

## Article

# Manure Effect on Soil–Plant Interactions in Capia Pepper Crops under Semiarid Climate Conditions

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**Abstract:** One of the biggest threats to agro-ecosystems, especially in arid and semiarid areas, is the deterioration of soil quality, which is associated with low soil organic matter levels. Despite the elevated volume of publications related to soil quality and crops, information about specific plants such as the Capia pepper (*Capsicum annuum* L. cv.) with clear economic relevance in semiarid environments is missing. The aim of present study is to investigate the effects of different doses of manure on Capia pepper focusing on soil–plant interaction, soil quality, and plant yield in an experimental area located in Turkey. Key soil properties were monitored and relationships between plant and soil properties were evaluated using the principal component analysis (PCA). At the end of the first and second growing season, the effects of manure application on some plant and soil characteristics were statistically significant at different levels. According to the PCA result, 15 plant characteristics and 7 soil characteristics were grouped into five factors and defined 85.4% and 90.9% of the total variability in the population in the first and second growing seasons, respectively. Our research concluded that sustainable soil management such as the use of specific dose of manure improves soil quality and plant productivity.

**Keywords:** aggregate stability; aridity; soil management; pepper; regional issues; nature-based solutions



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## 1. Introduction

The quality of life of human beings is strictly dependent on the soil sustainability and health of ecosystems. Agriculture fields are considered extremely complex and dynamic ecosystems in which human, plant, animal, and microorganism communities interact with each other [1]. Ecosystem services, on the other hand, are the benefits that people derive from the ecosystem and are grouped under four main headings: provisioning, regulating, cultural, and supporting [2]. Soil is considered a nonrenewable resource at a human scale, supporting the delivery of essential ecosystem services when it is of good quality and healthy [3,4]. Soil's health, which is an internal feature, and its quality, which is an external feature [5], are closely related to soil's physical, chemical, and biological properties, but it is impossible to characterize them without considering human impacts [6].

The positive effects of soil organic matter on soil physical properties are well-known [7–9], as are the improvements in plant yield and quality characteristics [4,10]. Organic soil conditioners are also widely used in horticultural cultivation [11–15]; however, the mechanisms of action are ambiguous, since organic matter as well as the soil has a complex nature [16]. Although the physical properties of soils such as compaction, pore geometry

and continuity, volume weight, and aggregate stability are evaluated under the concept of “physical fertility of the soil” under an agronomic point of view, the relationships between the soil’s physical properties, in addition to yield and quality characteristics of the plant, have not yet been fully defined and clarified [17,18].

The composition and maturity degree of a conditioner to be added to the soil as a source of organic matter determines the degree and direction of its effect on soil properties [19]. The physical properties of the soil can positively change with the application of organic conditioners [20,21]. It has been shown that the incorporation of exogenous organic matter into the soil provides greater porosity and high aggregate stability [7,9] and increases the water holding capacity, thus facilitating soil tillage and positively affecting crop yield [8]. Similarly, stimulation of soil microbial communities through the application of organic conditioners can indirectly improve soil structure, as microbial activity (for example, through secretion of exopolysaccharides) and, particularly, hyphal growth can significantly affect soil aggregation and aggregate stability [22], which means reaching a desired air–water balance in the soil profile. This facilitates the development of the root system of the plant and improves the quality of the habitable area for soil biological communities. In addition, organic components can affect the particle size distribution and the total surface area within the soil, increasing the number and types of voids available for biological colonization [23]. On the other hand, a decrease in soil porosity can trigger soil crust formation and make it difficult for water and air to move through the soil matrix with an increase in bulk density [24,25]. On the other hand, there are also studies that concluded that organic conditioners have no or negligible effects on soil water [26,27].

Soil conditioners can also increase the availability of nutrients by plants, for example, by reducing nitrate leaching and by suppressing heavy metal availability [28]. The effect of soil conditioners can affect chemical soil properties as well as physical soil properties in different ways, depending on the climatic conditions in which they are applied to the soil, soil properties, differences in application method, and inherent properties of the material. For example, some soil conditioners contain high amounts of calcium and magnesium, and in this case, soil pH may increase due to the liming effect [29]. Liming has been shown to significantly increase soil microbial activity in acidic soils [30], which increases soil fertility. On the other hand, the pH value of the soil may decrease due to the humic acids that will be released as a result of the disintegration of the carbon pool by the application of organic materials and through the nitrification of ammonium in the conditioner [31,32].

Manure, consisting of feces, urine, and animal bedding, has long been and continues to be used as a soil organic conditioner, as it can increase soil fertility by providing essential macro- and micronutrients as well organic matter [33,34]. The use of manure by European farmers dates back to 6000 BCE [35], and the importance of manure as a resource that can be used in agriculture began in the 16th century [21]. The application of manure plays a role in changing soil’s physical properties by reducing soil bulk weight and increasing soil porosity, infiltration rate, percolation rate, and aggregate stability [36,37]. In addition, manure-based improvements can stimulate soil microbial activity and biomass and increase soil fertility by changing the composition and diversity of soil microbial communities [38,39]. The positive effects of an organic conditioner which is thought to be beneficial may not be observed in the soil, and sometimes there is a risk of encountering the harmful effects of a soil conditioner under different conditions [4,39–42]. Especially in semiarid climatic regions such as Central Anatolia, the dose of the organic conditioner to be applied to the soil should be adjusted correctly, taking into account the type of plant to be grown. The effectiveness of the application to be made can only be increased in this way.

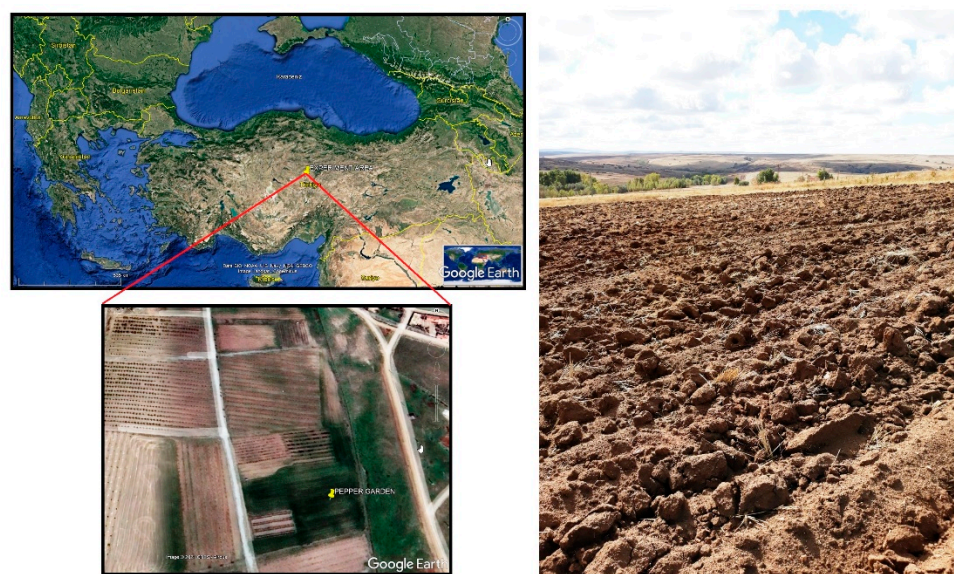
As mentioned above, since the response of the soil and the plant to the materials used as conditioners can be different depending on many factors, organic matter sources should be tested under different climatic conditions and different cultivation practices. There is little research in semiarid regions related to the use of manure. The aim of this study is to investigate the effects of differently dosed manure applications on some soil properties and yield and quality characteristics of plants in a *Capia* pepper orchard established in a

semiarid climate zone. To achieve this goal, we set up trials to test whether the application of mature manure in a pepper orchard would change the soil physical properties for two years and whether a possible positive change in soil properties would change the properties of the Capia pepper plant. The information to be obtained from this study will be a guide for the growers of this semiarid region and similar regions, where vegetable production is still mostly provided from other cities and vegetable cultivation is in its infancy.

## 2. Materials and Methods

### 2.1. Study Area

This study was carried out in a field used by the Yozgat Bozok University for agricultural research, located in Gedikhasanlı village of Sorgun district of Yozgat city, within the borders of Turkey. Location map and terrain views were given in Figure 1.



**Figure 1.** Location map and general view of the trial area (Copyright © Google Earth).

The altitude of the trial area is 1106 m a.s.l., and its coordinates are 4383930N and 685545E (UTM). Geologically, eocene-aged units dominate the area. These units can be described as a conglomerate, sandstone, sandy, and marl [43,44]. In the area located in the semiarid climate zone, the annual average precipitation is 560 mm, and the annual average temperature is 9 °C [45]. A high degree of soil compaction has also been identified in the area due to the use of heavy machinery [46].

The soil can be classified as Typic Calciorthid [47]. The general properties of this soil are given in Table 1 [48]. Organic matter content of the sandy-clay loam is textured, and slightly alkaline-reaction soil is very low, total CaCO<sub>3</sub> level is medium, and there is no salt problem. Total N and available P content are low, exchangeable K and Mg contents are sufficient, and exchangeable Ca content is high. There is no Na harm. The Fe content is moderate, and the Cu content is native to crop production. However, Zn and Mn contents are low.

**Table 1.** General characteristics of the surface soil in the trial area (Yakupoglu, 2018).

pH	EC (dS m <sup>-1</sup> )	SOM (%)	CaCO <sub>3</sub> (%)	Clay (%)	Silt (%)	Sand (%)	Textural Class	N-Tot (%)
7.91	0.82	0.99	5.36	29.9	8.9	61.2	SCL	0.05
P-av (µg g <sup>-1</sup> )	K (µg g <sup>-1</sup> )	Ca (µg g <sup>-1</sup> )	Mg (µg g <sup>-1</sup> )	ESP (%)	Fe (µg g <sup>-1</sup> )	Cu (µg g <sup>-1</sup> )	Zn (µg g <sup>-1</sup> )	Mn (µg g <sup>-1</sup> )
5.76	215	7561	167	<15	2.05	0.42	0.29	4.44

The amounts of K, Ca, and Mg that can be extracted with ammonium acetate were given. The amounts of Fe, Cu, Zn, and Mn that can be extracted with DTPA were given.

## 2.2. Experimental Procedures Related to Manure Application

Aged farmyard manure was used in the experiment. Before the applications, the manure was passed through a 20 mm sieve and homogenized in terms of particle size. The general characteristics of the farmyard manure used were as in Table 2. According to Table 2, farm manure does not contain heavy metals at a level to prevent plant production. Other properties of this farm manure are suitable for application to agricultural soils.

**Table 2.** General characteristics of the manure used.

OM (%)	OC (%)	WOM (mg L <sup>-1</sup> )	N-Tot (%)	N-min (%)	NH <sub>4</sub> <sup>+</sup> -N (µg g <sup>-1</sup> )	NO <sub>3</sub> <sup>-</sup> -N (µg g <sup>-1</sup> )	N-Org (%)	
35.7	20.7	45.4	1.695	0.248	189.3	2293.9	1.676	
P (%)	K (%)	Ca (%)	Mg (%)	Fe (µg g <sup>-1</sup> )	Cu (µg g <sup>-1</sup> )	Zn (µg g <sup>-1</sup> )	Mn (µg g <sup>-1</sup> )	Cr (µg g <sup>-1</sup> )
2.714	3.875	2.006	6.214	44,655.2	388.64	14,847.3	1596.8	721.04

The total forms of the mineral elements in the second row were given.

Twelve plots of 10 × 4 m in size (height and width) were prepared in the trial area. The experimental areas were first tilled with a plough when suitable tempering was achieved. In September 2018, aged and sieved farm manure at doses of 1 Mg da<sup>-1</sup> and 2 Mg da<sup>-1</sup> were applied to the relevant plots by hand sprinkling. Since the organic matter level of the soil is very low (Table 1) and the manure applications are planned to be 2 years in a row, these two different doses were decided. Afterwards, organic fertilizer was mixed in the first upper 15 cm of the soil with a cultivator. For each application, a control plot without farm manure was created and subjected to the same procedures as the manure-applied plots. The trials, which were designed according to the random plots' trial design, were carried out in triplicate (3 plots for first manure dose, 3 parcels for second manure dose, and 6 parcels for control). The plots were left to rest after the packer procedure until the spring when the seedlings would be planted. In May 2019, plot surfaces were leveled with a rake, and 4 full-leafed Capia pepper seedlings (*Capsicum annuum* L. cv.) were planted in 5 rows in each plot. The distances between rows and between seedlings were 80 and 40 cm, respectively. The plants were irrigated with the drip irrigation method. Furthermore, 18:18:18 compound fertilizer was applied to all plots twice (one month after planting and two months later) at a dose of 15 kg da<sup>-1</sup> by fertigation. In regular irrigation, the irrigation frequency was set to be once every 2 days, since the soil texture is sandy-clay loam (Table 1), and the soil moisture content drops below 70% of the field capacity rapidly because the air is dry during the growing periods. No herbicide application was made during the trial period. Weeds were manually removed one month after planting. Yalova oily-28 Capia pepper variety was used. This variety is used for tomato paste, roasting, drying, and fresh consumption. It is suitable for open field cultivation, has a flattened shape and dark red color, and is sweet when ripe. The fruit weighs 80–90 g, is 17–19 cm long, and has a thickness of 4–5 mm [49]. At the beginning of September, when the harvesting process was almost completed, disturbed and undisturbed soil samples were taken from 0–15 cm depth

for analysis from four different points of each plot, representing the plots in the best way possible. After sampling, five replications of penetration measurements were made at the intact points of the plots. Care was taken to make sampling and measurements over the rows. The trial was constructed over two growing seasons (2018–2019 and 2019–2020), and the operations in the second season were exactly the same as in the first season (Figure 2).



**Figure 2.** Pictures showing the field procedures carried out in the trial ((a): parceling, (b): sieving of manure, (c): moving the sieved manure to the garden, (d): the application of manure to the soil, (e): mixing manure into the soil with a cultivator, (f): raking of soil before planting for leveling, (g): installation of drip irrigation, (h): seedlings given life water, (i): grown pepper garden, (j): views from when peppers are green, (k): views from when peppers are red, (l): soil sampling procedure from 0–20 cm depth by auger).

### 2.3. Analyses and Measurements

All analyses and measurements were performed in triplicate. The organic carbon content in soil samples was determined by wet combustion with  $K_2Cr_2O_7$  and concentrated  $H_2SO_4$  according to the modified Walkley–Black method [50]. Soil pH and electrical conductivity (EC) were determined in 1:2.5 (*w:v*) soil–water suspension by using a Hanna pH-meter and EC-meter with glass-probe, respectively [51]. Total nitrogen (N) was determined by the Kjeldahl method using Gerhardt’s automatic steam distillation system [50].

For soil bulk density (Db) determination, intact soil core samples were collected using a Eijkelkamp metal ring (100 cm<sup>3</sup> volume). After drying the samples in an oven (at 105 °C for 24 h), soil dry weight was calculated, and then Db was calculated for each sample using soil volume [52]. Penetration resistance (PR) was measured at a soil depth of 0–10 cm by using Eijkelkamp hand penetrometer, and results were standardized to 0.1 kg kg<sup>-1</sup> soil moisture level [53,54]. Wet aggregate stability (WAS) was determined by the wet sieving method [55]. An Eijkelkamp wet sieving apparatus with a diving length of 1.3 cm was used in the sieving process. In the sieving process, 4 g of air-dry macroaggregate (1–2 mm) was premoistened for 5 min, then sieved through a 0.25 mm sieve in water for 3 min at about 34 times min<sup>-1</sup>.

Yield per plant (PY) was calculated by dividing the total amount of product obtained from each plot by the number of plants in the plot. Average fruit weight (AFW) was calculated by counting fruit at each harvest and dividing the total fruit weight by the number of fruits. Total soluble solids (TSS) were determined by reading with Hanna brand HI 96801 digital refractometer in the juice obtained from 4–5 ripe fruits taken from each parcel 3 times from the beginning to the end of the harvest [56]. Titratable acidity (TA) was determined by the titration acidity method in the juice obtained by squeezing 4–5 ripe fruits from each plot 3 times from the beginning to the end of the harvest. Vitamin C content (VIT C) was measured by making Perkin Elmer Lambda 25UV/VIS spectrometer readings on fruit samples taken 3 times from the beginning to the end of the harvest in both years of the experiment [57]. The total fresh weight (FW) was determined by weighing the stems and leaves on precision scales immediately after the plants cut from the soil surface were cleaned from the field. Total dry weight (DW) was determined by drying the stem and leaves in an oven. Leaf area (LA) was determined using the ADC BioScientific Area Meter AM300 brand leaf area meter. Plant height (PH) was measured in uprooted plants using a ruler.

#### 2.4. Statistical Analysis

After it was seen that the obtained data showed a normal distribution, the effects of the subjects on the measured soil and plant variables were tested with one-way ANOVA. When the subject effect on any variable was found to be significant, the subject averages were compared with the Duncan 0.05 test. Principal component analysis (PCA) was used to explain the relationship between plant and soil properties for two growing seasons separately. Eigenvalues were accepted as 1 and factor loading > [0.30]. When a variable is loaded on more than one factor, the interpretation of the analysis results becomes difficult, so varimax rotation was applied to reduce the number of variables loaded on more than one factor [58]. Statistical evaluation of the obtained data was carried out using the IBM SPSS 22.0 package program.

### 3. Results and Discussion

#### 3.1. Changes in Soil Properties

The average values of the determined soil properties are given in Table 3 separately for the first and second growing seasons. According to Table 3, there was no obvious change in soil pH value in the first year with manure application, but a significant decrease was detected in soil pH in the second year compared to control (8.17 to 7.77). This decrease in pH can be attributed to the release of humic acid as a result of the degradation of the manure used and the nitrification that occurred [32,59,60]. The EC of the soil increased depending on the manure application dose in both years, and at the end of the second year, this value increased to 0.716 dS m<sup>-1</sup> with high-dose application. The direction in which the soil EC will change with the application of organic conditioner depends on the characteristics of the organic matter source. With applications, the EC value of the soil can either decrease or increase [4,61]. Manure application increased SOM very clearly in both growing seasons; the SOM value of the soil, which was about 1%, increased to 1.92% at the end of the first growing season and to 3.46% at the end of the second growing

season with high-dose manure application. This was clearly due to the contribution of the applied manure to the soil's organic matter pool. Applied conditioners increase the organic matter content of the soil within a certain period of time [62], but many factors play a role in this increase, and the most complex factor is time [63]. It was concluded that the total N content of the soils increased with manure applications. The increases in the total N content of the soil were more pronounced at the end of the first year compared to the second year. The increase in the total N content of the soil can be attributed to the nitrogen contained in the manure used (Table 2), which is a rich source of nutrients [64,65]. Thanks to the applications, the Db values of the soils decreased to  $1.30 \text{ g cm}^{-3}$  on average in the control plots and to  $1.18 \text{ g cm}^{-3}$  with the application of  $2 \text{ Mg da}^{-1}$  manure at the end of the second harvest season. Parallel to this decrease in Db, the PR of the soils also decreased; the highest PR was measured in the control plots (2.51 MPa), while the lowest values were measured as 1.87 MPa at the end of the first growing season and 1.15 MPa at the end of the second growing season in the plots with high-dose manure. Organic conditioners decrease the Db value of the soils because they both have low Db values and increase the total porosity of the soils they are applied to in various ways, and accordingly, the PR value decreases [66]. In this study, the decrease in Db and PR values of the soil can be explained by the manure application. WAS values (about 30%) of the soils, which were very low at the beginning, could be increased up to 56.4% at the end of the second year with high-dose manure application. This increase in the WAS value of the soil can be attributed to the increase in organic matter of manure added to the soil, which can strengthen the aggregates in the wetting process against the disintegrating forces [67,68].

**Table 3.** Average values of soil variables determined at the end of the first and second growing seasons.

Growing Season	Application	Variables						
		pH	EC ( $\text{dS m}^{-1}$ )	SOM (%)	N (%)	Db ( $\text{g cm}^{-3}$ )	PR (MPa)	WAS (%)
I	Control	$8.18 \pm 0.05$	$0.424 \pm 0.036$	$1.00 \pm 0.04$	$0.14 \pm 0.024$	$1.31 \pm 0.01$	$2.51 \pm 0.19$	$30.8 \pm 2.9$
	$1 \text{ Mg da}^{-1}$	$8.19 \pm 0.08$	$0.423 \pm 0.040$	$1.21 \pm 0.08$	$0.23 \pm 0.015$	$1.28 \pm 0.02$	$2.45 \pm 0.07$	$30.9 \pm 2.7$
	$2 \text{ Mg da}^{-1}$	$8.20 \pm 0.04$	$0.476 \pm 0.015$	$1.92 \pm 0.09$	$0.32 \pm 0.016$	$1.23 \pm 0.01$	$1.87 \pm 0.26$	$41.8 \pm 1.9$
II	Control	$8.17 \pm 0.10$	$0.425 \pm 0.006$	$0.99 \pm 0.03$	$0.12 \pm 0.032$	$1.30 \pm 0.03$	$2.51 \pm 0.09$	$30.3 \pm 0.3$
	$1 \text{ Mg da}^{-1}$	$7.87 \pm 0.05$	$0.573 \pm 0.020$	$2.36 \pm 0.19$	$0.13 \pm 0.010$	$1.23 \pm 0.01$	$1.54 \pm 0.11$	$42.1 \pm 1.7$
	$2 \text{ Mg da}^{-1}$	$7.77 \pm 0.04$	$0.716 \pm 0.012$	$3.46 \pm 0.06$	$0.18 \pm 0.015$	$1.18 \pm 0.02$	$1.15 \pm 0.05$	$56.4 \pm 3.3$

### 3.2. Changes in Plant Properties

The average values of the measured plant characteristics are presented in Table 4 separately for both growing seasons. In both years, the highest PHe value was determined to be 43.6–38.1 cm (1st year and 2nd year, respectively) in low-dose manure application, while the lowest was determined in control applications. When the years were examined in terms of PY value, it was found that low-dose manure application gave the highest value, with  $101.3 \text{ g plant}^{-1}$  in the 1st year and  $64.3 \text{ g plant}^{-1}$  in the 2nd year, and the lowest measurements were obtained from the 1st- and 2nd-year control groups ( $60.2$ – $26.2 \text{ g plant}^{-1}$ , respectively). While AFW measured in both years was the lowest in the control groups, the highest value was obtained with  $34.9 \text{ g fruit}^{-1}$  in the 1st year and  $34.4 \text{ g fruit}^{-1}$  in the 2nd year from low-dose manure applications. Low-dose manure applied in the first year increased the LA value ( $990.9 \text{ cm}^2$ ), while high-dose manure ( $551.9 \text{ cm}^2$ ) decreased it. In the second year, low-dose manure gave the highest LA ( $1233.3 \text{ cm}^2$ ) value, while the lowest ( $486.3 \text{ cm}^2$ ) value was determined in control plants. While the VIT C- GR value was highest in the control ( $334.8 \text{ mg } 100 \text{ g}^{-1}$ ) group in the first year, it tended to decrease with the addition of manure. The lowest high dose was determined in manure ( $245.4 \text{ mg } 100 \text{ g}^{-1}$ ). In the second year, the highest control ( $129.5 \text{ mg } 100 \text{ g}^{-1}$ ) was detected, while the lowest was detected in the low-dose fertilizer application with  $120.9 \text{ mg } 100 \text{ g}^{-1}$ . When VIT CR values were examined in both years, it was determined that low-dose manure ( $381.1 \text{ mg } 100 \text{ g}^{-1}$ )

administration in the first year and high-dose manure ( $140.1 \text{ mg } 100 \text{ g}^{-1}$ ) administration in the second year gave the highest value. VIT C DR was detected at the highest dose of  $391.1 \text{ mg } 100 \text{ g}^{-1}$  in the first year in high-dose manure application and in the second year with  $135.3 \text{ mg } 100 \text{ g}^{-1}$  in control plants. TSS GR, obtained from the control group with the highest 3.46% in the first year, showed a decreasing trend as the manure dose increased and was determined at least in high-dose manure (6.94%). In the second year, the highest dose was measured in manure application (3.41%) and the lowest dose in manure application (2.94%). TSS R value was determined to be the most in high-dose manure (2.71 and 3.91%, respectively) in both years. TSS DR value by years was determined to be the most in low-dose manure (2.94 and 5.13%, respectively). In the first growing season, the TA GR value was 2.93%, obtained from the control group, while it was determined to be at least 2.04% in high-dose manure application, and in the second growing season, it was 3.41% in the high-manure dose and at least 2.94% in the low-manure dose. The highest TAR value was determined in high-dose manure application in both growing seasons. TA and DR values gave the highest value (2.94 and 5.13%, respectively) in both farming years with low-dose manure application. Low-dose manure applications, in terms of FW, gave the highest value of 146.6 g in the first year and 64.5 g in the second year, while the lowest measurements in both years were obtained from the control groups. In both growing seasons, the highest DW values were determined in low-dose manure application.

**Table 4.** Average values of Capia pepper plant variables determined at the end of the first and second growing seasons.

Growing Season	Application	Variables								
		PHe (cm)	PY (g Plant <sup>-1</sup> )	AFW (g Fruit <sup>-1</sup> )	LA (cm <sup>2</sup> )	VIT C GR (mg 100 g <sup>-1</sup> )	VIT C R (mg 100 g <sup>-1</sup> )	VIT C DR (mg 100 g <sup>-1</sup> )		
I	Control	40.4	60.2	27.7	617.0	334.8	228.7	352.1		
	1 Mg da <sup>-1</sup>	43.6	101.3	34.9	990.9	296.5	381.9	239.5		
	2 Mg da <sup>-1</sup>	40.9	66.5	29.9	551.0	245.4	244.1	391.1		
		TSS GR (%)	TSS R (%)	TSS DR (%)	TA GR (%)	TA R (%)	TA DR (%)	FW (g)	DW (g)	
	Control	3.46	2.12	2.50	2.93	2.12	2.50	79.6	18.0	
	1 Mg da <sup>-1</sup>	5.55	2.52	2.94	2.10	2.52	2.94	146.9	19.6	
	2 Mg da <sup>-1</sup>	6.94	2.71	2.72	2.04	2.71	2.72	95.3	14.9	
		PHe (cm)	PY (g plant <sup>-1</sup> )	AFW (g fruit <sup>-1</sup> )	LA (cm <sup>2</sup> )	VIT C GR (mg 100 g <sup>-1</sup> )	VIT C R (mg 100 g <sup>-1</sup> )	VIT C DR (mg 100 g <sup>-1</sup> )		
	Control	27.6	26.2	19.8	486.3	129.5	134.9	135.3		
	1 Mg da <sup>-1</sup>	38.1	64.3	34.4	1233.3	120.9	125.8	122.9		
2 Mg da <sup>-1</sup>	35.0	37.0	25.1	751.8	128.9	140.1	115.5			
II		TSS GR (%)	TSS R (%)	TSS DR (%)	TA GR (%)	TA R (%)	TA DR (%)	FW (g)	DW (g)	
	Control	3.30	3.69	4.57	3.30	3.69	4.57	33.8	10.6	
	1 Mg da <sup>-1</sup>	2.94	2.64	5.13	2.94	2.64	5.13	64.5	21.4	
	2 Mg da <sup>-1</sup>	3.41	3.91	4.40	3.41	3.91	4.40	45.9	16.8	

In the study in which the yield and quality characteristics of different Capia pepper varieties were examined, it was determined that the plant heights varied between 63.33 cm and 81.22 cm, depending on the cultivars. Plant height was measured to be 69.11 cm in another study with Yaglik-28 variety [69]. In a study examining the effect of salinity on yield and quality in Capia pepper, the TSS content, which was 7.98% in the control plant, increased to 9.40% at 4.5 dS m<sup>-1</sup> salinity level. Likewise, while the amount of TA in the control plant was 0.21%, it increased to 0.30% at 4.5 dS m<sup>-1</sup> salinity level [70]. In a



study examining the effects of different organic fertilizers on plant growth and fruit quality in Capia pepper, the amount of TSS in Postal pepper cultivar was 7.73% for the control, while it increased to 7.83% with the application of barnyard manure. While this value was 8.36% for control in Elephant Ear cultivar, it increased to 9.10% with barn manure application [71]. In a study examining the effect of N fertilization on yield, growth, and fruit quality in sweet pepper (*Capsicum annum* L. var. California Wander), the VIT C value was determined to be 131.7 mg 100 g<sup>-1</sup> at the Green Fruit stage and 198.3 mg 100 g<sup>-1</sup> at the Red Fruit stage [72]. Plant characteristics and fruit quality were investigated in two different sweet peppers fertilized with polyphosphates (P-15 and P-30) in soilless agriculture. In terms of plant height, while control plants were 63.40 cm in Aifos cultivar, it was 66.07 cm in P-15 application and 63.87 cm in P-30 application. In Palermo cultivar, plant height (control: 89.10 cm, P-15: 90.70 cm, P-30: 98.50 cm) increased with fertilizer applications. In the same application, it was determined that the amount of TSS decreased from 7.57 oBrix in the control plants in Aifos cultivar to 7.42 oBrix in the P-15 application and to 7.27 oBrix in the P-30 application. In Palermo cultivar, it was 9.45 oBrix in the control plant, while it increased to 10.15 oBrix in TSS P-15 application and decreased to 9.47 oBrix in P-30 application. In the applications examined in terms of VIT C, the measured value of 26.54 mg 100 g<sup>-1</sup> FW in the control of Aifos cultivar decreased with fertilization, reaching 22.33 mg 100 g<sup>-1</sup> FW in the P-15 application and 22.07 mg 100 g<sup>-1</sup> FW in the P-30 application. In Palermo cultivar, it increased with fertilization, from 15.96 mg 100 g<sup>-1</sup> FW in the control plant, to 21.00 mg 100 g<sup>-1</sup> FW in P-15 application, to 21.73 mg 100 g<sup>-1</sup> FW in P-30 application [73].

### 3.3. Meaning of Changes in Soil and Plant Characteristics

The results of ANOVA, which evaluates the effect of manure application, which is the source of variation, on the measured plant and soil variables, are given in Table 5 separately for the growing seasons. According to Table 5, at the end of the first year, the effect of manure application on plant variables LA, VIT C GR, VIT CR, VIT C DR, and FW was found to be significant ( $p < 0.05$ ). The effect of manure application on TSS was also significant ( $p < 0.001$ ). Applications did not have a statistically significant effect on PHe, PY, AFW, TSS R, TSS DR, TA GR, TA R, TA DR, and DW in the first year. For the first growing season, the changes caused by the applications in pH and EC variables were found to be statistically insignificant, while the changes in other soil properties were found to be significant ( $p < 0.001$ ). At the end of the second growing season, the effectiveness of manure treatments on plant variables PY, TSS DR, and FW was found to be statistically significant at  $p < 0.05$ , the effectiveness on PHe and DW at  $p < 0.01$ , and the effectiveness on AFW and LA at  $p < 0.001$  level. The effects of manure treatments on other plant variables in the second year were statistically insignificant. The effect of manure applications on the change in the total nitrogen content of the soil in the second growing season was significant at the  $p < 0.01$  level, and the effect on the change in other determined soil properties was also significant at the  $p < 0.001$  level.

The Duncan test results, in which the applications were compared in terms of their effects on the determined plant and soil properties, are given in Table 6. In the left column of the table, there are variable averages for the first growing season, which are in the right column for the second growing season. According to Table 6, at the end of the first growing season, the highest LA was measured (990 cm<sup>2</sup>) in pepper plants grown in plots with a manure dose of 2 Mg da<sup>-1</sup>. Application of 1 Mg da<sup>-1</sup> manure dose did not change the LA of the plant compared to the control. The highest VIT C GR values were measured as 348 and 296 mg 100 g<sup>-1</sup> in the plants grown in the unmanured and high-dose manure applied plots, respectively, and there was no statistical difference between the two values. The highest VIT CR value was measured in pepper plants (381 mg 100 g<sup>-1</sup>) in the high-dose manure plots, and this value was statistically different from the VIT CR values of the plants grown in other plots. The highest VIT C DR values were determined in peppers grown in control and low-dose manure applied plots, and there was no statistical difference

between them (in the control plot plant: 338 mg 100 g<sup>-1</sup>; in 1 Mg da<sup>-1</sup> manure plot: 391 mg 100 g<sup>-1</sup>). Manure applications significantly increased the TSS GR value of pepper compared to control (3.46, 5.55, and 6.94% for control, low-dose manure, and high-dose manure applications, respectively), but there was no statistical difference between manure application doses. While 1 Mg da<sup>-1</sup> dose was not successful in increasing the FW value of pepper, 2 Mg da<sup>-1</sup> dose made a difference with 146 g in increasing this value. The most successful application in increasing the SOM and total N contents of the soil and improving its physical properties has been the manure dose of 2 Mg da<sup>-1</sup>. While SOM was 1.01% in the control plot, it increased to 1.92% with this dose of manure. Similarly, the total N increased from 0.14% to 0.31%. The 1 Mg da<sup>-1</sup> manure dose was insufficient to decrease the Db value of the soil, but the 2 Mg da<sup>-1</sup> value reduced the soil Db value to 1.22 g cm<sup>-3</sup>. A similar situation exists for the changes in the PR and WAS values of the soil. While PR value was 1.30 MPa and WAS value was 30.8% in the control plot, PR decreased to 1.22 and WAS increased to 41.8% with high-dose manure application.

**Table 5.** ANOVA results of applications (source of variation) over measured variables.

Growing Season	Variables							
	PHe	PY	AFW	LA	VIT C GR	VIT C R	VIT C DR	
I	ns	ns	ns	*	*	*	*	
	TSS GR	TSS R	TSS DR	TA GR	TA R	TA DR	FW	DW
	***	ns	ns	ns	ns	ns	*	ns
	pH	EC	SOM	N	Db	PR	WAS	
	ns	ns	***	***	***	***	***	
II	PHe	PY	AFW	LA	VIT C GR	VIT C R	VIT C DR	
	**	*	***	***	ns	ns	ns	
	TSS GR	TSS R	TSS DR	TA GR	TA R	TA DR	FW	DW
	ns	ns	*	ns	ns	ns	*	**
	pH	EC	SOM	N	Db	PR	WAS	
	***	***	***	**	***	***	***	

\* Statistically significant at level of 0.05, \*\* statistically significant at level of 0.01, \*\*\* statistically significant at level of 0.001, ns: not significant statistically.

**Table 6.** Duncan test results ( $\alpha = 0.05$ ).

Variables	Applications					
	The First Growing Season			The Second Growing Season		
	Control	1 Mg da <sup>-1</sup>	2 Mg da <sup>-1</sup>	Control	1 Mg da <sup>-1</sup>	2 Mg da <sup>-1</sup>
PHe (cm)	-	-	-	27.5b	35.0a	38.1a
PY (g plant <sup>-1</sup> )	-	-	-	26.2b	36.9b	64.3a
AFW (g fruit <sup>-1</sup> )	-	-	-	19.8b	25.0b	34.3a
LA (cm <sup>2</sup> )	617b	551b	990a	468b	751b	1233a
TSS DR (%)	-	-	-	4.57b	5.13a	4.40ab
VIT C GR (mg 100g <sup>-1</sup> )	334a	245b	296ab	-	-	-
VIT C R (mg 100g <sup>-1</sup> )	229b	244b	381a	-	-	-
VIT C DR (mg 100g <sup>-1</sup> )	352a	391a	239b	-	-	-

Table 6. Cont.

Variables	Applications					
	The First Growing Season			The Second Growing Season		
	Control	1 Mg da <sup>-1</sup>	2 Mg da <sup>-1</sup>	Control	1 Mg da <sup>-1</sup>	2 Mg da <sup>-1</sup>
TSS GR (%)	3.46b	5.55a	6.94a	-	-	-
FW (g)	79.6b	95b	146a	33.8b	45.9ab	64.4a
DW (g)	-	-	-	10.6b	16.8ab	21.3a
pH	-	-	-	8.15a	7.87b	7.77b
EC (dS m <sup>-1</sup> )	-	-	-	0.42c	0.57b	0.71a
SOM (%)	1.01c	1.21b	1.92a	0.98c	2.36b	3.46a
N-tot (%)	0.14c	0.23b	0.31a	0.12b	0.13b	0.18a
Db (g cm <sup>-3</sup> )	1.30c	1.27b	1.22a	1.30a	1.23b	1.17c
PR (MPa)	2.50a	2.44a	1.87b	2.50a	1.53b	1.15c
WAS (%)	30.8b	30.9b	41.8a	30.3c	42.1b	56.4a

Different letters mean the subjects are statistically different from each other.

When the column of Table 6 belonging to the second growing season is examined in terms of the variables of Capia pepper, it is seen that the highest PHe values (38.1 and 35.0 cm) were measured in the plots with high-dose and low-dose manure, respectively, and there was no statistical difference between these values. The highest PY was measured as 64.3 g plant<sup>-1</sup> in the plot where high-dose manure was applied; low-dose manure application was not sufficient to increase this value. A similar situation applies to the AFW and LA variants. Low-dose manure application was more effective in increasing the TSS DR value compared to the control. Application of the 2 Mg da<sup>-1</sup> manure dose increased the FW value from 35.2 g to 64.4 g, and this increase was found to be statistically significant. The increase in the FW value caused by the application of the 1 Mg da<sup>-1</sup> manure dose was also remarkable. A similar situation applies to the DW variable. When Table 6 is examined for the soil variables measured in the second growing season, it is seen that both manure application doses statistically significantly reduced the soil pH, but there was no statistical difference between the doses. The electrical conductivity of the soil increased in parallel with the manure application dose, and the increases were found to be statistically significant. While the organic matter content of the soil was 0.98% in the control plots, this value increased to 2.36% with the 1 Mg da<sup>-1</sup> dose manure application and to 3.46% with the 2 Mg da<sup>-1</sup> dose manure application. These three values were statistically different from each other. While low-dose manure application did not make a statistical difference in increasing the total nitrogen content of the soil, this value increased to 0.18% with high-dose application, and this change caused by high dosage is statistically significant.

The effectiveness of manure on reducing the Db and PR values of the soil was dependent on the application doses, and the decreases were found to be statistically significant. The WAS value of the soil, which was 30.3% in the control plot, increased to 42.1% with the application of 1 Mg da<sup>-1</sup> manure and to 56.4% with the application of 2 Mg da<sup>-1</sup> manure, and these three values are statistically different from each other.

The fact that the pH and EC values of the soil did not change at the end of the first growing season can be attributed to the insufficient amount of manure applied in the first year, and the change in these lump properties at the end of the second growing season can be attributed to the fact that the manure was applied to the soil two years in a row.

In a study by Hao and Chang [74], it was concluded that the soil pH gradually decreases depending on the increasing application doses of manure. In another study, in which an organic conditioner was applied to the soil, decreases in pH were determined due to the increase in application doses [75]. In a study using manure as a soil conditioner, it was determined that the EC value of the soil increased depending on the manure application, just like in this study [76]. The increase in the EC value of the manure application may be due to the salt effect due to the components contained in the manure. The increase in SOM at the end of both growing seasons and the fact that this increase was more pronounced in the 2 Mg da<sup>-1</sup> application dose can be attributed to the contribution of the amount of SOM as a result of the humification of the organic components of the manure over time. For Butler et al. [77], a 73% increase in SOM compared to control was achieved by using 35 Mg ha<sup>-1</sup> manure. There are many studies that have concluded that organic materials have a positive effect on carbon sequestration in the soil when they are applied externally to the soil or when organic wastes are left in the soil by methods such as direct seeding [78–81], which is linked to an increase in SOM in soil. Manure application resulted in an increase in the total N content of the Capia pepper garden soil. This increase in nitrogen can be attributed to nitrogenous compounds released by the decomposition of manure in the soil [82,83]. Busari et al. [84] found that the application of organic conditioners increased the total N content of the soil, and this increase was more pronounced in the soil with 10 Mg ha<sup>-1</sup> manure application compared to the 5 Mg ha<sup>-1</sup> dose application. In our study, contrary to expectations, total N values measured in the second year were lower than those in the first year. This situation can be explained by the climatic difference between the growing seasons, because heavy rains in the second growing season may have caused nitrate leaching. How much the applied organic conditioner can affect the total N amount in the soil is closely dependent on time and environmental conditions [63,85]. The difference that manure makes in improving the physical properties of the Capia pepper garden soil is obvious for both growing seasons. Decreased soil compaction (decreased Db and PR values) and increased structural strength (increased WAS value) can be explained by the increased SOM content of the soil. The applied manure, especially the 2 Mg da<sup>-1</sup> dose, most likely promoted aggregation in the soil over time and increased the total porosity of the soil. The increase in total porosity resulted in a decrease in PR and Db values. According to the results of a study on manure application, the addition of 25 Mg ha<sup>-1</sup> yr<sup>-1</sup> compost or manure to the soil provided the lowest bulk weight compared to synthetic fertilizer. In the same study, average Db was measured as 1.21 Mg m<sup>-3</sup> at 0–15 cm soil depth in the plots where manure was applied, and as 1.40 Mg m<sup>-3</sup> in the plots where synthetic fertilizers, N, P, and K were applied [36]. Gulser et al. [86] found in a study they conducted that organic matter sources applied to the soil decreased Db. The researchers based this situation on the negative correlation ( $r = -0.979$ ) between the organic C content of the soil and Db. They found that the PR value of the soil, which was 1.72 MPa at the beginning, decreased to 0.91, 0.84, and 0.72 MPa, respectively, of the organic conditioner applied at 2, 4, and 6 doses to a clay-textured soil at the end of the 7-month period. As can be seen, the organic origin conditioners applied in many studies prevented soil compaction by reducing the bulk weight. The results of this study are in agreement with the findings of previous studies. Of course, the mechanism in the decrease in the volume weight can be explained by the fact that the applied manure has a positive effect on the soil porosity by increasing aggregation. In this study, the stability of the aggregate increased depending on the application dose, and the water resistance of the aggregates was related to the amount of organic matter [87]. This increase in the WAS values of the soils was also time-dependent, and when the manure was applied for two consecutive years, a further increase in WAS occurred. It should be noted that the Capia pepper garden is in a semiarid climate zone. The humification of SOM in soil releases humic substances, which are carriers of unique chemical compounds that can improve aggregate stability. Particulate organic matter and these humic substances play key roles in the aggregation cycle, increasing the WAS value. In a study investigating the long-term effects of manure and chemical fertilizer applications [88], it was concluded that

high manure treatment increased aggregate-related soil organic carbon and total nitrogen concentration by 40–50% in all size fractions when compared to no manure no fertilizer. In addition, it was determined that while high manure increased particulate organic matter 1.2 times compared to the other application, inorganic fertilizer application did not change these parameters. Researchers examined the increase in WAS over the increase in OM. According to Are et al. [89], the effects of 40 Mg ha<sup>-1</sup> manure application in potato and barley fields were investigated. Researchers have concluded that manure application has an effect on WAS, but this effect is not always observed, contrary to expectations. In our study carried out in the Capia pepper garden, WAS was also affected by the manure application, and the change in WAS occurred depending on the time and application dose.

When the PY value was examined, the first-year data were found to be insignificant, while the second-year data were found to be significant. In both years, the highest yield (101.3, 64.3 g plant<sup>-1</sup>, respectively) was determined in low-dose manure application. In a study examining the usability of different composts in Capia pepper cultivation, a yield of 13.6 kg ha in the first year and 15.2 kg ha in the second year was obtained from the first dose (10 t ha<sup>-1</sup>) of barnyard manure. In the same study, 13.9 kg ha<sup>-1</sup> yield was obtained in the first year from the second dose (20 t ha<sup>-1</sup>) of farm manure, while 23.3 kg ha<sup>-1</sup> yield was obtained in the second year [90]. In the study examining the effects of processing on vitamin C in sweet pepper at different maturity stages, the vitamin C contents were determined as Green Mature: 106.05 mg 100 g<sup>-1</sup>, Breaker (Green-Red): 127.40 mg 100 g<sup>-1</sup>, Red: 148.94 mg 100 g<sup>-1</sup> fresh weight [91]. It has been reported that the media and maturity stages of different pepper cultivars grown in peat or peat + perlite + sand media may change the VIT C and TSS values, although they differ between the cultivars [92]. VIT C plays a role in the protection against oxidative stress and in the defense mechanism against reactive oxygen species as an antioxidant in the plant [93]. In our study, the decrease in the amount of VIT CR with the decrease in soil compaction at the end of the first growing season brings to mind the idea that the plant grows in a stress-free environment. Likewise, when the second-year data were examined, VIT CR and TA R values decreased as the soil data improved. Being an antioxidant, VIT C has an important place in terms of its roles in plant growth and development and regulating cellular mechanisms against various stresses. VIT C can regulate the stress response through biochemical reactions such as increasing defense compounds against environmental stresses and production of defense compounds [94]. When soil properties improved, TSS GR values also decreased. When the effect of high-temperature stress on pepper was examined, the TSS value, which was 6.02% in the control plant, increased to 10.66% with stress [95]. This shows that the plants are in a stress-free period in the TSS GR stage. As the soil pH value increases, an increase is determined in the measured chemical values, while a decrease is observed in the physically measured values. This suggests that with the increase in pH value, stress symptoms are observed in the plant.

Since the success of manure application in soil depends on many factors such as application dose, application method, climate characteristics, and soil characteristics, it is extremely difficult to decide on the right application dose, especially in regions located in the Mediterranean climate zone, where weather characteristics vary from year to year. Sometimes the correct manure recommendation for one year may not be the solution for the next year. Therefore, it is of great benefit to examine the relationships between soil characteristics modified by manure and cultivated plant characteristics in order to develop more accurate management recommendations. It should always be considered that the yield and product quality, which are affected by plant health, are as important as sustainability in agricultural systems. In this study, the relationships between soil properties and plant properties were investigated with PCA, which was first introduced by Hotelling [96] and was and continues to be used in many scientific studies. The logic of PCA implementation is to reduce the number of predictive variables by using the principal components. These principal components are generated to successfully predict the target variable. PCA provides a new set of variables built on the concept of entropy, which has

the potential to clarify significant variance in the data set. Additionally, the new variants generated using PCA are orthogonal and avoid overfitting and multicollinearity effects [97].

### 3.4. Relations between Soil and Plant Properties

Principal component analysis (PCA) results were given in Table 7 as component matrix and in Figure 3 as component plots in rotated space. The 15 plant traits and 7 soil traits used in the factor analysis were grouped into five factors for both growing seasons and defined 85.4% and 90.9% of the total variability in the population in the first and second growing seasons, respectively (Figure 3 and Table 7). The reason for choosing five factors is that the model assigns values above 0.70 to some variables in the fifth factor. For the first growing season, the number of variables loaded on Factor 1 out of a total of 22 variables is 15, the number of variables loaded on Factor 2 is 11, the number of variables loaded on Factor 3 is 7, the number of variables loaded on Factor 4 is 6, and the number of variables loaded on Factor 5 is 5. Examining the relationships between the variables loaded on Factor 1 and Factor 2 is meaningful in terms of evaluating the relationships between soil properties and plant characteristics for the first growing season, because Factor 1 defined 37.2% of the total variability in the population and Factor 2 defined 16.9%. In addition, soil properties are mostly loaded on Factor 1 and Factor 2. All of the measured soil physical properties and measured soil chemical properties except soil pH significantly affected pepper plant characteristics under the first factor. Under Factor 1, unexpectedly, VIT C DR showed a positive correlation with soil compaction indicators Db and PR. Especially, the SOM, total N, Db, PR, and WAS properties of the soil positively affected the plant properties loaded on Factor 1 (PHe, PY, AFW, LA, VIT CR, TSS GR, TSS DR, and FW) with a very high correlation. Soil properties loaded on Factor 2 are EC, SOM, total N, Db, and WAS, and plant properties are PHe, LA, VIT C DR, TSS R, TA GR, and TA DR. Here, too, positive correlations were determined between the WAS, SOM, total N, and EC properties of the soil and the PHe, LA, VIT C DR, and TA DR properties of Capia pepper, and the aforementioned soil properties positively affected the listed plant properties. There is a negative correlation between the Db of the soil and these four plant characteristics, which means that the plant properties in question change positively with a decrease in soil volume weight. However, unexpectedly, TSS R and TA GR properties were generally negatively affected by the improvement in soil properties.

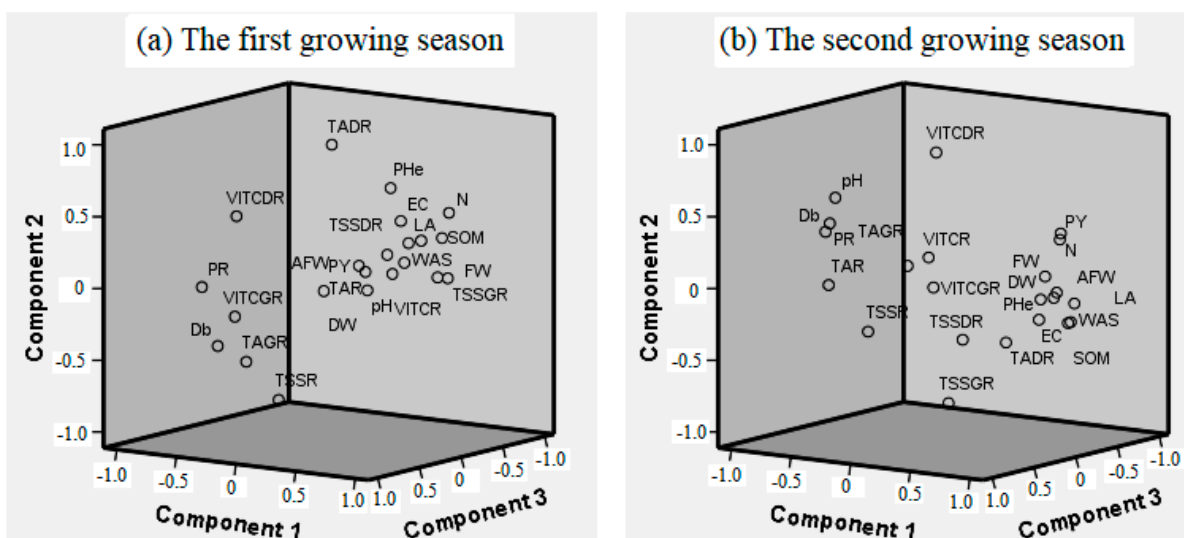


Figure 3. Component plots in rotated space produced by PCA.

**Table 7.** Rotated component matrix produced by principal component analysis (PCA).

Variables	Component									
	The First Growing Season					The Second Growing Season				
	1	2	3	4	5	1	2	3	4	5
PHe	0.44	0.68	-	-	-	0.87	-	-	-	-
PY	0.64	-	0.55	-	-	0.86	0.36	-	-	-
AFW	0.56	-	-	-	0.72	0.92	-	-	-	-
LA	0.77	0.36	-	-0.31	-	0.94	-	-	-	-
VIT C GR	-	-	0.92	-	-	-	-	-	-	0.93
VIT C R	0.78	-	0.36	-	-	-0.32	-	-	0.50	0.63
VIT C DR	-0.80	0.37	-	-	-	-	0.89	-	-	-
TSS GR	0.81	-	-	-	-	-	-0.81	-	-	-0.32
TSS R	-	-0.80	0.32	-	-	-	-	0.95	-	-
TSS DR	0.51	-	-	0.59	0.37	0.38	-0.32	0.30	0.75	-
TA GR	-	-0.47	0.74	-	-	-0.48	-	-	0.75	-
TA R	-	-	-0.36	0.85	-	-0.36	-	0.86	-	-
TA DR	-	0.96	-	-	-	-	-0.50	-0.58	0.35	-
FW	0.87	-	-	-	-	0.92	-	-	-	-
DW	-	-	-	-	0.95	0.90	-	-	-	-
pH	-	-	-	-0.78	-	-0.83	0.51	-	-	-
EC	0.59	0.48	-	-0.37	-	0.93	-	-	-	-
SOM	0.84	0.37	-	-	0.32	0.94	-	-	-	-
N	0.73	0.50	-0.39	-	-	0.76	0.37	-0.32	-	-
Db	-0.80	-0.50	-	-	-	-0.93	-	-	-	-
PR	-0.94	-	-	-	-	-0.92	0.32	-	-	-
WAS	0.70	0.35	-	0.33	0.30	0.96	-	-	-	-
% of variance	37.2	16.9	11.0	10.2	10.1	50.8	12.3	11.5	8.5	7.8
Cumulative, %	37.2	54.1	65.1	75.3	85.4	50.8	63.1	74.6	83.1	90.9

Rotation method: varimax with kaiser normalization, rotation converged in 7 iterations.

For the second growing season, the number of variables loaded on Factor 1 out of a total of 22 variables is 17, the number of variables loaded on Factor 2 is 8, the number of variables loaded on Factor 3 is 5, the number of variables loaded on Factor 4 is 4, and the number of variables loaded on Factor 5 is 3. It is meaningful to examine the relationships between the variables loaded on Factor 1 and Factor 2 in terms of evaluating the relationships between soil properties and plant characteristics for the first growing season because the cumulative variance of these two variables is 63.1%. In addition, all soil properties were loaded on Factor 1. Under factor 1, positive significant correlations were found between plant properties PHe, PY, AFW, LA, TSS DR, FW, and DW and soil SOM, total N, WAS, and EC properties, and negative correlations with Db and PR properties. On the other hand, unexpectedly, the correlations between the WAS value of the soil and the VIT CR, TSS GR, and TAR values of the plant were negative. The decrease in the VIT CR, TA GR, and TA AR values of the plant due to the decrease in soil compaction is also an unexpected result. While soil pH correlated negatively with plant physical properties, it mostly gave positive correlations with plant chemical properties. Factor 2 was loaded with three of the soil properties (pH, N, and PR) and mostly the chemical properties of the plant. While the correlation of pH and N with the PY and VIT C DR values of the plant is positive, their correlations with TSS GR, TSS DR, and TA DR are negative. The correlation of PR with TSS GR, TSS DR, and TA DR was found to be negative. However, contrary to expectations, the correlation of this variable with PY and VITC DR under Factor 2 is positive. Plants exhibit behaviors by being affected by soil–plant interactions. When an organic conditioner is applied to the soil, it affects the physical fertility of the soil depending on time and gives a response to the plant conditioner application depending on this change in the soil. The PCA

results in this study clearly showed that the change in the physical and chemical properties of the plant is related to how much the applied manure changes the soil properties.

Manure can be seen as a nature-based strategy [98] to restore degraded soils in environments such as the Mediterranean where soil erosion induces a huge degradation of the soil [99–101]. Manure should be part of a whole set of strategies to control the soil erosion rates and restore soil by means of regenerative agriculture, such as the use of organic conditioners or mulches suggest [102–106]. A new agriculture should be developed to achieve a sustainable management of the land, and manure is a key issue in the Mediterranean agriculture land.

#### 4. Conclusions

Strong benefits were found between soil and plant characteristics in both growing seasons, more pronounced at the end of the second year, when manure was applied. In addition, manure applied to the soil affected the fruit characteristics of the Capia pepper fruit more in the first year and the plant characteristics more in the second year. This shows that if an increase in yield is desired as well as an improvement in fruit quality, consecutive years of manure is more appropriate. As a result, we can confirm that when Capia pepper cultivation is desired in similar arid climatic regions where this study was conducted, 2 Mg da<sup>-1</sup> manure is enough to improve soil and plant conditions. These doses positively affect the soil properties and yield and quality characteristics of the plant after the first year. However, it should not be forgotten that the reaction of the plant to the manure application may be different depending on the characteristics of the manure to be applied and the soil to be cultivated. In fact, it should not be expected that every vegetable will give the same reaction to the manure application. In the future, we are committed to testing different doses of manure for other similar crop types in order to efficiently advise farmers and stakeholders in arid regions.

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