

Communications in Soil Science and Plant Analysis

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/lcss20

Impact of Organic Materials (Tea Waste and Farm Manure) on Yield, Protein Content, Fiber Fractions, and Mineral Composition of Tea Plants in an Organic System

Adil Bakoğlu & Muhammed İkbal Çatal

To cite this article: Adil Bakoğlu & Muhammed İkbal Çatal (2025) Impact of Organic Materials (Tea Waste and Farm Manure) on Yield, Protein Content, Fiber Fractions, and Mineral Composition of Tea Plants in an Organic System, Communications in Soil Science and Plant Analysis, 56:8, 1232-1246, DOI: 10.1080/00103624.2025.2452172

To link to this article: https://doi.org/10.1080/00103624.2025.2452172

Published online: 16 Jan 2025.

Submit your article to this journal

Article views: 66

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=lcss20

COMMUNICATIONS IN SOIL SCIENCE AND PLANT ANALYSIS
2025, VOL. 56, NO. 8, 1232–1246
https://doi.org/10.1080/00103624.2025.2452172

Taylor & Francis
Taylor & Francis Group

Check for updates

Impact of Organic Materials (Tea Waste and Farm Manure) on Yield, Protein Content, Fiber Fractions, and Mineral Composition of Tea Plants in an Organic System

Adil Bakoğlu[a] and Muhammed İkbal Çatal[b]

[a]Pazar Vocational High School, Department of Crop and Animal Production, Recep Tayyip Erdoğan University, Rize, Türkiye; [b]Faculty of Agriculture, Department of Field Crops, Recep Tayyip Erdoğan University, Rize, Türkiye

ABSTRACT

This study aimed to investigate the effects of organic materials and fertilizers on tea plant yield and quality in an organic tea garden in Türkiye. The objective was to identify sustainable alternatives to synthetic fertilizers that could enhance tea production while maintaining or improving nutritional quality. A two-year field study (2019–2020) was conducted in an organic tea garden in Pazar, Rize, Türkiye, to assess the impacts of various organic materials on tea plant yield and quality. A Randomized Complete Block Design with split-split plots was employed, with three organic materials (Control, Farm Manure, Tea Waste) as main plots, five organic fertilizers (Control, Organoferm, Neobioplus, Bionur, Orbitosol) as subplots, and three harvest times as sub-sub plots. The study analyzed fresh and dry yield, protein content, cell wall components (Acid Detergent Fiber [ADF] and Neutral Detergent Fiber [NDF] representing indigestible fiber fractions, and Acid Digestible Protein [ADP] indicating protein availability), and macroelements (Phosphorus [P], Potassium [K], Calcium [Ca], and Magnesium [Mg]). Tea waste significantly enhanced protein content, yield, and phosphorus levels, while farm manure increased fresh and dry yields, as well as potassium and magnesium concentrations. Organoferm fertilizer improved most quality parameters except for calcium and magnesium. Results indicated that organic amendments, particularly farm manure, tea waste and Organoferm fertilizer, can be effective in improving tea plant yield and nutritional quality, offering a sustainable alternative to synthetic fertilizers.

ARTICLE HISTORY
Received 4 April 2024
Accepted 7 January 2025

KEYWORDS
Farm manure; organic tea garden; quality; tea waste; yield

Introduction

Tea (*Camellia sinensis* L.) is a perennial shrub belonging to the *Theaceae* family. Thriving in humid climates, it exhibits high branching ability and evergreen characteristics. The leaves and buds of this plant are processed to produce various tea beverages. However, *Camellia sinensis* is selective in its climatic requirements and demonstrates significant sensitivity to agricultural practices impacting yield and quality (Nath 2014; Özdemir, T, and Durmuş 2020). In Türkiye, tea ranks as the second most consumed beverage after water. This highlights the importance of optimizing cultivation practices to ensure sustainable production of high-quality tea.

Tea cultivation holds significant global importance as a major source of income and livelihood for millions, particularly in developing countries. It plays a crucial role in the global beverage market and is deeply intertwined with cultural practices worldwide. Tea cultivation in Türkiye is primarily concentrated in the coastal regions of the Black Sea, particularly in the provinces of Rize, Artvin, and Trabzon. These areas offer a unique combination of climatic and geographical conditions that are

CONTACT Muhammed İkbal Çatal muhammed.catal@erdogan.edu.tr Faculty of Agriculture, Department of Field Crops, Recep Tayyip Erdoğan University, Rize 53300, Türkiye

© 2025 Taylor & Francis Group, LLC

ideal for tea production, including abundant rainfall, mild temperatures, and fertile soils. The region's steep topography often necessitates terraced cultivation, which is labor-intensive but helps to prevent soil erosion. Economically, tea cultivation is the backbone of the regional economy, providing employment to a significant portion of the population. The tea industry has not only stimulated local economic growth but has also shaped the cultural identity of the region, making tea an integral part of Turkish society. However, challenges such as aging tea plantations, climate change, and competition from other tea-producing countries have posed significant threats to the sustainability of the tea industry in Türkiye.

Historically, tea production in the Eastern Black Sea Region has relied on organic inputs such as farm manure and tea waste for soil conditioning. However, the widespread use of Ammonium Sulfate ((NH4)2SO4) fertilizer has led to a significant decrease in soil pH, often below the critical threshold of 4.5. This poses a substantial challenge as tea plants are inherently calcifuge, requiring high levels of available aluminum for optimal growth. The direct application of lime to increase soil pH is not a viable option, as it can render aluminum unavailable for plant uptake.

To effectively manage soil pH in tea plantations, a controlled program utilizing organic fertilizers, particularly farm manure, is recommended. However, limited animal husbandry practices in the region constrain the availability of sufficient farm manure. Consequently, alternative organic materials must be explored. Tea waste, a byproduct often discarded through burning or destruction, presents a promising opportunity. Rich in organic matter and essential minerals, tea waste can be effectively composted and utilized as a valuable organic fertilizer. Therefore, the practice of burning or discarding tea waste should be strictly prohibited and replaced with methods that promote its conversion into a sustainable soil amendment.

Farm manure has a long history of use in tea fertilization, and its positive effects on soil properties continue to be recognized. Manure application enhances soil structure, promoting both water holding capacity and permeability. Studies have shown that manure-treated soils can absorb nearly double the amount of water compared to untreated soils (Mazurak, Cosper, and Rhoades 1955). This improved water retention capacity reduces runoff and subsequent soil erosion. Furthermore, manure plays a crucial role in soil tilth. In sandy soils, manure aggregates particles, facilitating easier tillage. Conversely, in clay soils, manure loosens tightly bound particles, creating a more porous structure. These improvements in soil structure benefit plant growth by promoting root development and aeration. Additionally, the organic matter content of manure contributes to increased soil darkness, which can help regulate soil temperature to a more plant-favorable range (Kacar 2010).

This study aimed to address the critical gap in the literature concerning the comparative efficacy of diverse organic materials in enhancing crop yield and quality. While farm manure and commercial organic fertilizers have been extensively studied, the potential of unconventional organic resources, such as used tea leaves, remains largely unexplored. By directly comparing these materials, this research sought to identify novel and sustainable alternatives to conventional agricultural practices. The findings from this study are expected to contribute significantly to the development of more precise and environmentally friendly agricultural strategies, ultimately leading to increased agricultural productivity and improved product quality.

Materials and method

Study area

The research was conducted in a tea plantation situated in Derinsu village, Pazar district, Rize Province, Türkiye. The study area has an average elevation of 305 meters above sea level (N: 41°05′ 36″; E: 40°52′45″) and is located 13 kilometers from the district center. The specific location and representative photographs of the study site are presented in Figure 1. The tea plantation underwent pruning two years prior to the study and had completed the organic certification process, transitioning fully to organic farming practices.

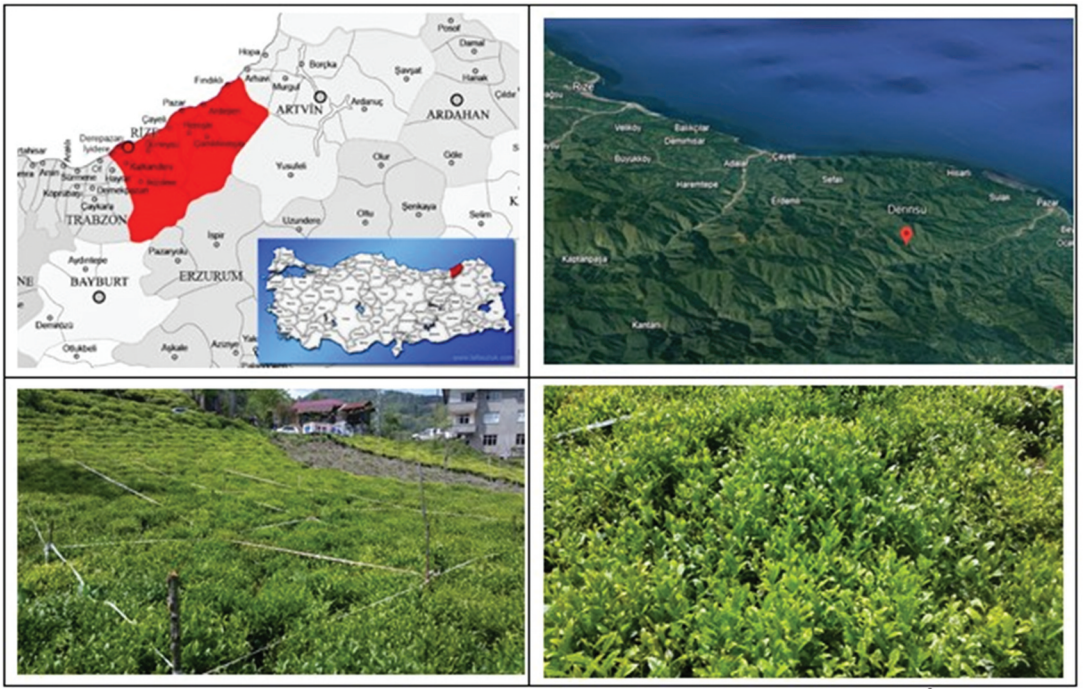


Figure 1. Location of the study area and photographs taken from the study area.

Soil analysis indicated a clayey texture with a saturation rate of 75.30%. Lime content was 0.26%, and salinity was 0.17 decisiemens per meter (dS/m). Soil reaction (pH) was 5.14. Organic matter content was 2.17%, while phosphorus (P2O5) and potassium (K2O) contents were 17.52 mg kg-1 and 115.05 mg kg-1, respectively.

From 1964 to 2018, the total precipitation in the research area was 2243.7 mm, followed by 1889.2 mm in 2019 and 1763.3 mm in 2020. The average temperature followed a similar trend, with values of 14.4°C, 16.0°C, and 15.8°C for the respective years. Likewise, the average relative humidity exhibited a similar pattern, recording 76.5%, 81.7%, and 78.8% (Anonymous 2021).

Method

The study employed a split-split plot design in randomized blocks with three replicates during 2019 and 2020. The main plots consisted of organic materials (Control, Farm manure, Tea Waste), subplots consisted of organic fertilizer applications (Control, Organoferm, Neobioplus, Bionur, and Orbitosol), and sub-subplots were harvest times (1st, 2nd, and 3rd) (Table 1).

In the first year of the study, organic materials (Control, Farm manure, and Tea waste) were applied to the main plots at a rate of 50 t ha^{-1}. No organic material was applied to the control plots. Organic

Table 1. Applications made in the experiment.

Organic Material (Main plot)	Organic Fertilizer (Sub plot)	Harvest (Sub-sub plots)
Control	Control	1. Harvest
Farm manure	Orbitosol	2. Harvest
Tea waste	Bionur	3. Harvest
	Neobioplus	
	Organoferm	

fertilizers (Control, Orbitosol, Bionur, Neobioplus, and Organoferm) were applied to the subplots at a rate of 1500 kg ha^{-1} in April of each year. The harvest was conducted at three time points (1st harvest, 2nd harvest, and 3rd harvest) within the subplots.

Fresh green tea leaves were harvested and dried at 60°C. Dry matter content and dry yield were then determined. The dried samples were ground in a 1 mm sieve diameter mill and prepared for further analysis. A Foss NIRSystems Model 6500 Win ISI II v1.5 device was used to determine crude protein, cell wall components (Acid Detergent Fiber [ADF], Neutral Detergent Fiber [NDF], and Acid Detergent Protein [ADP]), and macroelements (Phosphorus [P], Potassium [K], Calcium [Ca], and Magnesium [Mg]). The widely used calcium to phosphorus [Ca/P] and potassium to the sum of calcium and magnesium [K/(Ca+Mg)] ratios were also calculated for each sample.

We performed a variance analysis on the data using JMP 13 (SAS Institute Inc., Cary, NC, USA). Mean values of treatments with significant differences ($p < .05$) identified by the F-test were further compared using Tukey's Honestly Significant Difference (HSD) test.

Results and discussion

Data and statistical results for this study on the tea plant are presented in Table 2. Correlation analyses of the investigated properties are provided in Table 3.

Fresh yield averaged 8001.29 kg/ha (Table 2). The lowest and highest values, along with their significance levels, are presented for: organic material (7732.78–8173.89 kg/ha; Control – Farm manure; $p < .05$); organic fertilizer (6954.62–8784.25 kg/ha; Control – Organoferm; $p < .001$); interaction between organic material and organic fertilizer (6355.56–9077.78 kg/ha; Control*Control – Farm manure*Organoferm; $p < .05$); harvest (6718.89–9047.78 kg/ha; 3rd Harvest – 1st Harvest; $p < .001$); interaction between organic material and harvest (5805.00–9448.33 kg/ha; Control * 3rd Harvest – Control * 1st Harvest; $p < .001$); interaction between organic fertilizer and harvest (5836.11–9705.56 kg/ha; Control * 3rd Harvest – Organoferm * 1st Harvest; $p < .05$); and the three-way interaction between organic material, organic fertilizer, and harvest (4541.67–10375.00 kg/ha; Control*Control*3rd Harvest – Control*Organoferm *1st Harvest; $p < .01$).

The average Dry matter content across all treatments was 86.94%. Statistical analysis revealed no significant differences (ns) between the dry matter content of organic materials (86.89–86.99%, Farm manure – Tea waste), organic fertilizers (86.82–87.05%, Orbitosol – Bionur), or their combinations (86.73–87.17%, Farm manure*Orbitosol – Tea waste*Bionur). However, a significant difference ($p < .05$) was observed in dry matter content between harvests (86.77–87.22%, 1st Harvest – 3rd Harvest). No significant interactions were detected between organic material type, fertilizer type, and harvest time (ns).

The average Dry yield was 6955.60 kg/ha. Significant effects of organic material, organic fertilizer, harvest, and their interactions were observed ($p < .05$ or $p < .001$). The lowest and highest dry yield values were found with organic material amendment (6722.18–7102.13 kg/ha), organic fertilizer application (6042.03–7637.62 kg/ha), at the harvest (5861.62–7854.37 kg/ha), and for the interaction between organic material and harvest (5062.38–8204.84 kg/ha), organic fertilizer and harvest (5087.81–8425.74 kg/ha), and organic material, organic fertilizer and harvest (3959.25–9002.13 kg/ha).

The average Protein content across all samples was 17.14%. Statistical analysis revealed significant differences in protein content based on several factors ($p < .05$). Organic material source (Control vs. Tea waste) significantly impacted protein content (16.40% – 18.34%, $p < .001$). Similarly, the type of organic fertilizer used (Orbitosol vs. Bionur) resulted in significant variations (16.26% – 17.67%, $p < .001$). The interaction between organic material source and fertilizer type also showed a significant effect (15.20% – 19.11%, $p < .01$). Harvest time significantly influenced protein content, with the 3rd harvest having the highest values (15.48% – 19.33%, $p < .001$). Interestingly, the interaction between organic material source and harvest time did not yield statistically significant results (ns). However, the interaction between fertilizer type and harvest time showed significant differences (14.59% – 20.69%, $p < .001$). Finally, the three-way interaction between organic material source, fertilizer type, and harvest time produced significant variations in protein content (13.57% – 21.77%, $p < .05$).

Table 2. Yield and some quality characteristics of tea plant.

VARITAION SOURCES	VARITAION SOURCES	Fresh Yield (kg/ ha)	Dry Matter Ratio (%)	Dry Yield (kg/ ha)	Protein Ratio (%)	Protein Yield (kg/ ha)	ADF(%)	NDF (%)	ADP (%)	P (%)	K (%)	Ca (%)	Mg (%)	Ca/P	K/(Ca +Mg)
	ORGANIC MATERIAL	*	ns	**	***	***	ns	ns	ns	*	*	ns	**	*	**
	ORGANIC FERTILIZER	***	ns	***	***	***	***	***	ns	***	*	ns	**	***	ns
	ORGANIC MATERIAL.* ORGANIC FERTILIZER	*	ns	*	**	ns	**	ns	ns	ns	ns	ns	ns	*	ns
	HARVEST	***	*	***	***	***	***	***	***	***	***	ns	***	***	***
	ORGANIC MATERIAL.*HARVEST	***	ns	***	ns	***	*	*	ns	ns	ns	ns	***	ns	ns
	ORGANIC FERTILIZER.* HARVEST	*	ns	*	***	*	*	***	ns	ns	**	ns	***	ns	ns
	ORGANIC MATERIAL*ORGANIC FERTILIZER*HARVEST	**	ns	**	*	ns	***	***	ns	ns	ns	ns	*	ns	ns
ORGANIC MATERIAL	ORGANIC MATERIAL	Fresh Yield *	Dry Matter Ratio	Dry Yield **	Protein Ratio***	Protein Yield***	ADF	NDF	ADP	P *	K *	Ca	Mg **	Ca/P *	K/(Ca +Mg) **
	CONTROL	7732.78 b	86.93	6722.18 b	16.40 b	1130.68 b	32.30	50.91	1.38	0.27 b	1.88 b	1.80	0.068 a	6.56 a	1.02 b
	FARM MANURE	8173.89 a	86.89	7102.13 a	16.67 b	1203.86 b	32.47	50.91	1.39	0.28 ab	1.96 a	1.77	0.073 a	6.37 ab	1.07 a
	TEA WASTE	8097.22 a	86.99	7042.50 a	18.34 a	1297.86 a	32.49	50.85	1.39	0.30 a	1.89 b	1.76	0.061 b	6.07 b	1.04 a
ORGANIC FERTILIZER	ORGANIC FERTILIZER	Fresh Yield ***	Dry Matter Ratio	Dry Yield ***	Protein Ratio***	Protein Yield***	ADF ***	NDF ***	ADP	P ***	K *	Ca	Mg **	Ca/P ***	K/(Ca +Mg)
	CONTROL	6954.62 b	86.90	6042.03 b	17.26 a	1059.37 b	31.91 b	50.12 b	1.38	0.29 a	1.92 ab	1.78	0.066 ab	6.35 b	1.05
	ORBITOSOL	7324.07 b	86.82	6358.69 b	16.26 b	1053.76 b	32.22 ab	51.07 ab	1.39	0.27 b	1.94 a	1.81	0.074 a	6.70 a	1.04
	BİONUR	8390.74 a	87.05	7305.34 a	17.67 a	1306.77 a	32.44 ab	49.92 b	1.38	0.29 a	1.85 b	1.76	0.068 ab	6.17 b	1.02
	NEOBİOPLUS	8552.78 a	86.96	7434.33 a	17.34 a	1309.27 a	32.71 a	50.58 b	1.40	0.29 a	1.90 ab	1.77	0.070 a	6.25 b	1.04
	ORGANOFERM	8784.25 a	86.94	7637.62 a	17.16 a	1324.84 a	32.82 a	52.78 a	1.39	0.29 a	1.93 a	1.77	0.060 b	6.21 b	1.06
ORGANIC MATERIAL * ORGANIC FERTILIZER	ORGANIC MATERIAL * ORGANIC FERTILIZER	Fresh Yield *	Dry Matter Ratio	Dry Yield *	Protein Ratio**	Protein Yield	ADF **	NDF	ADP	P	K	Ca	Mg	Ca/P *	K/(Ca +Mg)
	CONTROL * CONTROL	6355.56 g	86.90	5522.02 e	15.92 ef	900.23	32.20 bc	51.35	1.39	0.27	1.91	1.82	0.066	6.81 ab	1.02
	CONTROL* ORBITOSOL	7250.00 d-g	86.93	6298.94 cde	15.20 f	979.22	32.11 bc	51.28	1.39	0.27	1.92	1.84	0.068	7.01 a	1.02
	CONTROL * BİONUR	8372.22 abc	87.04	7291.40 ab	17.21 bcd	1280.65	32.39 bc	50.00	1.36	0.29	1.81	1.76	0.072	6.19 bcd	1.00
	CONTROL * NEOBİOPLUS	8113.89 bcd	86.93	7051.12 abc	17.13 cde	1239.39	32.40 bc	50.39	1.38	0.28	1.86	1.78	0.074	6.37 bcd	1.01
	CONTROL * ORGANOFERM	8572.22 ab	86.85	7447.41 a	16.56 de	1253.91	32.42 bc	51.52	1.39	0.29	1.93	1.80	0.062	6.41 a-d	1.04
	FARM MANURE * CONTROL	7100.00 fg	86.91	6169.37 de	16.77 de	1046.88	31.33 c	49.86	1.35	0.28	2.02	1.78	0.077	6.41 a-d	1.09
	FARM MANURE * ORBITOSOL	7147.22 efg	86.73	6200.28 cde	16.21 def	1030.50	31.95 bc	51.44	1.38	0.27	1.95	1.82	0.080	6.76 abc	1.03
	FARM MANURE * BİONUR	8716.67 ab	86.93	757.83 a	17.39 bcd	1329.61	32.37 bc	49.97	1.38	0.29	1.89	1.76	0.077	6.13 d	1.03
	FARM MANURE * NEOBİOPLUS	8827.78 ab	86.92	7670.13 a	16.43 def	1280.16	32.96 ab	51.28	1.42	0.28	1.97	1.77	0.068	6.41 a-d	1.08
	FARM MANURE * ORGANOFERM	9077.78 a	86.94	7892.53 a	16.53 de	1332.16	33.74 a	52.03	1.42	0.29	1.96	1.74	0.066	6.16 cd	1.09
	TEA WASTE * CONTROL	7408.33 def	86.90	6434.71 cd	19.11 a	1231.00	32.19 bc	49.14	1.40	0.31	1.85	1.75	0.057	5.82 d	1.04
	TEA WASTE * ORBITOSOL	7575.00 c-f	86.81	6576.86 bcd	17.35 bcd	1151.55	32.61 abc	50.48	1.39	0.28	1.96	1.78	0.076	6.33 bcd	1.07
	TEA WASTE * BİONUR	8083.33 b-e	87.17	7046.28 abc	18.39 abc	1310.05	32.58 abc	49.80	1.40	0.30	1.85	1.78	0.055	6.18 cd	1.02
	TEA WASTE * NEOBİOPLUS	8716.67 ab	87.02	7581.74 a	18.47 ab	1408.26	32.76 ab	50.06	1.40	0.30	1.88	1.75	0.069	5.96 d	1.04
	TEA WASTE * ORGANOFERM	8702.78 ab	87.04	7572.91 a	18.38 abc	1388.45	32.31 bc	54.79	1.37	0.30	1.90	1.76	0.052	6.06 d	1.05

(*Continued*)

Table 2. (Continued).

VARITAION SOURCES	VARITAION SOURCES	Fresh Yield (kg/ha)	Dry Matter Ratio (%)	Dry Yield (kg/ha)	Protein Ratio (%)	Protein Yield (kg/ha)	ADF(%)	NDF (%)	ADP (%)	P (%)	K (%)	Ca (%)	Mg (%)	Ca/P	K/(Ca+Mg)
HARVEST	HARVEST	Fresh Yield ***	Dry Matter Ratio *	Dry Yield ***	Protein Ratio***	Protein Yield***	ADF ***	NDF ***	ADP ***	P ***	K ***	Ca	Mg ***	Ca/P ***	K/(Ca+Mg) ***
	1. HARVEST	9047.78 a	86.77 b	7854.37 a	19.33 a	1525.48 a	29.35 c	46.01 c	1.26 c	0.31 a	2.11 a	1.76	0.058 b	5.86 c	1.17 a
	2. HARVEST	8237.22 b	86.81 b	7150.81 b	16.60 b	1194.47 b	35.34 a	54.44 a	1.53 a	0.28 b	1.76 c	1.78	0.085 a	6.36 b	0.95 c
	3. HARVEST	6718.89 c	87.22 a	5861.62 c	15.48 c	912.45 c	32.57 b	52.23 b	1.38 b	0.27 c	1.85 b	1.78	0.061 b	6.78 a	1.01 b
ORGANIC MATERIAL * HARVEST	ORGANIC MATERIAL * HARVEST	Fresh Yield ***	Dry Matter Ratio	Dry Yield ***	Protein Ratio	Protein Yield***	ADF *	NDF *	ADP	P	K	Ca	Mg ***	Ca/P	K/(Ca+Mg)
	CONTROL *1. HARVEST	9448.33 a	86.79	8204.84 a	18.41	1519.81 a	29.55 c	45.51 c	1.26	0.30	2.09	1.78	0.050 d	6.08	1.15
	CONTROL *2. HARVEST	7945.00 de	86.81	6899.31 cd	16.25	1135.73 b	34.93 a	54.45 a	1.52	0.28	1.75	1.80	0.085 a	6.52	0.93
	CONTROL *3. HARVEST	5805.00 g	87.18	5062.38 f	14.56	736.51 c	32.43 b	52.77 ab	1.37	0.26	1.82	1.81	0.070 bc	7.08	0.97
	FARM MANURE * 1. HARVEST	9140.00 ab	86.72	7930.55 ab	19.05	1526.90 a	29.63 c	45.31 c	1.27	0.31	2.13	1.75	0.066 bc	5.87	1.18
	FARM MANURE * 2. HARVEST	8660.00 bc	86.79	7516.34 bc	16.11	1212.99 b	35.36 a	54.57 a	1.54	0.28	1.83	1.78	0.078 ab	6.42	0.98
	FARM MANURE * 3. HARVEST	6721.67 f	87.16	5859.49 e	14.83	871.70 c	32.42 b	52.86 ab	1.37	0.26	1.91	1.78	0.077 ab	6.83	1.03
	TEA WASTE * 1. HARVEST	8555.00 bcd	86.81	7427.73 bc	20.54	1529.74 a	28.88 c	47.22 c	1.24	0.32	2.12	1.75	0.058 cd	5.62	1.18
	TEA WASTE * 2. HARVEST	8106.67 cde	86.84	7036.77 cd	17.43	1234.70 b	35.72 a	54.30 a	1.53	0.29	1.72	1.77	0.090 a	6.15	0.93
	TEA WASTE * 3. HARVEST	7630.00 e	87.32	6663.00 d	17.06	1129.15 b	32.86 b	51.05 b	1.40	0.28	1.83	1.76	0.036 e	6.44	1.02
ORGANIC FERTILIZER.* HARVEST	ORGANIC FERTILIZER * HARVEST	Fresh Yield *	Dry Matter Ratio	Dry Yield *	Protein Ratio***	Protein Yield*	ADF *	NDF ***	ADP	P	K **	Ca	Mg ***	Ca/P	K/(Ca+Mg)
	CONTROL *1. HARVEST	8188.89 bc	86.78	7104.21 bc	18.82 bc	1345.36 c	28.79 e	44.96 d	1.25	0.30	2.06 ab	1.76	0.065 c-g	6.04	1.14
	CONTROL *2. HARVEST	6838.89 de	86.77	5934.08 de	16.10 efg	958.31 de	35.49 a	55.21 a	1.53	0.28	1.78 cde	1.80	0.076 bcd	6.45	0.95
	CONTROL *3. HARVEST	5836.11 f	87.16	5087.81 e	16.87 ef	874.45 de	31.44 cd	50.18 c	1.35	0.28	1.92 bc	1.77	0.060 d-g	6.55	1.05
	ORBITOSOL *1. HARVEST	8741.67 ab	86.67	7582.23 ab	18.51 bcd	1400.88 bc	29.28 e	45.43 d	1.23	0.29	2.12 a	1.76	0.064 c-g	5.98	1.18
	ORBITOSOL *2. HARVEST	7286.11 cd	86.67	6312.24 cd	15.67 fg	998.40 d	35.01 a	54.72 ab	1.56	0.27	1.84 cd	1.84	0.088 ab	6.87	0.96
	ORBITOSOL *3. HARVEST	5944.44 ef	87.13	5181.60 e	14.59 g	762.00 e	32.39 bc	53.05 abc	1.38	0.25	1.86 cd	1.83	0.072 b-e	7.25	0.98
	BİONUR *1. HARVEST	8988.89 ab	86.89	7818.41 ab	20.69 a	1631.70 a	29.06 e	43.46 d	1.26	0.33	2.14 a	1.77	0.066 c-f	5.64	1.17
	BİONUR *2. HARVEST	9044.44 ab	86.88	7857.22 ab	17.13 def	1346.01 c	35.56 a	54.07 ab	1.52	0.28	1.62 e	1.76	0.083 abc	6.23	0.89
	BİONUR *3. HARVEST	7138.89 d	87.38	6240.38 cd	15.17 g	942.60 de	32.70 bc	52.25 abc	1.37	0.27	1.79 cd	1.76	0.055 efg	6.63	0.99
	NEOBİOPLUS *1. HARVEST	9613.89 a	86.76	8341.27 a	19.58 ab	1629.27 a	29.45 e	44.96 d	1.27	0.32	2.11 a	1.75	0.051 fg	5.67	1.18
	NEOBİOPLUS *2. HARVEST	8908.33 ab	86.88	7738.44 ab	17.31 cde	1346.90 c	35.47 a	53.90 abc	1.53	0.29	1.75 de	1.78	0.096 a	6.25	0.94
	NEOBİOPLUS *3. HARVEST	7136.11 d	87.23	6223.29 cd	15.14 g	951.64 de	33.20 b	52.87 abc	1.40	0.26	1.85 cd	1.77	0.065 c-g	6.82	1.01
	ORGANOFERM *1. HARVEST	9705.56 a	86.77	8425.74 a	19.06 b	1620.21 ab	30.19 de	51.26 bc	1.27	0.31	2.12 a	1.77	0.046 g	5.94	1.18
	ORGANOFERM *2. HARVEST	9108.33 ab	86.85	7912.06 ab	16.77 ef	1322.73 c	35.16 a	54.29 ab	1.51	0.29	1.83 cd	1.75	0.081 abc	6.03	1.00
	ORGANOFERM *3. HARVEST	7538.89 cd	87.21	6575.04 cd	15.65 fg	1031.57 d	33.13 b	52.78 abc	1.40	0.27	1.84 cd	1.78	0.053 fg	6.65	1.00
ORGANIC MATERIAL * ORGANIC FERTILIZER * HARVEST	ORGANIC MATERIAL * ORGANIC FERTILIZER * HARVEST	Fresh Yield **	Dry Matter Ratio	Dry Yield **	Protein Ratio*	Protein Yield	ADF ***	NDF ***	ADP	P	K	Ca	Mg *	Ca/P	K/(Ca+Mg)
	CONTROL * CONTROL * 1. HARVEST	8266.67 b-k	86.84	7178.65 b-m	18.04 b-l	1296.62	28.53 no	44.77 h-m	1.23	0.30	2.07	1.79	0.048 e-k	6.17	1.13
	CONTROL * CONTROL * 2. HARVEST	6258.33 l-q	86.71	5428.16 m-q	15.15 k-p	822.69	34.92 a-e	55.34 ab	1.53	0.27	1.85	1.85	0.071 b-h	6.94	0.97
	CONTROL * CONTROL * 3. HARVEST	4541.67 q	87.14	3959.25 q	14.58 m-p	581.40	33.15 b-ı	53.94 a-e	1.41	0.26	1.81	1.82	0.079 a-g	7.33	0.96
	CONTROL * ORBITOSOL * 1. HARVEST	9383.33 a-f	86.80	8144.71 a-f	17.00 d-o	1381.83	30.40 ı-o	47.42 c-m	1.28	0.29	2.14	1.77	0.057 c-k	6.29	1.18
	CONTROL * ORBITOSOL * 2. HARVEST	6858.33 ı-p	86.68	5940.64 j-p	15.04 l-p	903.29	34.29 a-g	54.29 a-e	1.55	0.27	1.81	1.89	0.080 a-g	7.15	0.93
	CONTROL * ORBITOSOL * 3. HARVEST	5508.33 pq	87.30	4811.47 pq	13.57 p	652.55	31.65 f-n	52.14 b-ı	1.35	0.25	1.82	1.85	0.066 b-j	7.61	0.96

(*Continued*)

Table 2. (Continued).

VARITAION SOURCES	VARITAION SOURCES	Fresh Yield (kg/ ha)	Dry Matter Ratio (%)	Dry Yield (kg/ ha)	Protein Ratio (%)	Protein Yield (kg/ ha)	ADF(%)	NDF (%)	ADP (%)	P (%)	K (%)	Ca (%)	Mg (%)	Ca/P	K/(Ca +Mg)
	CONTROL * BİONUR *1. HARVEST	9033.33 a-g	86.85	7854.84 a-h	19.38 a-g	1544.62	29.05 l-o	44.27 j-m	1.23	0.31	2.11	1.77	0.059 b-k	5.98	1.17
	CONTROL * BİONUR *2. HARVEST	9866.67 a-d	86.94	8582.61 abc	17.41 c-o	1502.10	35.92 abc	54.05 a-e	1.52	0.29	1.53	1.75	0.089 a-d	6.13	0.84
	CONTROL * BİONUR *3. HARVEST	6216.67 l-q	87.35	5436.75 m-q	14.85 l-p	795.24	32.17 e-l	51.70 b-k	1.34	0.28	1.80	1.76	0.066 b-j	6.47	0.98
	CONTROL * NEOBİOPLUS *1. HARVEST	10183.33 ab	86.84	8843.89 ab	19.95 a-e	1753.02	29.29 k-o	44.25 j-m	1.26	0.32	2.04	1.77	0.041 g-k	5.70	1.13
	CONTROL * NEOBİOPLUS *2. HARVEST	7975.00 d-n	86.86	6925.33 c-n	17.09 d-o	1191.28	35.43 a-d	54.19 a-e	1.52	0.28	1.68	1.78	0.096 abc	6.37	0.89
	CONTROL * NEOBİOPLUS *3. HARVEST	6183.33 m-q	87.10	5384.15 n-q	14.36 op	773.88	32.50 d-j	52.75 a-g	1.36	0.26	1.86	1.79	0.084 a-e	7.03	0.99
	CONTROL * ORGANOFERM * 1. HARVEST	10375.00 a	86.66	9002.13 a	17.68 c-m	1622.94	30.48 i-o	46.84 d-m	1.29	0.30	2.09	1.81	0.044 f-k	6.25	1.13
	CONTROL * ORGANOFERM * 2. HARVEST	8766.7 a-ı	86.85	7619.82 a-k	16.55 f-p	1259.28	34.09 a-g	54.41 a-d	1.49	0.30	1.87	1.77	0.088 a-e	6.01	1.01
	CONTROL * ORGANOFERM * 3. HARVEST	6575.00 k-p	87.04	5720.29 l-q	15.45 j-p	879.50	32.70 d-j	53.32 a-f	1.41	0.27	1.83	1.83	0.054 d-k	6.98	0.98
	FARM MANURE * CONTROL *1. HARVEST	8150.00 c-m	86.75	7069.99 b-n	18.67 a-ı	1330.37	28.21 o	44.55 ı-m	1.21	0.30	2.17	1.76	0.083 a-f	6.04	1.19
	FARM MANURE * CONTROL *2. HARVEST	7025.00 h-p	86.82	6097.53 h-p	16.00 h-p	975.91	34.89 a-e	54.21 a-e	1.52	0.28	1.86	1.78	0.074 a-h	6.41	1.00
	FARM MANURE * CONTROL *3. HARVEST	6125.00 n-q	87.17	5340.60 n-q	15.63 ı-p	834.31	30.89 h-o	50.84 b-l	1.31	0.27	2.02	1.79	0.073 b-h	6.76	1.09
	FARM MANURE * ORBITOSOL * 1. HARVEST	8633.33 a-j	86.59	7484.29 a-l	18.46 b-j	1390.42	28.80 mno	45.20 g-m	1.24	0.30	2.11	1.75	0.066 b-j	5.97	1.16
	FARM MANURE * ORBITOSOL * 2. HARVEST	7191.67 g-p	86.67	6229.92 g-p	15.76 h-p	989.90	34.65 a-f	54.91 abc	1.53	0.27	1.84	1.86	0.084 a-e	7.06	0.95
	FARM MANURE * ORBITOSOL * 3. HARVEST	5616.67 opq	86.95	4886.63 opq	14.43 nop	711.19	32.39 d-j	54.20 a-e	1.40	0.26	1.90	1.84	0.089 a-d	7.25	0.99
	FARM MANURE * BİONUR *1. HARVEST	9116.67 a-g	86.88	7925.87 a-g	20.94 ab	1670.67	29.28 k-o	43.61 lm	1.29	0.33	2.10	1.77	0.066 b-j	5.46	1.14
	FARM MANURE * BİONUR *2. HARVEST	9416.67 a-f	86.72	8166.57 a-e	16.38 g-p	1330.18	36.13 ab	54.47 a-d	1.53	0.28	1.67	1.75	0.086 a-e	6.28	0.91
	FARM MANURE * BİONUR *3. HARVEST	7616.67 f-o	87.19	6642.55 e-o	14.86 l-p	987.98	31.69 f-m	51.82 b-j	1.34	0.27	1.89	1.76	0.079 a-g	6.64	1.04
	FARM MANURE * NEOBİOPLUS *1. HARVEST	9733.33 a-e	86.53	8424.38 a-e	18.26 b-k	1548.41	30.39 i-o	46.73 d-m	1.31	0.30	2.17	1.74	0.059 b-k	6.06	1.21
	FARM MANURE * NEOBİOPLUS *2. HARVEST	9800.00 a-e	86.99	8527.85 a-d	16.45 g-p	1401.45	35.12 a-e	53.79 a-e	1.57	0.29	1.88	1.78	0.076 a-h	6.19	1.01
	FARM MANURE * NEOBİOPLUS *3. HARVEST	6950.00 h-p	87.25	6058.17 ı-p	14.60 m-p	890.61	33.37 b-ı	53.32 a-f	1.40	0.26	1.87	1.78	0.067 b-j	6.98	1.02
	FARM MANURE * ORGANOFERM * 1. HARVEST	10066.67 abc	86.85	8748.22 ab	18.95 a-h	1694.62	31.46 g-n	46.46 e-m	1.32	0.31	2.12	1.73	0.055 d-k	5.80	1.20
	FARM MANURE * ORGANOFERM * 2. HARVEST	9866.67 a-d	86.74	8559.85 abc	15.99 h-p	1367.45	36.02 abc	55.48 ab	1.55	0.29	1.89	1.75	0.067 b-j	6.17	1.05
	FARM MANURE * ORGANOFERM * 3. HARVEST	7300.00 g-p	87.23	6369.52 f-p	14.67 m-p	934.40	33.75 a-h	54.15 a-e	1.41	0.27	1.88	1.75	0.074 a-h	6.51	1.03
	TEA WASTE * CONTROL * 1. HARVEST	8150.00 c-m	86.75	7064.01 b-n	19.76 a-f	1409.08	29.63 j-o	45.55 f-m	1.31	0.31	1.96	1.75	0.062 b-j	5.90	1.10
	TEA WASTE * CONTROL * 2. HARVEST	7233.33 g-p	86.78	6276.55 g-p	17.15 d-o	1076.28	36.66 a	56.09 ab	1.56	0.30	1.64	1.77	0.080 a-g	5.99	0.89
	TEA WASTE * CONTROL * 3. HARVEST	6841.67 ı-p	87.18	5963.57 j-p	20.41 abc	1207.63	30.28 ı-o	45.77 f-m	1.34	0.32	1.95	1.72	0.028 jk	5.57	1.19
	TEA WASTE * ORBITOSOL * 1. HARVEST	8208.33 b-l	86.64	7117.71 b-n	20.07 a-d	1430.39	28.63 mno	43.66 lm	1.18	0.31	2.13	1.75	0.067 b-j	5.69	1.19
	TEA WASTE * ORBITOSOL * 2. HARVEST	7808.33 e-n	86.68	6766.18 d-n	16.21 g-p	1102.00	36.09 ab	54.97 abc	1.59	0.28	1.88	1.79	0.098 ab	6.39	1.01
	TEA WASTE * ORBITOSOL * 3. HARVEST	6708.33 j-p	87.13	5846.69 k-p	15.78 h-p	922.25	33.12 b-ı	52.82 a-g	1.41	0.26	1.86	1.79	0.060 b-j	6.89	1.01
	TEA WASTE * BİONUR *1. HARVEST	8816.67 a-ı	86.94	7674.52 a-j	21.77 a	1679.81	28.86 mno	42.49 m	1.27	0.34	2.20	1.77	0.072 b-h	5.48	1.20
	TEA WASTE * BİONUR *2. HARVEST	7850.00 e-n	86.99	6822.48 c-n	17.62 c-n	1205.76	34.64 a-f	53.68 a-e	1.51	0.29	1.67	1.78	0.072 b-h	6.27	0.91
	TEA WASTE * BİONUR *3. HARVEST	7583.33 f-o	87.59	6641.84 e-o	15.80 h-p	1044.58	34.25 a-g	53.24 a-f	1.43	0.27	1.70	1.77	0.019 k	6.79	0.95

(*Continued*)

Table 2. (Continued).

VARITAION SOURCES	VARITAION SOURCES	Fresh Yield (kg/ha)	Dry Matter Ratio (%)	Dry Yield (kg/ha)	Protein Ratio (%)	Protein Yield (kg/ha)	ADF(%)	NDF (%)	ADP (%)	P (%)	K (%)	Ca (%)	Mg (%)	Ca/P	K/(Ca+Mg)
	TEA WASTE * NEOBİOPLUS *1. HARVEST	8925.00 a-h	86.91	7755.54 a-ı	20.55 abc	1586.38	28.68 mno	43.91 klm	1.23	0.34	2.12	1.73	0.050 d-k	5.25	1.20
	TEA WASTE * NEOBİOPLUS *2. HARVEST	8950.00 a-h	86.80	7762.14 a-ı	18.40 b-j	1447.98	35.87 abc	53.74 a-e	1.52	0.29	1.70	1.77	0.113 a	6.19	0.90
	TEA WASTE * NEOBİOPLUS *3. HARVEST	8275.00 b-k	87.35	7227.55 a-l	16.46 g-p	1190.43	33.74 a-h	52.55 b-h	1.45	0.28	1.83	1.76	0.043 g-k	6.45	1.02
	TEA WASTE * ORGANOFERM * 1. HARVEST	8675.00 a-j	86.81	7526.88 a-k	20.54 abc	1543.05	28.63 mno	60.49 a	1.22	0.32	2.17	1.77	0.037 h-k	5.79	1.21
	TEA WASTE * ORGANOFERM * 2. HARVEST	8691.67 a-j	86.96	7556.52 a-k	17.78 b-m	1341.46	35.37 a-d	53.00 a-g	1.49	0.30	1.73	1.74	0.087 a-e	5.91	0.95
	TEA WASTE * ORGANOFERM * 3. HARVEST	8741.67 a-ı	87.37	7635.33 a-j	16.83 e-o	1280.84	32.93 c-ı	50.88 b-l	1.39	0.28	1.81	1.78	0.029 ı-k	6.48	0.99
MEAN		8001.29	86.94	6955.60	17.14	1210.80	32.42	50.89	1.39	0.29	1.91	1.78	0.067	6.33	1.04

***:$p < .001$; **:$p < .01$; *:$p < .05$.

Table 3. Correlation and significance levels of yield and some quality characteristics of tea plant.

Correlations Probability	Fresh Yield	Dry Matter Ratio	Dry Yield	Protein Ratio	Protein Yield	ADF	NDF	ADP	P	K	Ca	Mg	Ca/P	K/(Ca+Mg)
Fresh Yield	1.0000	−0.0149	0.9980	0.4333	0.8663	−0.0320	−0.2227	0.0193	0.3439	0.1411	−0.1084	−0.0655	−0.3432	0.1719
	<.0001	0.8077	<.0001	<.0001	<.0001	0.6006	0.0002	0.7526	<.0001	0.0203	0.0752	0.2837	<.0001	0.0046
Dry Matter Ratio	−0.0149	1.0000	0.0465	0.0829	0.0809	−0.1267	0.0691	−0.0709	0.0209	0.0911	−0.2018	−0.1647	−0.1182	0.1714
	0.8077	<.0001	0.4470	0.1742	0.1849	0.0375	0.2578	0.2459	0.7327	0.1355	0.0009	0.0067	0.0523	0.0047
Dry Yield	0.9980	0.0465	1.0000	0.4383	0.8710	−0.0407	−0.2192	0.0135	0.3453	0.1486	−0.1204	−0.0766	−0.3501	0.1839
	<.0001	0.4470	<.0001	<.0001	<.0001	0.5055	0.0003	0.8250	<.0001	0.0145	0.0480	0.2094	<.0001	0.0024
Protein Ratio	0.4333	0.0829	0.4383	1.0000	0.8096	−0.4072	−0.4502	−0.1619	0.7995	0.3781	−0.2300	−0.3064	−0.7147	0.4573
	<.0001	0.1742	<.0001	<.0001	<.0001	<.0001	<.0001	0.0077	<.0001	<.0001	0.0001	<.0001	<.0001	<.0001
Protein Yield	0.8663	0.0809	0.8710	0.8096	1.0000	−0.2538	−0.3895	−0.0838	0.6461	0.3031	−0.1778	−0.2223	−0.5893	0.3594
	<.0001	0.1849	<.0001	<.0001	<.0001	<.0001	<.0001	0.1700	<.0001	<.0001	0.0034	0.0002	<.0001	<.0001
ADF	−0.0320	−0.1267	−0.0407	−0.4072	−0.2538	1.0000	0.6095	0.7938	−0.4009	−0.7160	0.1920	0.3446	0.3623	−0.6928
	0.6006	0.0375	0.5055	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0015	<.0001	<.0001	<.0001
NDF	−0.2227	0.0691	−0.2192	−0.4502	−0.3895	0.6095	1.0000	0.5027	−0.3732	−0.4891	0.0892	0.3371	0.3016	−0.4723
	0.0002	0.2578	0.0003	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.1436	<.0001	<.0001	<.0001
ADP	0.0193	−0.0709	0.0135	−0.1619	−0.0838	0.7938	0.5027	1.0000	−0.1788	−0.6208	0.2229	0.2794	0.1975	−0.6115
	0.7526	0.2459	0.8250	0.0077	0.1700	<.0001	<.0001	<.0001	0.0032	<.0001	0.0002	<.0001	0.0011	<.0001
P	0.3439	0.0209	0.3453	0.7995	0.6461	−0.4009	−0.3732	−0.1788	1.0000	0.3551	−0.2186	−0.3079	−0.8853	0.4263
	<.0001	0.7327	<.0001	<.0001	<.0001	<.0001	<.0001	0.0032	<.0001	<.0001	0.0003	<.0001	<.0001	<.0001
K	0.1411	0.0911	0.1486	0.3781	0.3031	−0.7160	−0.4891	−0.6208	0.3551	1.0000	−0.1696	−0.2399	−0.3066	0.9019
	0.0203	0.1355	0.0145	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0052	<.0001	<.0001	<.0001
Ca	−0.1084	−0.2018	−0.1204	−0.2300	−0.1778	0.1920	0.0892	0.2229	−0.2186	−0.1696	1.0000	0.1200	0.6125	−0.5460
	0.0752	0.0009	0.0480	0.0001	0.0034	0.0015	0.1436	0.0002	0.0003	0.0052	<.0001	0.0489	<.0001	<.0001
Mg	−0.0655	−0.1647	−0.0766	−0.3064	−0.2223	0.3446	0.3371	0.2794	−0.3079	−0.2399	0.1200	1.0000	0.2552	−0.3832
	0.2837	0.0067	0.2094	<.0001	0.0002	<.0001	<.0001	<.0001	<.0001	<.0001	0.0489	<.0001	<.0001	<.0001
Ca/P	−0.3432	−0.1182	−0.3501	−0.7147	−0.5893	0.3623	0.3016	0.1975	−0.8853	−0.3066	0.6125	0.2552	1.0000	−0.5301
	<.0001	0.0523	<.0001	<.0001	<.0001	<.0001	<.0001	0.0011	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
K/(Ca+Mg)	0.1719	0.1714	0.1839	0.4573	0.3594	−0.6928	−0.4723	−0.6115	0.4263	0.9019	−0.5460	−0.3832	−0.5301	1.0000
	0.0046	0.0047	0.0024	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

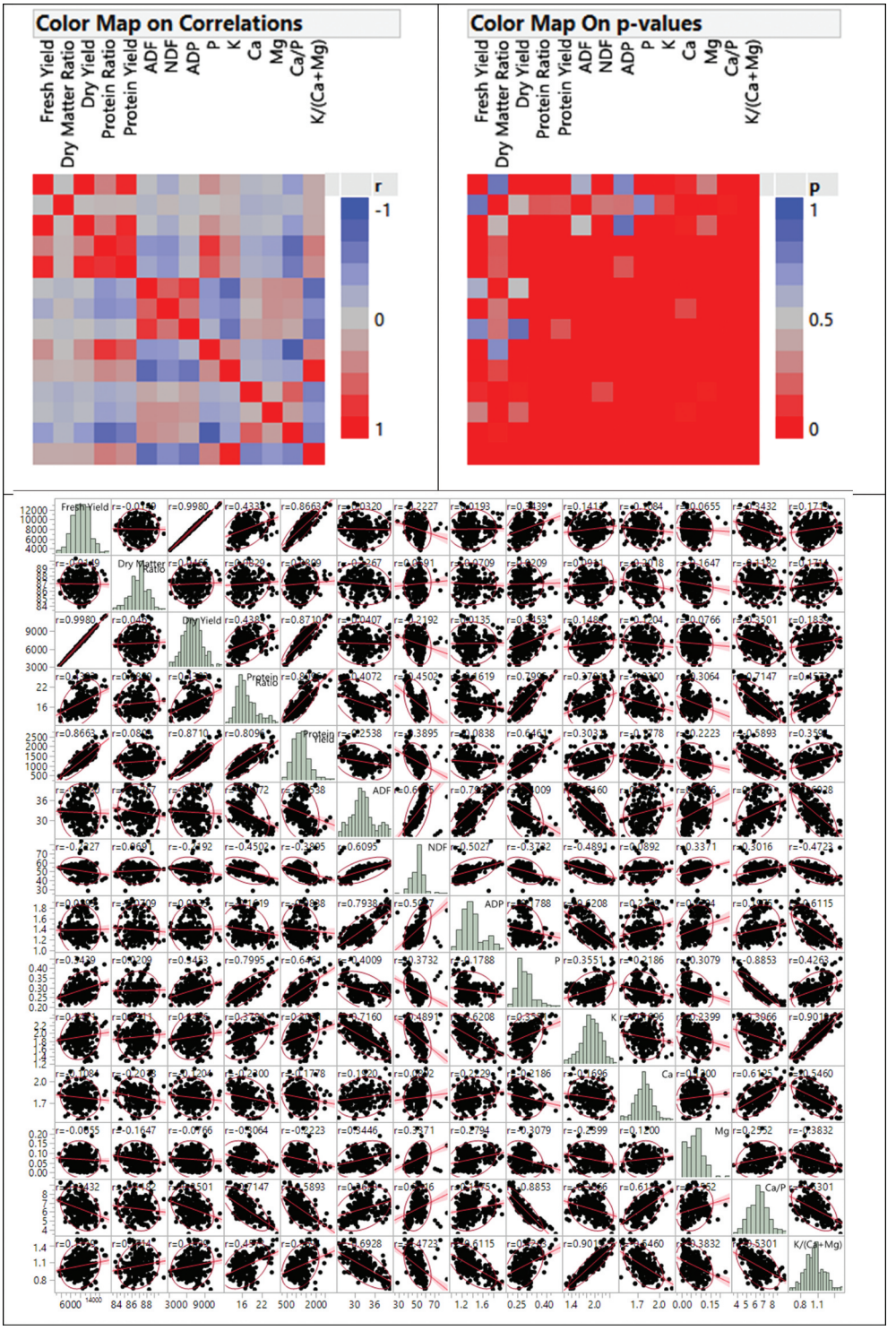


Figure 2. Correlation, significance levels and distribution of the examined characteristics of the tea plant.

The average Protein yield across all treatments was 1210.80 kg/ha. Significant differences ($p < .001$) were observed in protein yield due to organic material source (1130.68–1297.86 kg/ha; Control – Tea waste) and organic fertilizer application (1053.76–1324.84 kg/ha; Orbitosol – Organoferm). No significant interaction (ns) was detected between organic material and organic fertilizer source. Protein yield also varied significantly ($p < .001$) across harvest times (912.45–1525.48 kg/ha; 3rd Harvest – 1st Harvest). Significant interactive effects ($p < .001$; $p < .05$) were observed between organic material source, organic fertilizer application, and harvest time.

The average Acid Detergent Fiber (ADF) content was 32.42%. Significant differences ($p < .001$) were observed in Acid Detergent Fiber content between organic material treatments (Control vs. Tea waste) and between harvest times (1st vs. 2nd Harvest). The interaction between organic material and organic fertilizer source also significantly affected ($p < .01$) Acid Detergent Fiber content. Specifically, Acid Detergent Fiber content ranged from 32.30% to 32.49% for organic material (Control vs. Tea waste), from 31.91% to 32.82% for organic fertilizer (Control vs. Organoferm), and from 28.21% to 36.66% for the interaction of organic material, organic fertilizer, and harvest (Farm manure*Control *1st Harvest vs. Tea waste*Control *2nd Harvest).

The average Neutral Detergent Fiber (NDF) content was 50.89%. There were significant effects of both organic material (OM) and harvest (H) on Neutral Detergent Fiber content ($p < .001$). The interaction between OM and H was also significant ($p < .001$). Neutral Detergent Fiber content from organic material sources ranged from 50.85% (Tea waste) to 50.91% (Control/Farm manure), with no significant difference (ns). Neutral Detergent Fiber content from plots amended with organic fertilizers ranged from 49.92% (Bionur) to 52.78% (Organoferm), with a significant difference ($p < .001$). The interaction between organic material (OM) and organic fertilizer (OF) was not significant (ns). Neutral Detergent Fiber content across harvests ranged from 46.01% (1st Harvest) to 54.44% (2nd Harvest), with a significant difference ($p < .001$). All two-way interactions between organic material (OM), organic fertilizer (OF), and harvest (H) were significant ($p < .05$ or $p < .001$).

The average Acid Detergent Protein (ADP) content across all treatments was 1.39%. There were no significant differences (ns) detected for the effects of organic material (Farm manure vs. Tea waste), organic fertilizer type (Control vs. Bionur/Neobioplus), or the interaction between organic material and fertilizer type. However, harvest significantly impacted Acid Detergent Protein content ($p < .001$), with values ranging from 1.26% to 1.53% (1st Harvest vs. 2nd Harvest). No significant interactions were observed between organic material and harvest, organic fertilizer and harvest, or the three-way interaction of organic material, organic fertilizer, and harvest.

The average Phosphorus (P) content was 0.29%. Statistical analysis revealed significant differences ($p < .05$) in phosphorus concentration between organic material treatments (0.27–0.30%, Control – Tea waste). Organic fertilizers also significantly affected phosphorus content ($p < .001$), with values ranging from 0.27% to 0.29% (Orbitosol – Control/Bionur/Neobioplus/Organoferm). No significant interactions (ns) were observed between organic material and organic fertilizer sources, or organic material and harvest time. However, harvest time significantly influenced phosphorus content ($p < .001$), with the highest value measured in the 3rd harvest (0.31%) compared to the 1st harvest (0.27%).

The average Potassium (K) content was 1.91%. Significant differences ($p < .05$) were observed between organic material treatments (Control – Farm manure: 1.88–1.96%) and organic fertilizer treatments (Bionur – Orbitosol: 1.85–1.94%). The interaction between organic material and organic fertilizer was not significant (ns; Control*Bionur – Farm manure*Control: 1.81–2.02%). However, harvest time significantly affected potassium content ($p < .001$), with higher levels measured in the second harvest (2nd Harvest – 1st Harvest: 1.76–2.11%). The interaction between organic material and harvest was not significant (ns; Tea waste * 2nd Harvest – Farm manure * 1st Harvest: 1.72–2.13%). In contrast, the interaction between organic fertilizer and harvest was significant ($p < .01$), with Bionur treatment showing the greatest difference between harvests (Bionur *2nd Harvest – Bionur * 1st Harvest: 1.62–2.14%). No significant effect (ns) was observed for the three-way interaction of organic material, organic fertilizer, and harvest (Control*Bionur *2nd Harvest – Tea waste*Bionur *1st Harvest: 1.53–2.20%).

Calcium (Ca) content displayed minimal variation across treatments. The average calcium value was 1.78%, with no significant difference observed between the lowest (1.74%) and highest (1.89%) values. This consistency was evident within organic material types (1.76–1.80%), organic fertilizer types (1.76–1.81%), harvest times (1.76–1.78%), and all interaction effects (1.74–1.89%). Statistical analysis using (mention the statistical test used) revealed no significant differences (ns) in calcium content across any treatment combinations.

The average Magnesium (Mg) content was 0.067%. Significant differences ($p < .01$) were observed between organic material types (0.061–0.073%, Tea waste – Farm manure) and organic fertilizer types (0.060–0.074%, Organoferm – Orbitosol). The interaction between organic material and fertilizer was not significant (ns; 0.052–0.080%, Tea waste*Organoferm – Farm manure*Orbitosol). Magnesium content varied significantly ($p < .001$) across harvests (0.058–0.085%, 1st harvest – 2nd harvest). Furthermore, the interaction between organic material and harvest ($p < .001$; 0.036–0.090%, Tea waste * 3rd Harvest – Tea waste * 2nd Harvest) and the interaction between organic fertilizer and harvest ($p < .001$; 0.046–0.096%, Organoferm * 1st Harvest – Neobioplus * 2nd Harvest) were significant. The three-way interaction between organic material, fertilizer, and harvest was also significant ($p < .05$; 0.019–0.113%, Tea waste*Bionur *3rd Harvest – Tea waste*Neobioplus *2nd Harvest).

The average calcium to phosphorus (Ca/P) ratio was 6.33. Significant differences ($p < .05$) were observed between organic material treatments (6.07–6.56), with the lowest value in tea waste and the highest in the control. Similarly, significant differences ($p < .001$) were found among organic fertilizer types (6.17–6.70), with Bionur exhibiting the lowest and Orbitosol the highest Ca/P ratio. The interaction between organic material and organic fertilizer also showed significant effects ($p < .05$), ranging from 5.82 to 7.01. Here, the combination of tea waste with control resulted in the lowest ratio, while control combined with Orbitosol yielded the highest. Harvest time significantly influenced the Ca/P ratio ($p < .001$), with values ranging from 5.86 in the 1st harvest to 6.78 in the 3rd harvest. However, no significant interactions (ns) were detected between organic material and harvest (5.62–7.08) or organic fertilizer and harvest (5.64–7.25). Likewise, the three-way interaction of organic material, organic fertilizer, and harvest yielded no significant effects (ns), ranging from 5.25 to 7.61.

The average potassium to the sum of calcium and magnesium (K/(Ca+Mg)) ratio across all treatments was 1.04. Significant differences ($p < .01$) were observed between organic material sources (Control – Farm manure: 1.02–1.07), indicating a slight enrichment with K in manure-treated soils. No significant differences (ns) were found between organic fertilizer types (Bionur – Organoferm: 1.02–1.06) or in the interaction between organic material and organic fertilizer (Control*Bionur – Farm manure*Organoferm: 1.00–1.09). In contrast, harvest time significantly impacted the K/(Ca+Mg) ratio ($p < .001$), with higher values observed in the second harvest (0.95–1.17) compared to the first harvest. Interactions between organic material, organic fertilizer, and harvest time did not show significant effects (ns). These interactions ranged from 0.93–1.18 (Control *2nd Harvest/Tea waste * 2nd Harvest – Farm manure * 1st Harvest) for organic material*harvest to 0.84–1.21 (Control*Bionur *2nd Harvest – Farm manure*Neobioplus *1st Harvest/Tea waste*Organoferm *1st Harvest) for organic material*organic fertilizer*harvest.

The correlation analysis of Table 3 and Figure 2 revealed several statistically significant relationships among the examined features. Positive correlations were observed between fresh yield and dry yield, protein content, protein yield, P, K, and K/(Ca+Mg). Dry matter content showed a positive correlation only with K/(Ca+Mg). Similarly, dry yield exhibited positive correlations with protein content, protein yield, P, K, and K/(Ca+Mg). Protein content was positively correlated with protein yield, P, K, and K/(Ca+Mg), while protein yield itself correlated positively with P, K, and K/(Ca+Mg). Furthermore, ADF content displayed positive correlations with NDF, ADP, Ca, Mg, and Ca/P ratio. Similar positive correlations were observed between NDF and ADP, Mg, and Ca/P ratio, and between ADP and Ca, Mg, and Ca/P ratio. Additionally, P content was positively correlated with K and K/(Ca+Mg), while K itself showed a positive correlation with K/(Ca+Mg). A positive correlation was also found between Ca and Mg. Finally, Mg content exhibited a positive correlation with Ca/P ratio.

Conversely, several statistically significant negative correlations were identified. Fresh yield was negatively correlated with NDF and Ca/P ratio. Dry matter content exhibited negative correlations with ADF, Ca, and Mg. Similarly, dry yield showed negative correlations with NDF, Ca, and Ca/P ratio. Protein content was negatively correlated with ADF, NDF, ADP, Ca, Mg, and Ca/P ratio. Likewise, protein yield displayed negative correlations with all the aforementioned features (ADF, NDF, ADP, Ca, Mg, and Ca/P ratio). Furthermore, ADF content exhibited negative correlations with P, K, and K/(Ca+Mg). Similar negative correlations were observed between NDF and P, K, and K/(Ca +Mg), and between ADP and P, K, and K/(Ca+Mg). Additionally, P content was negatively correlated with Ca, Mg, and Ca/P ratio. Likewise, K showed negative correlations with Ca, Mg, and Ca/P ratio. Interestingly, a negative correlation was found between Ca and K/(Ca+Mg), and between Mg and K/(Ca+Mg). Finally, the Ca/P ratio exhibited a negative correlation with K/(Ca+Mg).

Previous research has investigated the nutrient status of tea (*Camellia sinensis* L.) grown in the Eastern Black Sea Region of Türkiye. Adiloglu and Adiloglu (2006) reported that the leaves contained phosphorus, potassium, calcium, and magnesium in the ranges of 0.06–0.40%, 1.46–2.68%, 0.33–0.86%, and 0.15–0.38%, respectively. Several studies have investigated the yield and nutrient content of tea leaves harvested at different times. Horuz and Korkmaz (2006) reported varying yields across three harvest periods: 6500 kg/ha, 5500 kg/ha, and 3000 kg/ha for the first, second, and third harvests, respectively. Phosphorus content remained relatively constant across harvests (0.22%, 0.21%, and 0.22%). However, potassium content exhibited a distinct pattern, increasing from 1.21% in the first harvest to 1.65% in the second and then decreasing slightly to 1.60% in the third harvest. Calcium content followed a similar trend, with values of 1.95%, 2.05%, and 1.66% for the first, second, and third harvests, respectively. Magnesium content also varied, with the highest level observed in the second harvest (0.47%) and lower values in the first (0.33%) and third (0.39%) harvests. In a separate study, Tabu, Kekana, and Kamau (2015) investigated the impact of fertilization on tea yields in Kenya. Applying 150 kg N/ha per year with a 1:4 ratio of cattle manure to NPKS (25:5:5:5) resulted in peak yields of 4055 kg/ha and 2356 kg/ha during the first and second seasons, respectively. In a study by Taşkın et al. (2015), the elemental composition of tea leaves from the Eastern Black Sea Region was investigated. The analysis revealed that phosphorus concentrations ranged from 0.06 to 0.43 g/kg, with an average of 0.17 g/kg. Similarly, potassium content varied between 0.08 and 3.46 g/kg, with a mean value of 0.94 g/kg. Calcium concentrations were found to be in the range of 0.07–1.74 g/kg, with an average of 0.61 g/kg. Finally, magnesium content ranged from 0.04 to 0.57 g/kg, with a mean concentration of 0.18 g/kg. Ramdani et al. (2017) investigated the nutritional composition of tea leaf products and other forage plants. Their analysis revealed that green tea leaves contained 937, 240, 211, 254, and 37.6 g/kg dry matter (DM) of dry matter, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid lignin (ADL), respectively. Black tea leaves exhibited similar dry matter content (942 g/kg DM) and crude protein (242 g/kg DM) but displayed higher ADF (309 g/kg DM), NDF (323 g/kg DM), and lower ADL (27.4 g/kg DM) compared to green tea leaves. Özyılmaz and Genç (2019) investigated the nutritional composition of organic and conventionally grown tea plants. The dry matter, crude protein, ADF, and NDF values of organic tea plants were 89.48–90.75%, 15.46–18.56%, 24.75–32.37%, and 31.01–36.89%, respectively. In conventionally produced tea plants, these values were 89.86–91.67%, 33.89–38.77%, 29.20–34.73%, and 16.65–17.79%, respectively. Nyabundi, Owuor, and Netondo (2019) conducted a study in Kenya to investigate the yield and yield components of clonal tea (*Camellia sinensis*). The study also aimed to determine the fertilizer response and environmental interactions. The researchers applied different fertilizer rates to the tea plants and measured the yield and yield components. The results showed that the highest yield (3195 kg/ha/year) was obtained with the application of 300 kg/ha/year of a fertilizer blend containing 25% nitrogen, 5% phosphorus, 5% potassium, and 5% sulfur (NPKS; 25:5:5:5). The study also found that the yield and yield components were significantly influenced by environmental factors such as rainfall and temperature. Thang and Hiep (2020) investigated the nutrient digestibility of tea by-products in beef cattle. The dry matter (DM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) contents of tea by-products were determined to be 90.67%, 22.88%, 21.13%,

and 32.45%, respectively. These findings suggest that tea by-products could be a potential source of nutrients for beef cattle. In a study conducted by Ahmad et al. (2021) at the National Tea and High Value Crop Research Institute (NTHRI) in Pakistan, the impact of compost application on tea plant yield and nutrient content was investigated. The findings revealed that compost application significantly increased fresh tea yield by 60% compared to the control group, reaching a maximum yield of 491.6 kg ha-1. Furthermore, compost application also led to substantial improvements in the plant's N, P, and K content. Compared to the control, the application resulted in maximum N, P, and K contents of 2.85%, 0.128%, and 1.18%, respectively, representing increases of 35%, 40%, and 38%. These results suggest that compost application can be a valuable strategy for enhancing both tea yield and plant nutrient composition.

Our findings exhibit both concordance and divergence with those reported by researchers mentioned above. These discrepancies may stem from variations in the vegetation structure across the studied landscapes. Additionally, the application of distinct management practices within each area is likely a contributing factor.

Conclusions

A two-year field study investigated the effects of organic materials, organic fertilizers, and harvest periods on yield and quality parameters in organic tea gardens of Pazar district, Rize Province, Türkiye. The experiment included three organic materials (Control, Farm manure, and Tea waste), five organic fertilizers (Control, Orbitosol, Bionur, Neobioplus, and Organoferm), and three harvest periods (1st, 2nd, and 3rd). Mean values across treatments were: fresh yield (8001.29 kg/ha), dry matter ratio (86.94%), dry yield (6955.60 kg/ha), protein ratio (17.14%), protein yield (1210.80 kg/ha), Acid Detergent Fiber (ADF, 32.42%), Neutral Detergent Fiber (NDF, 50.89%), Acid Digestible Protein (ADP, 1.39%), Phosphorus (P, 0.29%), Potassium (K, 1.91%), Calcium (Ca, 1.78%), and Magnesium (Mg, 0.067%). Statistically significant ($p < .05$) effects were observed for several parameters. Organic material application significantly influenced fresh yield, dry yield, protein ratio, protein yield, P, K, Mg, Ca/P ratio, and K/(Ca+Mg) ratio. Similarly, organic fertilizer application significantly impacted fresh yield, dry yield, protein ratio, protein yield, ADF, NDF, P, K, Mg, Ca/P ratio. The interaction between organic material and organic fertilizer significantly affected fresh yield, dry yield, protein ratio, ADF, and Ca/P ratio. Harvest period significantly influenced all yield and quality parameters except dry matter ratio. Further significant interactions were observed between organic material and harvest period (fresh yield, dry yield, protein yield, ADF, NDF, Mg), organic fertilizer and harvest period (fresh yield, dry yield, protein ratio, protein yield, ADF, NDF, K, Mg), and all three factors together (fresh yield, dry yield, protein ratio, ADF, NDF, Mg). A comparative analysis of organic materials revealed that tea waste exhibited superior performance in terms of protein content, yield, and phosphorus concentration. Similarly, farm manure demonstrated excellent results in terms of fresh and dry matter yields, as well as potassium and magnesium content. Furthermore, the application of Organoferm fertilizer significantly enhanced various quality parameters, with the exception of calcium and magnesium, outperforming other organic fertilizers. In conclusion, for optimal yield and quality in organic tea production under the studied conditions, tea waste and farm manure are recommended as organic materials, while Organoferm fertilizer is the most effective organic fertilizer option.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Muhammed İkbal Çatal and Adil Bakoğlu. The first draft of the manuscript was written by Muhammed İkbal Çatal and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Consent to publish

Authors read the manuscript and showed his willingness to publish this study.

Data availability statement

All data needed to conduct this study is provided within the manuscript.

References

Adiloglu, A., and S. Adiloglu. 2006. An investigation on nutritional status of tea (Camellia sinensis L.) grown in Eastern Black Sea Region of Turkey. *Pakistan Journal of Biological Sciences* 9 (3):365–70. doi: 10.3923/pjbs.2006.365.370.

Ahmad, W., A. H. Shah, M. S. Rafiullah, and M. Dildar. 2021. Effect of farmyard manure and compost application with chemical fertilizers on yield and quality of tea (Camellia sinences L). *Journal of Agricultural Research Pesticides and Biofertilizers* 1 (5):1–8.

Horuz, A., and A. Korkmaz. 2006. Yield, nitrogen content and mineral matter composition of tea plant harvested in different shoot periods. *Journal of the Faculty of Agriculture, OMU* 21 (1):49–54.

Kacar, B. 2010. *Çay Bitkisi, Biyokimyası, Gübrelenmesi, İşleme Teknolojisi*. Nobel Yayın Dağıtım Ankara.

Mazurak, A. P., H. R. Cosper, and H. F. Rhoades. 1955. Rate of water entry into an irrigated chestnut soil as affected by 39 years of cropping and manurial practices 1. *Agricultural Journal* 47 (10):490–93. doi: 10.2134/agronj1955.00021962004700100011x.

Nath, T. N. 2014. Soil bulk density and its impact on soil texture, organic matter content and available macronutrients of tea cultivated soil in Dibrugarh District of Assam. *International Journal of Development Research* 4 (2):343–46.

Nyabundi, K. W., P. O. Owuor, and G. W. Netondo. 2019. Fertilizer response and environment interactions of yield and yield components of clonal tea (Camellia sinensis) in Kenya. *International Journal of Tea Science* 14 (1):6–13. doi: 10.20425/ijts1412.

Özdemir, N., Ö. T, and Ö. T. K. Durmuş. 2020. Effects of organic and traditional tea farming practices on some soil quality parameters and micronutrient availability. *Journal of Soil Science and Plant Nutrition* 8 (1):61–68. doi: 10.33409/tbbbd.757336.

Özyılmaz, N., and B. Genç. 2019. Determination of nutrient content and in vitro digestibility values of organic and conventional tea (Camellia sinensis) factory wastes. *International Journal of Veterinary and Animal Research (IJVAR)* 2 (2):32–36.

Ramdani, D., A. S. Chaudhry, I. Hernaman, and C. J. Seal. 2017. Comparing tea leaf products and other forages for in-vitro degradability, fermentation, and methane for their potential use as natural additives for ruminants. *KnE Life Sciences* 2 (6):63–71.

Tabu, I. M., V. M. Kekana, and D. M. Kamau. 2015. Effect of varying ratios and rates of enriched cattle manure on leaf nitrogen content, yield and quality of tea (Camellia sinensis). *The Journal of Agricultural Science* 7 (5):175. doi: 10.5539/jas.v7n5p175.

Taşkın, M. B., M. Balcı, R. Soba, E. C. Kaya, P. Özer, G. Tanyel, A. Kabaoğlu, M. A. Turan, and S. Taban. 2015. Doğu Karadeniz Bölgesinde Çay Tarımı Yapılan Toprakların ve Çay Bitkisinin Azot, Fosfor, Potasyum, Kalsiyum, Magnezyum ve Kükürt Durumları. *Toprak Su Dergisi* 4 (2):30–40. doi: 10.21657/tsd.05240.

Anonymous. 2021. T.C. Prime ministry general directorate of state meteorological affairs, rize provincial directorate records.

Thang, C. M., and T. Hiep. 2020. Combined effects of cottonseed oil and tannin from tea by-products (Camellia sinensis) supplementation on nutrient digestibility, performance and enteric methane production of fattening cattle. *Advances in Animal Veterinary Sciences* 8 (6):633–38. doi: 10.17582/journal.aavs/2020/8.6.633.638.