19	3080.19	3080.19	56.00	56.00	56.00
IV. Fixed Costs (£ da^{-1})	250.00	250.00	250.00	498.50	498.50	498.50	279.93	279.93	279.93
TOTAL EXPENSES (£ da^{-1})	**4116.00**	**4116.00**	**4116.00**	**4719.57**	**4719.57**	**4719.57**	**1112.93**	**1112.93**	**1112.93**
NET PROFIT (£ da^{-1})	**1221.90**	**2503.50**	**4380.00**	**-315.27**	**3.720.93**	**3737.13**	**3216.38**	**7477.58**	**7417.28**

(£: Turkish Lira)

Conclusion

Findings of green manure practices foreground, green manure plants gave better results when using poultry manure slurry and increase the amount of organic matter, total N, available P and K in the soil. This result is important in terms of improving the soil structure negatively affected as a result of excessive and improper fertilization applied to get high yield per unit area. It was concluded that it is possible to improve the soil fertility with green manure. It is recommended that green manure be included in production programs as an alternative form of fertilization due to its sensitivity to human health and the environment. One of the main purposes of the study is to evaluate the economic viability of these practices. Because the economic data in these applications are important in terms of the continuity of applications and transferring them to practice. The result of the current study shows that green manure application increases income due to its efficiency. According to the data of this study, it was more profitable to use green manure and poultry manure at low cost in strawberry production. Thus, it is thought that these wastes arising from poultry farming can be taken from the drip irrigation system by making slurry and be included in the production programs and converted into economic value.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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