

Effects of farmyard manure and chemical fertilizer application rates on soil biology, cotton and fiber yield

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Abstract

Organic and inorganic fertilizers have significant effect on plant physiology, yield per unit area, available plant nutrient contents and extracellular enzyme activities of soils. This study was carried out in field conditions in arid and semi-arid regions between 2020-2021 years, May 01. The effects of farmyard manure (FM) (20, 40, 60 Mg ha⁻¹) and chemical (CF) (350 kg urea ha⁻¹, 100, 200, 300 kg DAP ha⁻¹) fertilizers applied at different rates on plant nutrient (N, P, K, Ca, Mg, Fe, Cu, Zn and Mn) contents, SPAD value and NDVI of cotton plants, seed cotton yield and soil enzymes (urease, catalase, dehydrogenase, alkaline phosphatase) were investigated. The results showed that FM applications significantly ($p < 0.01$) increased the plant macro and micronutrients compared to CF applications, except for N (200 + 150 kg urea ha⁻¹), Zn and Cu (300 kg DAP + 200 + 150 kg urea ha⁻¹) in the 2021 cotton growing season. Mineralization of FM is slow under natural conditions; therefore, the use of FM alone is not sufficient to meet the nutrient needs of high yielding varieties. Urease and dehydrogenase activities increased significantly in FM treated soils compared to CF, while no significant ($p < 0.01$) increase was recorded in alkaline phosphatase and catalase activities. Farmyard manure is a useful management practice for increasing soil biological activity. Physiological parameters of NDVI, SPAD and seed cotton yield significantly increased in FM treated soils compared to CF applications. The increase in cotton yield was 29.15%, in NDVI value was 22.38% and in SPAD value was 121.7%. The main issues with cotton in the area are the low organic carbon content of the soils, high clay content, arid and semi-arid soils, and their detrimental impact on the uptake of particular nutrients (N, P and B).

Keywords: cotton; farmyard manure; NDVI; plant nutrition; soil enzyme activity

Introduction

Cotton is an important feedstock for textile industry with fibers, for oil and feed industries with the seed and pulp. In addition, cotton stalks have recently been used in biomass production (Poyraz, 2012). The importance of cotton increases even more considering the effect on textile sector. Although the amount of cotton production varies by years, annual average fiber cotton production in the world is 25 million tons and

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it is 1 million 600 thousand tons in Turkey (National Cotton Council, 2021). The raw material of fiber consists of high cellulose which makes cotton fibers valuable in the textile industry. Cellulose is the raw material of starch produced with photosynthesis. Therefore, the quality of cotton fibers depends largely on the photosynthesis rate and the adequate utilization of plant nutrition's.

Soil health is the integration of chemical, physical and biological properties that enable soils to perform various functions. Microorganisms play a vital role in soil fertility and crop production through enzyme activities, decomposition of organic matter, and nutrient cyclings (Antonious *et al.*, 2020). The application of animal farmyard manure contributes to soil fertility and helps to increase yield. The use of bioindicators such as soil enzyme activities was recommended to monitor soil health and assess the potential impacts of agricultural practices and amendments (Hinojosa *et al.*, 2008; Xie *et al.*, 2017). Organic fertilizer is an organic carbon-rich material that not only improves soil structure and available nutrient contents, but also increases soil microbial biomass and enzyme activities (Nyiraneza *et al.*, 2018). The mineralization of various organic and inorganic materials and the consequent availability of nutrients in soils depend on the enzymatic activities of hydrolases and oxidoreductases (Xu *et al.*, 2020).

Average of 1.3 billion tons of animal waste (biosolid) is produced annually in the world. Biosolid production in the world is expected to increase to 2.2 billion tons/year by 2025 (Moya *et al.*, 2017). Recycling of biosolids and farmyard manures as fertilizers will reduce reliance on synthetic fertilizers and enable farmers with limited resources to improve soil structure and nutrient status at low cost (Antonious *et al.*, 2020). Addition of animal wastes to soils increases the microbial activity. Microbial activity increases availability of plant nutrients by increasing enzyme activities. Plant and animal wastes used as soil amendments increase plant nutrients, soil organic matter, soil microbial activities and nutrient availability.

Organic (farmyard manure) and inorganic (chemical) fertilizers not only improve the physical, chemical and biological properties of soils, but also provide necessary nutrients for plants (Akhtar *et al.*, 2019). These amendments improve soil structure, increase soil nutrient content, number of soil microorganisms, bacterial and fungal diversity which increases extracellular enzyme activities, and crop growth (Wu *et al.*, 2020). Organic fertilizer, for example poultry farmyard manure, is an organic carbon-rich additive that improves soil structure, increases available nutrients, soil microbial biomass and enzyme activities (Nyiraneza *et al.*, 2018).

The aims of this study were to investigate the effects of different doses and amounts of farmyard manure and chemical fertilizers applied to cotton-grown soil on (i) plant nutrient contents, (ii) soil enzyme activities, (iii) plant SPAD value (chlorophyll) and vegetation index (Normalized Difference Vegetation Index, NDVI).

Materials and Methods

Plant material and experimental design

The experimental site is located in Harran Plain (altitude: 465 m; 37° 08' North and 38° 46' East), near to the Turkish-Syrian border. The study was initiated on in the Karaali village located in the Harran Plain of Şanlıurfa province, Turkey. May-455 cotton variety (*Gossypium hirsutum* L.) was used as plant material of the experiment. This study was carried out in field conditions in arid and semi-arid regions between 2020-2021 years, May 01 and carried out for two years. The experimental design was randomized blocks with three replicates. Each plot had 4 rows, the plot length was 12 m, the interrow spacing was 70 cm and intra-row spacing was 10-12 cm. Three meters buffer zone was left around every plot and between the blocks. The experiment consisted of 24 plots. Top dressing treatment was applied in 2 different times.

The treatments are;

I- Control

II- Base fertilizer (0 kg) + Top dressing (200+150 kg Urea ha⁻¹)

III- Base fertilizer (100 kg DAP ha⁻¹) + Top dressing (200+150 kg Urea ha⁻¹)

- IV- Base fertilizer (200 kg DAP ha⁻¹) + Top dressing (200+150 kg Urea ha⁻¹)
 V- Base fertilizer (300 kg DAP ha⁻¹) + Top dressing (200+150 kg Urea ha⁻¹)
 VI- Base fertilizer (20 Mg farmyard manure ha⁻¹) + Top dressing (200+150 kg Urea ha⁻¹)
 VII- Base fertilizer (40 Mg farmyard manure ha⁻¹) + Top dressing (200+150 kg Urea ha⁻¹)
 VIII- Base fertilizer (60 Mg farmyard manure ha⁻¹) + Top dressing (200+150 kg Urea ha⁻¹)

Climate and soil parameters

Some physical and chemical properties of soil samples (0-30 cm) collected from the experimental field were given in Table 1, long-term average climate data of Sanliurfa province was in Table 2 and nutrient content of farmyard manure used in the experiment were given in Table 3. Application of diammonium phosphate (DAP 18% N, 46% P) and urea fertilizers decreased soil pH due to the acidic nature of fertilizers. Farmyard manure application increased the soil pH. Fresh farmyard manure was applied to the experimental plots. No precipitation has occurred throughout the cotton vegetation period.

Table 1. Some soil properties of the experimental field soils before and after the experiment

Treatments	pH	EC (mmhos cm ⁻¹)	CaCO ₃ (%)
I	8.33 ± 0.08	0.81 ± 0.03	29.71 ± 1.00
II	8.24 ± 0.07	1.24 ± 0.29	31.30 ± 0.92
III	8.06 ± 0.13	1.21 ± 0.29	34.24 ± 0.99
IV	8.20 ± 0.06	1.09 ± 0.27	30.43 ± 0.79
V	8.30 ± 0.10	1.58 ± 0.03	31.39 ± 1.41
VI	8.43 ± 0.03	0.69 ± 0.13	30.82 ± 0.34
VII	8.36 ± 0.09	0.70 ± 0.22	32.52 ± 0.37
VIII	8.34 ± 0.03	0.45 ± 0.06	31.98 ± 1.49

Sanliurfa province has dry and hot summers, cool and low rainy winters. Cotton is irrigated about 10 times (around 800 mm) in a growing season. The average temperature between May and October, which includes the cotton growth period, ranged between 9.4 and 34.2 °C, the average precipitation was between 0 and 39.1 mm, the average relative humidity was between 24.9% and 60.9 and the soil temperature was between 23.9 and 36.6 °C.

Table 2. Climate data of Şanlıurfa province for 2021 and the long-term average values

Months	Average monthly temperature (°C)		Precipitation (kg m ⁻¹)		Average relative humidity (%)		Long-term average temperature (°C) Between 1929 and 2020
	2020	2021	2020	2021	2020	2021	
April	17.1	19.1	69.3	0.4	54.2	40.0	16.2
May	23.2	26.6	39.1	2.7	41.0	25.7	22.2
June	28.9	28.9	0.4	0.0	29.9	29.6	28.1
July	34.2	33.8	0	0.0	24.9	25.9	32.0
August	30.9	32.7	0	7.7	25.3	30.2	31.5
September	24.0	27.3	0	0.0	29.2	33.8	27.2
October	13.5	22	0	2.3	27.5	32.0	20.6
December	9.4	15.6	84.3	14.0	60.9	51.6	13.1
Average	23,7	8.4	24,1	17.8	36,6	58.6	23.9

The farmyard manure (cattle) used in the experiment was obtained from an animal farm and applied to soil as fresh. Farmyard manure laid on soil surface was mixed with the rake before planting. The results of farmyard manure analysis carried out before the application were given in Table 3.

Table 3. Macro and micro nutrient concentrations of farmyard manure used in the experiment

Macro Nutrients [%]					Micro Nutrients [mg kg ⁻¹]	
N	P	K	Ca	Mg	Fe	Zn
1.22	0.15	0.45	0.02	0.01	39	43

Cultural practices

The experimental field was tilled with a plow in autumn and a cultivator in early spring. Before planting, 3 Mg ha⁻¹ of herbicide containing 4800 g/l Pendimethalin per ha was applied. The soil was mixed with a disc harrow and then a leveler was used to level the field surface. Then, the fertilizers were mixed into the soil with a rake before planting.

After preparing the field, the seeds were planted with a pneumatic planter under suitable weather conditions. Cotton seedlings were thinned in 2 - 4 true leaves period. Hoeing was carried out when the plants had 5-6 leaves to control weeds, aerate the soil and break the surface compacted layer. Insecticides were applied against aphid (*Aphis gossypii*), leafhopper (*Empoasca ssp*), whitefly (*Bemisia tabaci Genn*) and green worm (*Heliothis armigera Hübner*) considering the economic damage thresholds. Irrigation was carried out with drip irrigation method, considering water consumption demand of cotton plants.

Measurement of parameters

SPAD and NDVI values were measured during the peak flowering period (75th day) of cotton plant and leaf samples were collected simultaneously (Oosterhuis *et al.*, 1992). The chlorophyll content (SPAD values) was measured on the leaves of selected plants using a SPAD meter (CCM 200 Plus). NDVI values were determined using the GreenSeeker crop sensor hand device.

Methods

Soil reaction (pH) and electrical conductivity (EC) were measured in 1:2.5 soil water mixture (Jackson, 1958). Calcium carbonate (CaCO₃) content was measured by Scheibler calcimeter method (Allison and Moodie, 2016). The plant leaves were burned following the method described by Jones Jr. and Case (1990), and macro and micro elements were determined using an ICP-MC device. Total nitrogen in plant tissues was determined according to the Kjeldahl method reported by Bremner and Mulvaney (1982). Dehydrogenase activity in soil was determined by measuring the triphenyl formazan (TPF) formed following the incubation of soil samples added with triphenyl tetrasodium chloride (TTC) solution, at 24 h 25 °C. The TPF was measured using a spectrophotometer at 485 nm (Tabatabai, 1982). Urease enzyme activity was determined by spectrophotometric measurement of ammonium released by urease following one hour incubation at 37 °C. The measurement was carried out using a spectrophotometer at 578 nm according to the method of Tabatabai and Bremner (1972). Alkaline phosphatase content was determined using the method described by Tabatabai and Bremner (1972). Soil was incubated with buffered (pH 6.5) sodium p-nitrophenyl phosphate solution and toluene at 37 °C for 60 minutes. Free p-nitrophenol content was measured using a spectrophotometer at 400 nm wavelength (Tabatabai 1994). In catalase enzyme activity; 10 ml of phosphate buffer (pH:7) and 5 ml of a 3% H₂O₂ substrate solution were added to 5 g soil. The volume (ml) of O₂ released within 5 minutes at 20 °C was determined (Beck, 1971).

Statistical analysis

The experiment was laid out according to a randomized block design. Descriptive statistics of data were determined and mean values were obtained. The effects of fertilizer treatments on available plant nutrient (N, P, K, Ca, Mg, Fe, Cu, Zn and Mn) contents, SPAD value and NDVI of cotton plants, seed cotton yield and soil enzymes (urease, catalase, dehydrogenase, alkaline phosphatase) were assessed by variance analysis, which was performed using JMP 13.2 statistical software (ANOVA). The means were grouped using Tukey-HSD test. The relationships between the data examined in the study have been illustrated using the Pie chart

correlation graph in the R studio package program. Principal Component Analysis was analyzed using the OriginPro program.

Results

Plant nutrient elements concentrations

The differences in the parameters examined in the cotton leaves were statistically significant between chemical fertilizers and farmyard manure for both growing seasons (2020 - 2021) (Tables 4 and 5). Germination was achieved in all fertilizer applications under field conditions and cotton plants were examined for the characteristics investigated when they reached a certain physiological development stage. The N, P, K, Ca and Mg contents of plant leaves were significantly different ($P < 0.01$) among the fertilizers used. The lowest N content (1.96%) was obtained in 60 Mg farm farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} and the highest N content (3.01%) was recorded in 300 kg ha^{-1} + top dressing 200+150 kg urea ha^{-1} application and the lowest N content (2.70%) was obtained in 60 Mg farm farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} and the highest N content (3.02%) was recorded in 300 kg ha^{-1} + top dressing 200+150 kg urea ha^{-1} application for 2020-2021 growing season, respectively (Figure 1A). Respectively, 2020-2021 growing season the lowest and highest K (0.31-0.58% and 0.31-0.62%), Ca (1.78-2.85% and 1.88-2.87%), Mg (0.29-0.39% and 0.30-0.41) contents in cotton leaves were recorded in 60 Mg farm farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} application (Tables 4 and 5; Figure 1). The lowest phosphorus (P) content (0.07%) was obtained in 0 kg ha^{-1} + top dressing 200+150 kg urea ha^{-1} and the highest P content (0.10%) was in 60 Mg farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} application for 2020 and 0.07% was obtained in 0 kg ha^{-1} + top dressing 200+150 kg urea ha^{-1} and the highest P content (0.10%) was in 60 Mg farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} application for 2021. Leaf P content was significantly different ($p < 0.01$) between fertilizer applications.

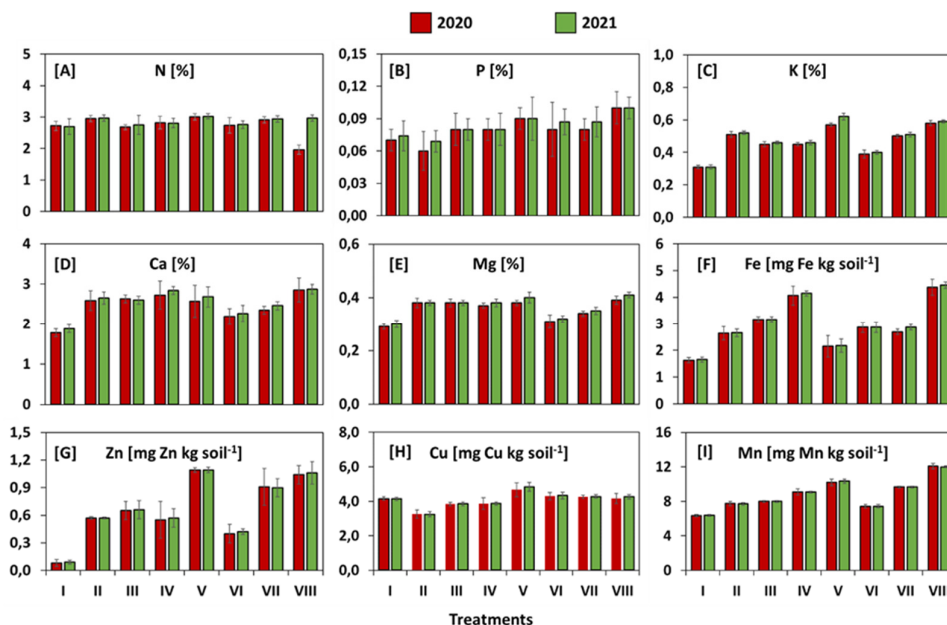


Figure 1. Macro and micro plant nutrient contents in plant leaf tissues for both growing seasons (2020 - 2021)

Table 4. Macro and micro plant nutrient contents in cotton plant leaf tissues and cotton and fiber yields for the first (2020) growing season

Treatments	Macro Plant Nutrients [%]				Micro Plant Nutrients [mg kg ⁻¹]					Yield [kg ha ⁻¹]	Fiber yield (kg ha ⁻¹)
	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn		
I	2.72d	0.07d	0.31g	1.78h	0.29f	1.63h	0.08h	4.16d	6.35h	4011.6e	1687.7c
II	2.95ab	0.06e	0.51c	2.59d	0.38ab	2.64f	0.57e	3.26g	7.76f	4412.0c	1959.1b
III	2.68d	0.08c	0.45e	2.63c	0.38ab	3.18c	0.65d	3.84f	8.00e	4216.7d	1896.3bc
IV	2.82c	0.08c	0.45e	2.73b	0.37c	4.07b	0.55f	3.87e	9.09d	4206.7d	1878.3bc
V	3.01a	0.09b	0.57a	2.57e	0.38a	2.15g	1.09a	4.67a	10.20b	4235.7d	1882.8bc
VI	2.74d	0.08c	0.39f	2.19g	0.31e	2.86d	0.40g	4.30c	7.43g	4303.3cd	1936.6b
VII	2.91b	0.08c	0.50d	2.35f	0.34d	2.69e	0.91c	4.26d	9.68c	4765.0b	2048.1b
VIII	1.96ab	0.10a	0.58b	2.85a	0.39ab	4.38a	1.04b	4.16d	12.08a	5264.0a	2316.5a
CV (%), Tukey (0.01,0.05)	2.35 (%1)	1.17 (%1)	0.51 (%1)	0.05 (%1)	0.27 (%1)	0.33 (%1)	0.30 (%1)	0.14 (%1)	0.45 (%1)	1.43 (%1)	3.97 (%1)

Table 5. Macro and micro plant nutrient contents in cotton plant leaf tissues and cotton and fiber yields for the second (2021) growing season

Treatments	Macro Plant Nutrients (%)				Micro Plant Nutrients (mg kg ⁻¹)					Yield [kg ha ⁻¹]	Fiber yield (kg ha ⁻¹)
	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn		
I	2.70b	0.07e	0.31f	1.88e	0.30e	1.65g	0.09g	4.14c	6.39h	3987.f	1713.4 d
II	2.96a	0.07f	0.52	2.65b	0.38ab	2.65e	0.57e	3.25e	7.70f	4386.c	1944.3 c
III	2.75b	0.08d	0.46d	2.60bc	0.38ab	3.18c	0.66d	3.86d	8.01e	4093.ef	1833.1 cd
IV	2.81b	0.08d	0.46d	2.84a	0.38b	4.15b	0.57e	3.88d	9.09d	4113.def	1926.7 c
V	3.02a	0.09b	0.62a	2.68b	0.40a	2.18f	1.09a	4.84a	10.35b	4153.de	1921.1 c
VI	2.76b	0.09c	0.40e	2.27d	0.32d	2.87d	0.42f	4.34b	7.44g	4244.d	1957.5 c
VII	2.94a	0.09c	0.51c	2.46c	0.35c	2.87d	0.90c	4.28b	9.68c	4653.b	2214.2 b
VIII	2.97a	0.10a	0.59b	2.87a	0.41a	4.47a	1.06b	4.27b	12.01a	5147.a	2458.4 a
CV (%), Tukey (0.01,0.05)	1.29 (%1)	2.07 (%1)	0.93 (%1)	2.00 (%1)	1.01 (%1)	1.04 (%1)	1.14 (%1)	0.67 (%1)	0.57 (%1)	1.79 (%1)	2.37 (%1)

The Fe and Mn contents of cotton leaves were significantly different ($p < 0.01$) between chemical fertilizer and farmyard manure applications. The highest positive effect on Fe and Mn contents of cotton leaves was obtained in 60 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ for growing period 2021. 2020-2021 growing season respectively, the lowest Fe and Mn contents (1.63 and 4.38 mg kg⁻¹) were obtained in the control application and the highest Fe and Mn contents (6.35 and 12.08 mg kg⁻¹) were obtained in 60 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application. The Zn and Cu contents of cotton leaves were significantly different ($p < 0.01$) between chemical fertilizers and farmyard manure applications. The lowest Zn and Cu content (0.08 and 1.09 mg kg⁻¹) in cotton leaves was obtained in the control for 2020 year and the highest Zn and Cu content (3.25 and 4.84 mg kg⁻¹) was obtained in 300 kg DAP ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application for 2021 growing period.

Cotton yield (kg ha⁻¹)

Variance analysis showed a statistically significant ($p < 0.01$) difference in seed cotton yield between chemical fertilizer and farmyard manure applications. For 2020-2021 year, the lowest cotton yield (4011 and 3987 kg ha⁻¹) was obtained in the control and the highest seed cotton yield (5264 and 5147 kg ha⁻¹) was obtained in 60 Mg farm farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application (Beyyavas *et al.*, 2022) (Table 4 and 5; Figure 2A). The combination of agricultural manure and urea manure produced the best results. In addition to NPK, FYM also offers secondary and micronutrients. In addition to providing nutrients, FYM aids in the storage of soil moisture, which is crucial in rainfed agriculture. These outcomes might account for some of FYM application's benefits.

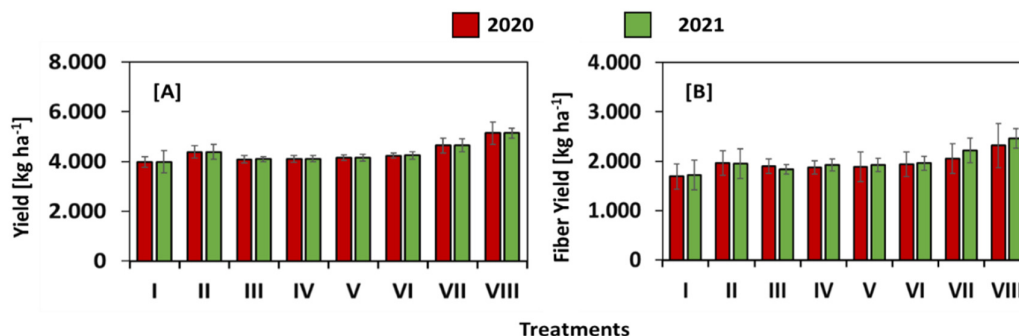


Figure 2. Cotton and fiber yields for both growing seasons (2020 - 2021)

Fiber yield (kg ha⁻¹)

As a result of the analysis of variance, a statistically ($p < 0.01$) difference was found between the chemical and farm yard manure applied in the cotton variety in terms of fiber yield obtained at the time of harvest at the harvest maturity of the plant. The lowest fiber yield value in terms of the fertilizers used was from the control application ($1687.7 \text{ kg ha}^{-1}$ - $1713.4 \text{ kg ha}^{-1}$) in 2020 and 2021 (Table 4 and 5; Figure 2B). The highest fiber yield value was obtained from 60 Mg farm yard manure ha^{-1} + Top manure 200+150 kg Urea ha^{-1} application ($2316.5 \text{ kg ha}^{-1}$ - $2458.4 \text{ kg ha}^{-1}$) (Table 1). According to the results obtained from the study, farmyard manures and N fertilizers in the form of urea gave better results than control and DAP fertilizer applications. Therefore, balanced 60 Mg farm farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} application fertilization is preferred for optimal fiber quality.

Soil enzyme activities

Soil organic matter (OM) content was significantly different ($p < 0.01$) between chemical fertilizer and farmyard manure applications (Tables 6 and 7; Figure 3). The lowest OM content (0.58 and 0.59%) was obtained in 200 kg DAP ha^{-1} + top dressing 200+150 kg urea ha^{-1} and the highest OM content (1.25 and 1.26%) was in 40 Mg farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} applications for 2020-2021 growing season respectively (Tables 6 and Figure 3A). Organic matter content of soils in farmyard manure applications increased by 55%.

Catalase (CAT) enzyme activity of the soil in the control treatment was significantly different ($p < 0.01$) from chemical fertilizer and farmyard manure applications. The lowest CAT enzyme activity ($32.29 \text{ ml O}_2 \text{ g}^{-1} \text{ dry soil } 5 \text{ min}^{-1}$) was obtained in the control and the highest CAT activity ($71.27 \text{ ml O}_2 \text{ g}^{-1} \text{ dry soil } 5 \text{ min}^{-1}$) was in the base fertilizer 100 kg DAP ha^{-1} + top dressing (200+150 kg urea ha^{-1}) application in the season of 2021 (Table 7; Figure 3B). The CAT enzyme activity was 97% higher compared to the control group. The effect of other treatments to stimulate CAT enzyme activity was not as high as urea fertilizer application.

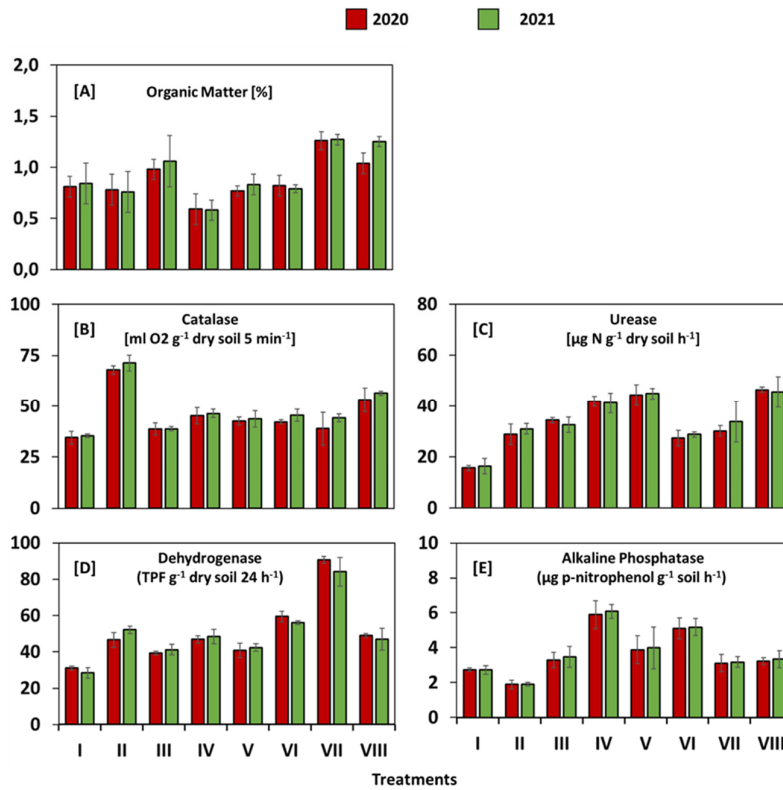


Figure 3. Changes in soil organic matter and enzyme activities for both growing seasons (2020 - 2021)

Table 6. Results for soil organic matter and enzyme activities for the first (2020) growing season

Treatments	Organic matter (%)	Catalase (ml O ₂ g ⁻¹ dry soil 5 min ⁻¹)	Urease (μg N g ⁻¹ dry soil h ⁻¹)	Dehydrogenase (TPF g ⁻¹ dry soil 24 h ⁻¹)	Alkaline phosphatase (μg p-nitrophenol g ⁻¹ soil h ⁻¹)
I	0.81ab	34.41d	15.64d	31.10c	2.75e
II	0.78b	67.93a	28.79c	46.55bc	1.89f
III	0.98ab	38.74c	34.34bc	39.40bc	3.28d
IV	0.59b	45.24bc	41.83ab	46.88bc	5.90a
V	0.77b	42.57bc	44.36ab	40.77bc	3.89c
VI	0.82ab	42.12bc	27.37c	59.45b	5.11b
VII	1.26a	38.86c	30.13c	90.66a	3.12de
VIII	1.04ab	53.17b	46.54a	49.02bc	3.24d
CV (%), Tukey (0.01,0.05)	18.18 (%1)	10.77 (%1)	10.64 (%1)	14.34 (%1)	3.56 (%1)

Table 7. Results for soil organic matter and enzyme activities for the second (2021) growing season

Treatments	Organic matter (%)	Catalase (ml O ₂ g ⁻¹ dry soil 5 min ⁻¹)	Urease (µg N g ⁻¹ dry soil h ⁻¹)	Dehydrogenase (TPF g ⁻¹ dry soil 24 h ⁻¹)	Alkaline phosphatase (µg p-nitrophenol g ⁻¹ soil h ⁻¹)
I	0.84c	35.29d	16.38d	28.44d	2.73d
II	0.76c	71.27a	30.95c	52.15bc	1.91e
III	1.06b	38.75d	32.50c	41.21c	3.47cd
IV	0.58d	46.34c	41.18b	48.50bc	6.09a
V	0.83c	43.67c	44.90ab	42.39c	3.99c
VI	0.79c	45.46c	28.74c	55.99b	5.18b
VII	1.27a	44.20c	33.71c	84.09a	3.18d
VIII	1.25ab	56.51b	45.58a	46.89bc	3.34cd
CV (%), Tukey (0.01,0.05)	4.95 (%1)	3.13 (%1)	4.24 (%1)	8.51 (%1)	7.00 (%1)

Alkaline phosphatase enzyme activity (APA) showed a significant variation among the fertilizers applied. The lowest APA (1.89 µg p-nitrophenol g⁻¹ soil h⁻¹) was obtained in 0 kg ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ and the highest APA (5.90 µg p-nitrophenol g⁻¹ soil h⁻¹) was in 200 kg DAP ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application in the 2020 season (Table 6; Figure 3E). The increase in APA compared to control was 114%. For the year 2021, the lowest APA (1.91 µg p-nitrophenol g⁻¹ soil h⁻¹) was obtained in 0 kg ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ and the highest APA (6.09 µg p-nitrophenol g⁻¹ soil h⁻¹) was in 200 kg DAP ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application in the 2020 season. The increase in APA compared to control was 115%.

The response of urease and dehydrogenase enzymes was different among the fertilizers applied. For the year 2020 and 2021, the lowest urease activity (15.64 and 16.38 µg N g⁻¹ dry soil h⁻¹) was obtained in control and the highest urease activity (46.54 and 45.58 µg N g⁻¹ dry soil h⁻¹) was in 60 Mg farm farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application. The increase in farmyard manure doses caused 97% increase in the urease enzyme activity compared to the control group. The lowest dehydrogenase enzyme activity (31.10 and 28.44 TPF g⁻¹ dry soil 24 h⁻¹) was recorded in control and the highest dehydrogenase activity (90.66 and 84.09 TPF g⁻¹ dry soil 24 h⁻¹) was in 40 Mg farm farmyard manure ha⁻¹ +top dressing 200+ 150 kg urea ha⁻¹ application in the 2020-2021 season.

SPAD value

SPAD content of cotton plant leaves were significantly different (P<0.01) between chemical fertilizer and farmyard manure treatments (Table 8). There is no significant difference between the two growing periods. However, there is a partial increase in the 2021 season. The lowest SPAD value (18.66) was obtained in the control and the highest chlorophyll value (42.03) was recorded in 60 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application for 2020-2021 growing period. The SPAD values increased depending on Ca, Mg, K, N and Fe contents of soils (Tables 4 and 5). The yield was also high at these application doses. High chlorophyll values of plants indicates that the crop has high yield potential.

Vegetation Index NDVI (Normalized Difference Vegetation Index)

The NDVI value of cotton plants was significantly different (p<0.01) between chemical fertilizers and farmyard manure treatments (Table 8). The lowest NDVI value (0.67) was obtained in the control treatments, while the highest NDVI value (0.83) was recorded in 60 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ treatment in the 2021 season. However, no significant difference was detected in both seasons. Farmyard manure application increased the vegetation index compared to other applications in the 2020-2021 season.

Table 8. Chlorophyll and NDVI values for cotton plants for both growing seasons (2020-2021)

Treatments	Chlorophyll		NDVI	
	2020	2021	2020	2021
I	18.66d	18.66d	0.67b	0.67b
II	20.46cd	20.46cd	0.78a	0.78a
III	24.32cd	24.32cd	0.79a	0.79a
IV	27.33bc	27.33bc	0.78a	0.78a
V	39.80a	39.80a	0.80a	0.80a
VI	33.74ab	33.74ab	0.77a	0.77a
VII	40.69a	40.69a	0.79a	0.79a
VIII	41.37a	42.03a	0.82a	0.83a
CV (%), Tukey (0.01,0.05)	8.70 (%1)	8.70 (%1)	2.36 (%1)	2.36 (%1)

Data grouping technique: Correlation plots

The pie chart correlation graph is an illustrative tool where the size of the slices represents the statistical significance, while the intensity of the colors denotes the degree of correlation (Figure 4). This graphical representation offers substantial insights into the relationships between plant nutrient elements, soil enzyme activities, and the yields of cotton and its fiber. A notably high correlation was identified between K and P, with a correlation coefficient ($r = 0.96$; $P < 0.01$). Similarly, a strong positive correlation exists between Ca and Mg, two other macro plant nutrient elements, reflected by an equally impressive correlation coefficient ($r = 0.98$; $P < 0.01$).

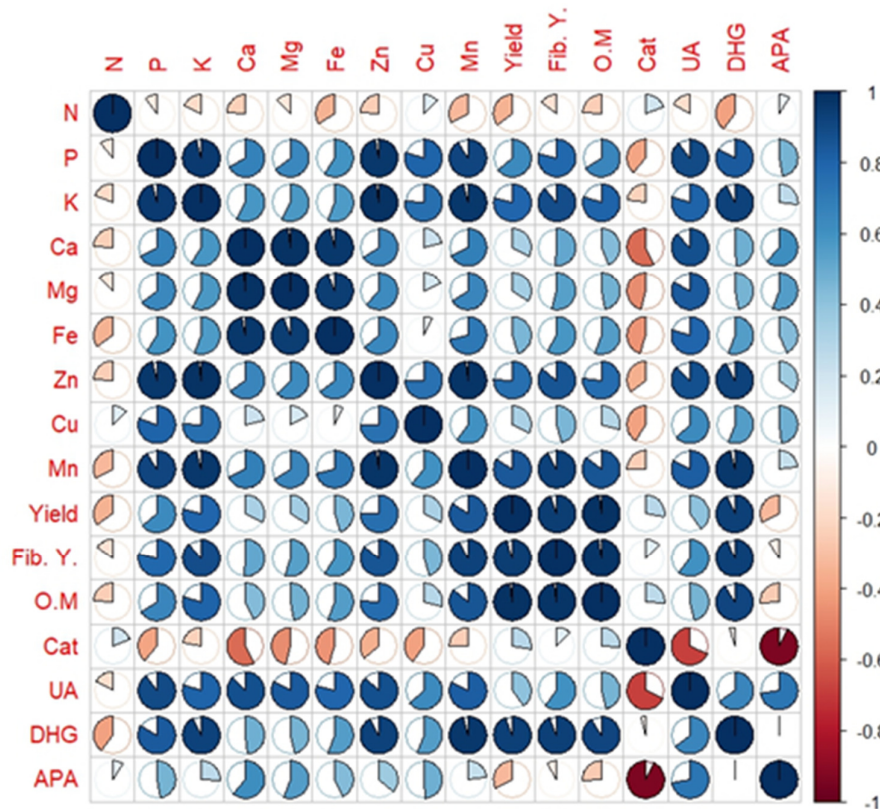


Figure 4. Pie chart correlation graph

Soil enzymes, which are pivotal biological parameters in soil, demonstrated a direct and meaningful relationship with the macro plant nutrient elements, underscored by high correlation coefficients. For instance, soil DHG activity showed a significant correlation with Mn ($r = 0.98$; $P < 0.01$), suggesting that Mn might play a role in enhancing soil DHG activity by stimulating microbial activity in the soil. Furthermore, there was a strong correlation between urease enzyme activity and K ($r = 0.80$; $P < 0.01$), while a highly significant negative correlation was observed between Cat and APA ($r = 0.93$; $P < 0.01$).

One of the critical components of soil quality, soil organic matter, was found to have a high correlation ($r = 0.98$; $P < 0.01$) with cotton yield. The study's findings imply that the addition of organic matter to soil, such as farmyard manure, not only enhances the uptake of plant nutrients but also boosts soil enzyme activities, which in turn directly affects yield. These results highlight the multifaceted benefits of organic amendments in agricultural practices, emphasizing their role beyond nutrient supply, by also invigorating soil biological functions that contribute to crop productivity.

Data grouping technique: Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a significant statistical method that elucidates the relationships between parameters in our dataset and how these parameters explain the variance within the dataset (Figure 5). The parameters in our dataset are categorized into three groups: plant nutrient elements, cotton yield, and soil enzyme activities.

PC1 represents the largest variation within the dataset. Within this group, microelements like manganese (Mn) and copper (Cu), along with soil organic matter (OM), possess high positive loadings, whereas nitrogen (N) and iron (Fe) have lower loadings in comparison, marking the extreme values in PC1 (Figure 5).

PC2 and PC3 signify the other two significant sources of variance, with cation exchange capacity (Cat) exhibiting high positive loadings on PC2, and oxalic acid (APA) showing high negative loadings on the same component. PC1 typically captures the largest variance in the dataset, and in this example, micro-nutrient elements such as manganese (Mn) and copper (Cu), as well as organic matter (O.M), take on high positive loadings. Nitrogen (N) and iron (Fe) are associated with lower or negative loadings, placing them at the negative ends of this component. PC2 and PC3 represent other substantial sources of variance; notably, cation exchange capacity (Cat) receives a high positive loading on PC2, whereas oxalic acid (APA) carries a high negative loading, suggesting a potential contrast between Cat and APA and their differing involvements in biological and environmental processes.

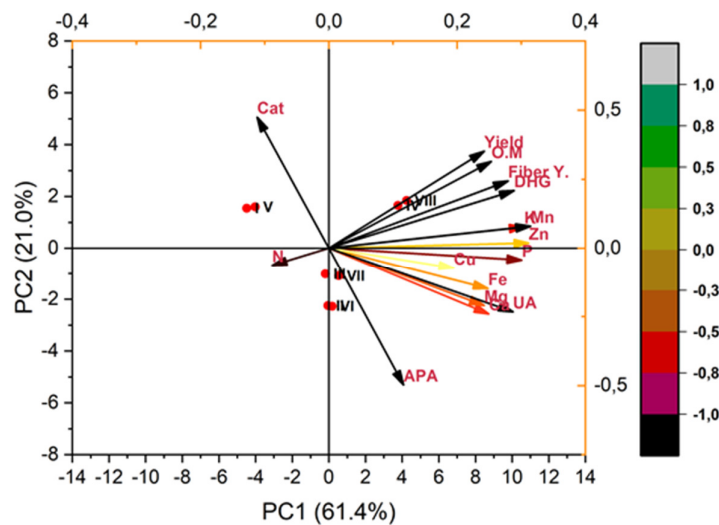


Figure 5. Principal Component Analysis

PC3 is distinguished by a positive loading for potassium (K), suggesting a distinct relational dynamic of K with other variables in the dataset. Observation scores (I-VIII) indicate the positioning of each measurement on the principal components, providing researchers with the opportunity to examine the interrelations among variables more closely for developing soil and plant nutrition management strategies. This in depth analysis facilitates a better understanding of the complex relationships and underlying trends within the dataset.

Discussion

The effect of farmyard manure and chemical fertilizers on soil fertility and quality primarily depends on the behavior of nitrogen (N) in soil. Nitrogen is the major plant nutrient limiting the yield, and is also important for environmental quality. The application of farmyard manure to soil improves physical, chemical and biological properties of soils and some other parameters. However, the use of farmyard manure alone is not sufficient to meet the nutrient needs of high yielding varieties. Application of farmyard manure had a significant effect on total N content, but the effect was not as strong as the urea used in the experiment. The nitrogen content of the plant in the 2021 cotton-growing season was determined to be higher than in 2020 in the current study. This is most likely due to fertilizer that was used throughout the growing season as well as fertilizer that was left in the soil the previous year. The N content of plants was sufficient according to the Baloch and Baloch (2004), classification (1.4-4.39%). However, excessive use of chemical fertilizers can cause N leaching, acidification of soil, decrease in soil organic matter and carbon losses in soil (Lin *et al.*, 2019).

The effect of chemical fertilizer and farmyard manure applications on plant phosphorus (P) content was similar in the 2020-2021 cotton-growing season. However, the small difference is largely dependent on soil conditions (pH, P content of fertilizers used). Phosphorus is an important plant nutrient for crop productivity (Zhang *et al.*, 2016). The lowest P content in plant samples (0.06%) was obtained in 0 kg ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ and the highest P content (0.10%) was obtained in 60 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application in both cotton-growing seasons. The amount of available P in cotton plants was quite low and considered as poor (Güner, 1968). The study revealed that farmyard manure application increased the available P content. Similarly, Tesfaye *et al.* (2021) stated that available soil P content increased with the application of organic residues to soil. Most of P applied to soil is fixed depending on soil and climate characteristics. The P content of cotton plants was insufficient according to the Baloch and Baloch (2004) classification (0.15 - 0.67%). Available P content in soil solution is very low, usually less than 1% of the total P content. More than 80% of soil P becomes immobile due to adsorption, fixation and conversion of P to organic forms; therefore, plant uptake of soil P becomes very difficult (Van Vuuren *et al.*, 2010).

Application of farmyard manure to soil had a positive effect on potassium (K) content of soils. Potassium regulates opening and closing of stomata, especially in arid and semi-arid climates, as in all climatic conditions. Therefore, K deficiency limits plant growth and causes serious yield losses. The lowest (0.31%) K contents were recorded in 0 kg ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ in the 2020-2021 growing period and highest (0.59%) K contents were recorded in 60 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application in the 2021 season. According to the IFA (2009) classification, the K content of cotton plants is insufficient (1.5 - 3.0%). However, application of 60 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ increased the available K content compared to other applications (Amadou *et al.*, 2020). It was concluded that applying farm farmyard manure to the soil could result in an increase in plant K content.

Weak acids released by the decomposition of farm farmyard manure dissolve the lime and cause the release of Ca into soil solution. In addition, Ca⁺² content in soils increases with high lime content which induced shrinkage of the electrical double layer and flocculation. According to the IFA (2009) classification, the Ca content of cotton plants is high (2.0-3.0%). The application of farmyard manure to soil partially lowered soil pH, caused dissolution of CaCO₃ and release of calcium (De Vries and Breeuwsma, 1987). There was no significant difference in the calcium content of the plants in both growing seasons. However, the plant's

calcium content was found to be somewhat higher in the 2021 growing season than in the 2020 growth season. Farmyard manure application decreases soil pH for a short time. Low soil pH can cause dissolution of CaMgCO_3 and increases the availability of Ca and Mg ions (De Vries and Breeuwsma, 1987).

There was no significant difference between the two growing periods in terms of Mg content of the plant. However, it was found to be partially high in the 2021 season. This can be explained by the high mg content of the soil. High CaMgCO_3 content of soils had a positive effect on the Ca^{+2} and Mg^{+2} contents of soils. Magnesium is a divalent cation; therefore, the electrical double layer affects it. The shrinkage of double layer causes an increase in Mg content. According to the IFA (2009) classification, Mg content of cotton plants is sufficient (0.3-0.9%). Farmyard manure application decreases soil pH for a short time. Low soil pH can cause dissolution of CaMgCO_3 and increases the availability of Ca and Mg ions (De Vries and Breeuwsma, 1987).

Iron (Fe) content of farmyard manure was high, therefore, Fe content of soils in which farmyard manure applied, increased compared to the control. In terms of the Fe content of the plant, there was no significant variation between the two growing periods. However, in the 2021 season, it was shown to be somewhat high. This problem is assumed to be caused by the addition of farm farmyard manure to the soil. Farmyard manure contributes macro and micro nutrient contents of soils (Effron *et al.*, 2004). The highest positive effect on Fe content was recorded in 60 Mg farmyard manure ha^{-1} + top dressing 200+150 kg urea ha^{-1} applications. The lowest Fe content (1.65 mg kg^{-1}) was obtained in the control and the highest Fe content (4.38 mg kg^{-1}) was recorded in 60 Mg farmyard manure ha^{-1} + 200+150 kg urea ha^{-1} application in the 2021 growing period. According to the IFA (2009), classification, the Fe content of cotton plants was insufficient (50-200 mg kg^{-1}). Iron is an essential element for photosynthesis and chlorophyll synthesis in plants. Therefore, the presence of sufficient Fe in soil affects the distribution, yield and quality of plant species in natural ecosystems.

There was no significant difference between the two growing periods in terms of the Zn content of the plant. However, it was seen to be partially high in the 2021 season. This situation is thought to be caused by farm farmyard manure added to the soil. Farm farmyard manure's delayed breakdown allows plant nutrients to be released gradually and absorbed by plants (Albuquerque *et al.*, 2014). High soil reactions, high lime content and low soil water content in arid and semi-arid climatic regions adversely affect Zn uptake of plants. However, some of these disadvantages can be eliminated with the farmyard manure application (Effron *et al.*, 2004). According to the IFA (2009) classification, the Zn content of cotton plant is insufficient (20-200 mg kg^{-1}).

Copper (Cu) binds strongly to clay minerals and organic compounds. Therefore, it is thought that this may cause the plant to have a low copper content. Copper content increased in farm farmyard manure applied plots compared to control, but the highest increase was determined in 300 kg DAP ha^{-1} + 200+150 kg urea ha^{-1} application in the 2021 growing season. The results suggested that the organic residues may have formed a strong bond with Cu (Ugulu *et al.*, 2020). According to the IFA (2009) classification, the Cu content of cotton plants is insufficient (5-25 mg kg^{-1}). Many agricultural soils have low Cu content (McLaren *et al.*, 1990). The low copper content may be due to the strong binding of Cu to clay complexes and organic compounds in soils (Bolan *et al.*, 2003).

Available manganese (Mn) content of soils is affected by soil pH, organic matter content, soil moisture and aeration. Soil aeration is high in farmyard manure applied plots; therefore, available Mn content is high in farmyard manure amended soils. Organic residues had a positive effect on Mn uptake of plants. In both growing seasons, no significant difference was determined in terms of the Mn content of the plant. According to the IFA (2009) classification, the Mn content of cotton plants is insufficient (25-300 mg kg^{-1}). Insufficient Mn content in plots other than farmyard manure applied ones may be due to the inability of plants to uptake sufficient Mn, insufficient contact between root and soil (Passioura and Leeper, 1963) or adverse soil and environmental conditions that limit the development of root system and limit soil volume that plant can uptake Mn. Other elements may also have an impact on the deficiency of Mn (Hossner and Blanchar, 1970).

Soil organic matter

Most of the chemical fertilizers applied to soil cause a decrease in organic matter content of soils, while organic matter content increases with the application of farmyard manure. Continuous and excess application of chemicals to soil deteriorates physical, chemical and biological properties of soils and adversely affects quality of soils. Therefore, soil organic matter is an important indicator of soil health. Appropriate organic matter management should be developed to mitigate growing concerns about the sustainability of soil health. Application of farmyard manure increases soil organic matter. (Bhattacharyya *et al.*, 2003; Lehmann and Kleber, 2015; Angst *et al.*, 2019; Gross and Glaser, 2021). Organic matter increased significantly in the 40 Mg farm yard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ application in the 2021 growing season. In addition, soil organic matter is important for adapting to and mitigating adverse impacts of climate change (Sakin, 2016; Gross and Glaser, 2021). With short-term treatments, the increase of organic matter is minimal. As a result, there was little difference between the two periods of growth. The collection and continuation of organic matter takes a long time.

Cotton yield

The yield of seed cotton is a crucial part of the cotton crop, which normally depends on a number of variables such soil fertility, environmental factors, and crop management techniques (Wang *et al.*, 2014). The results of the present study demonstrated that the growth, morphological, and yield-related characteristics of cotton were significantly enhanced by the application of farmyard manure in combination with chemical fertilizers (Ahmad *et al.*, 2021; Beyyavaş *et al.*, 2022). Various other studies have reported improvement in these parameters (cotton and fiber yield) with the use of farm manure in combination with chemical fertilizers.

Fiber yield

In the study, the highest yield was determined in the parcel where farm manure was applied. Farm manure improves the physical, chemical and biological structures of soils. It prevents the leaching of plant nutrients from the soil, making it easier for the plant to take it (Cevheri *et al.*, 2022). Martínez-López *et al.* (2014) found in the organic cotton production study that the highest seed yield was obtained from 8 tone ha⁻¹ farm yard manure dose and that the yield increased with the increase in the dose of farm yard manure. Cevheri *et al.* (2022), state that organic fertilizers increase fiber yield is in line with our study.

Catalase enzyme activity (CAT)

Catalase enzyme, which is a biological index, enables the release of nutrients and converting them into available forms. High alkalinity and lime content of soils caused higher catalase enzyme activity (CAT). The CAT activity was high in 0 kg ha⁻¹ bottom fertilizer + top dressing 200+150 kg urea ha⁻¹ application in the 2021 growing season. The CAT decomposes peroxide, which is released from metabolic events in soils, so that peroxide does not cause any harmful negative effects on soil microorganisms and takes part in important nutrient (C, N, P) cycles (García and Hernández, 1997). The CAT is closely related to soil aeration. High clay content of experimental soil caused low CAT in the control group (Xu *et al.*, 2021; Sakin *et al.*, 2021).

Urease enzyme activity (UA)

There was no significant difference in urease enzyme activity between the two growth periods (2020-2021) in the current investigation. Urea in farmyard manure and chemical fertilizers cannot be directly uptaken by plants. The urea must be hydrolyzed for a long time to be transformed into an available form. Urease enzyme hydrolyzes urea and converts the urea into available form in a shorter time. Therefore, urease enzyme is needed to reduce the hydrolysis time in agricultural soils. Urease activity increased in farmyard manure applied plots. Organic and chemical fertilizers are energy sources for microorganisms in soils. Therefore, microorganism and enzyme activities in fertilizers applied plots increased (Sakin *et al.*, 2021; Cevheri *et al.*, 2022; Ramazanoglu,

2023). The decomposition and degradation of organic fertilizers in soils take place under natural conditions. However, urease enzyme activity increases with the co-application of chemical fertilizers and farmyard manure. High urease enzyme activity in chemical fertilizer + farmyard manure (40 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹) application can be attributed to the aforementioned fact (Pramanik *et al.*, 2007; Brassard *et al.*, 2018; Karmegam *et al.*, 2019; Xu *et al.*, 2021; Sakin *et al.*, 2021; Sakin *et al.*, 2021).

Dehydrogenase enzyme activity (DHG)

In terms of dehydrogenase enzyme activity, there is no substantial difference between the two growth seasons. DHG activity, on the other hand, was shown to be higher in the 2020 growing season. The responses of living organisms in fertilizers applied to soil was different, which is due to the physico-chemical properties of fertilizers used. Soft-hardness and C content of organic material affect the dehydrogenase enzyme activity (DHG) in soils. The DHG increased by 191% with the applications. The results showed that 40 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ was the appropriate dose to obtain high DHG. Farmyard manure application increased the microbial activity in the soil compared to chemical fertilizers; thus, it also increased the DHG. The DHG in soils depends on various factors such as organic matter, soil colloids, clay and environmental factors (Mcclung and Frankenberger, 1985). The DHG is one of the soil fertility factors and a measure of biological activity (Meena and Rao, 2021). Dehydrogenases perform a wide variety of oxidative activities responsible for decomposition, i.e., dehydrogenation of organic matter (Włodarczyk *et al.*, 2002). The mean value of DHG in soils had a high and positive correlation with organic matter content (Camiña *et al.*, 1998). In this context, DHG is closely related to the release of CO₂ from soils (Ross, 1971).

Alkaline phosphatase activity (APA)

Alkaline phosphatase activity (APA) acts as a key to the organic phosphorus mineralization potential of soils. The APA depends on soil organic matter, organic and inorganic P, clay type, soil pH, lime content, climate, soil and topography conditions. The APA has high variability due to the aforementioned factors. The application of N, P and K fertilizers increases APA in soils (Khan, 1970). However, the APA was higher in 200 kg DAP ha⁻¹ + top dressing 200+150 kg Urea ha⁻¹ urea treatment in the 2021 growing season. This may be due to the new fertilizer added together with the DAP fertilizer applied last year. Fauci and Dick (1994) indicated that organic improves promote soil enzyme activities. The response of phosphatase activity was positive in chemical fertilizers treatments compared to the farmyard manure due to the alkalinity nature of soils studied. The result may be attributed to the acid character of the urea which lowers the pH in plant root zone for a short time. Optimal phosphatase enzyme activity in soils occurs at neutral pH. (Juma and Tabatabai, 1977; Meena and Rao, 2021). In the present study, the effects of fertilizers applied on enzyme activity were significantly positive (Cevheri *et al.*, 2022). Perucci (1990) and Xu *et al.* (2021) stated that the application of different agricultural wastes into the soils caused significant differences in enzyme activity.

SPAD value

SPAD is a commonly used physiological properties of plants. The SPAD varies with the environmental factors and characteristics of the varieties, however, the SPAD provides valuable information on net photosynthesis rate of a plant (Fisher *et al.*, 2017). The SPAD values of plants in farmyard manure treated soil was high (41.37). The yield obtained in the same plots was also high (5147 kg ha⁻¹). The results revealed the yield-SPAD relationship (Soltani and Gaeshi, 2002). Therefore, the SPAD values can be used to estimate crop yield. The SPAD values increased with the decrease in N content of soils. In other words, the increase in N content of soils decreased the SPAD value of plants (Feibo *et al.*, 1998). The results revealed that SPAD measurements could partially give information about the N content of plants. Xiong *et al.* (2015) reported a linear relationship between SPAD and N content, and stated that SPAD values vary with environmental factors.

Vegetation Index NDVI (Normalized Difference Vegetation Index)

SPAD, which is one of the physiological properties of the plant, is one of the properties used recently. Although it varies according to the environment and varieties, it gives the net photosynthesis rate of the plant (Fisher *et al.*, 2017). The lands should be regularly monitored and the field conditions should be examined to ensure NDVI used efficiently in agricultural cultures. This index is actively used to determine land cover, monitor agricultural lands, investigate temporal changes and predict crop yield (Singh *et al.*, 2002; Bognár *et al.*, 2004; Prasad *et al.*, 2006). The highest vegetation index in the present study was determined in 40 Mg farmyard manure ha⁻¹ + top dressing 200+150 kg urea ha⁻¹ treatment in the 2021 growing season. The yield (5147 kg ha⁻¹) obtained in plots with high SPAD value was also high. According to the results obtained, the yield-SPAD relationship was also revealed (Soltani and Galeshi, 2002).

Conclusions

Infertility in the soil is a serious issue all over the world. To improve soil fertility, a variety of organic and chemical fertilizers are used. In this study, we applied chemical fertilizer and farmyard manure to improve soil fertility and cotton plant growth. All morphological measures reached their maximum values after FM therapy. Micronutrient concentrations in all sections of the cotton specimens were higher in farmyard manure applications than in control applications, according to the current data. This could be owing to farmyard manure's higher micronutrient content. Because farmyard manure has a high organic matter content, it improved the chemical, physical, and biological aspects of the soil and provided more sites for cation exchange. As a result, the availability of N, Cu, and Zn on farmyard manure treatments was higher when compared to other treatments. The activities of urease and dehydrogenase from soil enzymes were elevated after farm farmyard manure was applied. Farm farmyard manure application is a good management strategy for enhancing soil biology activity as measured by enzyme activity. The use of farm farmyard manure had a good impact on the plant's physiological parameters. We discovered that the highest dose used in this trial was insufficient. We couldn't observe the maximum point for cotton yield since we couldn't see it. As a result, future investigations will need to apply higher doses to find the maximum point.

Authors' Contributions

Conceptualization, Data curation; Formal analysis, Investigation; Methodology: ER, VB and CİC; Methodology, Resources, Software, VB, ES and SNY, Writing - original draft: ER, ES, VB and CİC, Writing - review and editing: ER, CİC, VB and ES. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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