

## **Teff (*Eragrostis tef* (Zucc.) Trotter) fodder yield and quality as affected by cutting frequency**

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**Abstract.** Teff (*Eragrostis tef* (Zucc.) Trotter) is a well-adapted, fast-growing crop with competitive forage quality as its nutritive value for livestock fodder is similar to other grasses utilized as hay or ensiled feeds. Two field experiments were conducted from May to October 2017 in order to determine the effect of cutting frequency on yield and quality of teff (*Eragrostis tef*) as fodder crop under Mediterranean climatic conditions. The agronomic performance and nutritive value of teff was analyzed in order to define alternatives to local forages for animal feeding in the Mediterranean region. The experiments conducted at two sites (Western and Central Greece) were laid out in a completely randomized design with three replicates and three cutting frequencies (10, 20, 30 days' interval between cuttings - F10, F20, and F30, respectively). The results of this study demonstrate that the cutting interval has a marked effect on the fodder yield and quality. The highest total dry matter yield (6,322–6,778 kg ha<sup>-1</sup>) was found in F10 treatment. In terms of qualitative characteristics, the highest fat levels and lowest ADF levels was found in F30 treatment, the highest protein levels and the lowest NDF levels in F10 treatment, and the highest levels of fibrous substances, ADF and NDF, in F20 treatment. Data suggest that teff could be successfully integrated into Mediterranean grasslands with the prospect for improving their nutritional quality and the possibility for increasing protein yield through the application of frequent cuttings.

**Key words:** alternative fodder crop, Mediterranean region, crude protein, acid detergent fiber, neutral detergent fiber.

### **INTRODUCTION**

For sustainable and stable food production, the genetic diversity maintenance of crop types is increasingly being realized as the most indispensable action. This is further emphasized by unpredictable human food needs, changes in taste, and the biotic and the abiotic production constraints that change with the environments (Ketema, 1997). At the same time, meat production and consumption increase likewise plant materials are required for this production (Herak, 2016; Raphaeli & Marinova, 2016). Nowadays, there is a great demand of innovative fodder crops and many new crops evaluated as quinoa, chia etc. (Kakabouki et al., 2014, Bilalis et al., 2016).

Teff (*Eragrostis tef* (Zucc.) Trotter) is a self-pollinated, warm season, annual grass that belongs to Poaceae family (Watson & Dallwitz, 1992) and it is native to Ethiopia. Although its attractive nutrition profile made it worldwide known mostly for its grains - as it is predominantly grown as a cereal crop - teff is also used as a livestock forage or pasture crop. It is characterized as an 'orphan crop', a term used to describe plants that have not been genetically improved and are highly underutilized (Chanyalew et al., 2019). These orphan (or minor) crops are considered to be an alternative solution to the economic dependence on the major cereals and will help the cropping and farming system (Chanyalew et al., 2019). Low productivity is the main restriction for these kinds of crops to be cultivated but in case of *Eragrostis tef* several studies have shown potential of great economic and scientific importance in terms of quality and yield (Roseberg et al., 2005; Roussis et al., 2019).

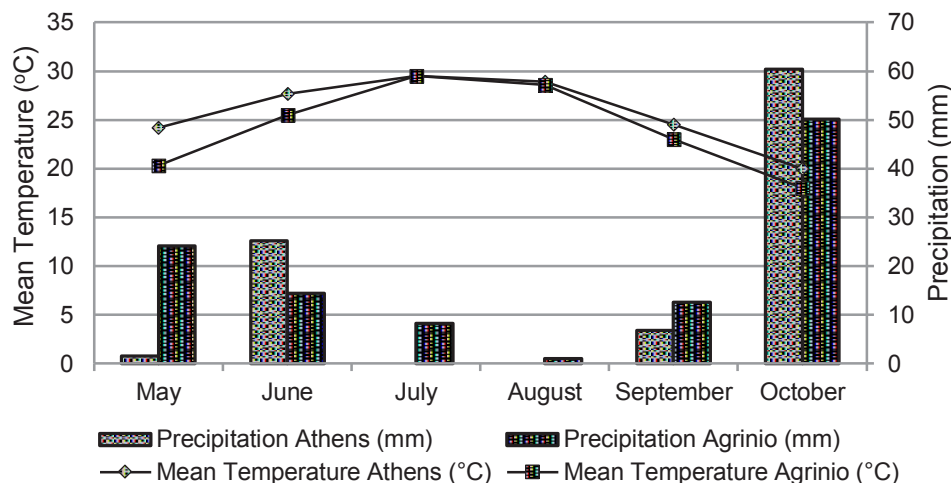
The increasing interest for this crop gravitates to its wide range of adaptation. Teff is well suited to various marginal growing conditions; from arid areas, salt-affected and drought-stressed soils to waterlogged soils (Hunter et al., 2007). Besides this, it is a fast-growing crop with competitive forage quality. Teff is typically fed as hay or straw for livestock, including ruminants, while, it is also relatively popular as forage for horses in the form of hay or pasture grass (Yami, 2013). The nutritive value of teff for livestock fodder is similar to other grasses utilized as hay or ensiled feeds (Boe et al., 1986; Twidwell et al., 2002). Its ability to produce high-quality hay in a relatively short growing season with relatively low inputs makes teff a promising forage crop. Moreover, its straw is highly preferred feed for livestock, compared to the other cereal straws, especially during the dry season with somewhat deficient in nitrogen supply (Mengistu & Mekonnen, 2012).

Although many studies have demonstrated the beneficial properties in animals and trait diversity, limited data are available regarding the fodder yield and quality of teff crop (Mengistu & Mekonnen, 2012; Yami, 2013; Bilalis et al., 2018). Forage yields of teff are highly dependent upon planting date and number of cuttings (Stallknecht et al., 1993). In addition, climate change effect is expected to lead to large reductions in crop productivity of the Mediterranean region and a strategy to cope with the increasing demand for feed production includes the introduction of alternative crops, such as teff characterized by adequate yield and exceptional nutritional value (Bilalis et al., 2018; Roussis et al., 2019). Therefore, the objective of this study was to determine the effects of cutting frequency on dry matter, yield protein and quality of teff crop in order to define alternatives to local forage sources for animals feeding in the Mediterranean region.

## MATERIALS AND METHODS

The experiments were conducted from May to October 2017 growing season on two experimental sites. The first site is situated in the experimental field of the Agricultural University of Athens (Central Greece, Latitude: 37° 5'01.8"N, Longitude 23° 4'07.3" E, Altitude 170 m above sea level). The soil is classified as a Clay Loam (35.9% sand, 29.8% clay and 34.3% silt), with pH 7.21 (1:1 water H<sub>2</sub>O), 0.113% total nitrogen, available phosphorus (P) 47 mg kg<sup>-1</sup> soil, available potassium (K) 338 mg kg<sup>-1</sup> soil, 16.82% CaCO<sub>3</sub> and 1.39% organic matter content (Wakley & Black, 1934). The second site was located in the Agrinio region (Western Greece, Latitude: 38°35' N, Longitude: 21°25' E, Altitude: 80 m above sea level). The soil type was a Silt Loam

(13.9% sand, 61.2% loam, and 24.9% clay) with 1.46% organic matter, 0.156% total nitrogen, available phosphorus (P) 172 mg kg<sup>-1</sup> soil, available potassium (K) 621 mg kg<sup>-1</sup> soil, 14.34% CaCO<sub>3</sub>, and a pH of 7.44. The sites were managed according to organic agricultural guidelines (EC 834/2007).



**Figure 1.** Meteorological data (mean temperature: °C and precipitation: mm) for the experimental sites (Athens and Agrinio) during the experimental period (May-October 2017).

Mean values of meteorological data concerning air temperature and precipitation of the experimental sites are presented in Fig. 1. Each experiment was set up according to a Completely Randomized Design with three replicates and three cutting frequencies. The cutting interval was every 10 (F10), 20 (F20) and 30 days (F30), since 41 DAS (Table 1) in three levels. The experimental area was 90 m<sup>2</sup>, which was devised in 3 replicates with 3 plots (10 m<sup>2</sup>) each. Soil tillage encompasses agronomical ploughing at a depth of 20 cm. Organic fertilizer (2,000 kg ha<sup>-1</sup> seaweed compost, 1–2% N) was applied as basal fertilization by hand on the soil surface and then harrowed in. Teff was sown at the beginning of May by a 10- rows manual seed planter (seed rate 3.7 kg ha<sup>-1</sup>). A drip irrigation system was installed in the experimental plots. The drip irrigation frequency was designed to be 7 days, and the irrigation amount was 10–15 mm each time.

Mean values of meteorological data concerning air temperature and

**Table 1.** The cutting dates in treatments (F10: 10 days' interval, F20: 20 days' interval, F30: 30 days' interval). The dates expressed as days after sowing (DAS) are the same for both of the experimental sites (Athens and Agrinio)

Cutting dates	Interval between cuttings		
	F10	F20	F30
41 DAS	x	x	x
51 DAS	x		
61 DAS	x	x	
71 DAS	x		x
81 DAS	x	x	
91 DAS	x		
101 DAS	x	x	x
111 DAS	x		
121 DAS	x	x	
131 DAS	x		x
141 DAS	x	x	
151 DAS	x		

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Dry weight sampling dates were the same as cutting frequency. So, there are 12 samples for 10 days' frequency, 6 samples for 20 days' frequency and 4 samples for 30 days' frequency (Table 1). Dry weight was determined after drying for 72 h at 75 °C.

The samples were chosen randomly within each plot. All samples were analyzed for neutral detergent fiber (NDF) assayed without a heat stable amylase and expressed inclusive of residual ash and acid detergent fiber (ADF) expressed exclusive of residual ash according to Van Soest et al. (1991). Furthermore, the total nitrogen and protein content was determined by the Kjeldahl method (Bremmer, 1960) using a Buchi 316 device. After all, the AOAC method 920.39 used to determine crude fat (AOAC, 2000).

The Total Dry Matter and Protein Yield were estimated by the following mathematical equations.

$$\text{Total Dry Matter} = \sum_{i=1}^n DW_i$$

where  $n = 12$  (cutting frequency 10 days),  $n = 6$  (cutting frequency 20 days),  $n = 4$  (cutting frequency 30 days).

$$\text{Protein Yield} = \sum_{i=1}^n (\text{Protein Content}_i * DM_i)$$

where  $n = 12$ ,  $n = 6$ ,  $n = 4$  (respectively for each treatment).

Analysis of variance was carried out on data using the Statistica (StatSoft Inc., 2300 East 14th Street, Tulsa, OK 74104, USA) statistical software as a Completely Randomized Design. The significance of differences between treatments was estimated using LSD test and probabilities equal to or less than 0.05 ( $P \leq 0.05$ ) considered significant.

## RESULTS AND DISCUSSION

In the present study, it was indicated that teff growth in the experimental site in Athens was significantly affected ( $F = 85.01$ ;  $P < 0.001$ ) by cutting frequency. More specifically, the plants in F30 treatment had the greatest height (73.06 cm) followed by the plants in F20 and F10 with a height of 59.83 cm and 41.51 cm, respectively. A same trend was also noticed in Agrinio region ( $F = 64.82$ ;  $P < 0.001$ ) with the highest plant (69.45 cm) observed in F30 treatment. The cutting frequency effects on teff growth and yields are shown in Table 2.

Although in F20 the plant' height levels increased during the second cut, from the third cut until the last have been showed a decrease. In the experiment of Kannika et al. (2011), the studding objective was the cutting frequency impact on yield biomass and

growth components of Napiergrass (*Pennisetum purpureum* Schumach) in Thailand (tropical climate), where the height process indicated an upward trend until the fourth cut, while in the fifth cut it declined in all of the three varieties.

Regarding the total dry matter yield, our results revealed that there were statistically significant differences among the cutting treatments. Teff total dry matter yield in the experimental site in Athens ranged from a low of 3,656 to a high of 6,778 kg ha<sup>-1</sup> for the F30 and F10 treatment, respectively (Table 2). A same trend observed in the experimental site in Agrinio with total dry matter yield ranged from a low of 3,708 to a high of 6,322 kg ha<sup>-1</sup> for the F30 and F10 treatment, respectively, and the mean difference were statistically significant between F10- F20 and F10-F30. In general, it was found that the total dry matter yield was increased as the cutting interval increased from every 10<sup>th</sup> to 30<sup>th</sup> days. Similar results were also noticed by Slepety's (2010) for the biomass yield of galega (*Galega officinalis* L.) crop.

The crude protein constitutes a critical component in cattle diet and the deficiency of this component can lead to reduced growth and milk production (Ul-Allaha et al., 2014). The results of this research indicated that protein content was influenced by the cutting frequency with F10 at 18.93% DM / 17.25% DM, F20 at 17.53% DM / 15.52% DM and F30 16.63% DM / 14.21% DM (Athens / Agrinio, respectively) (Table 2). As the cutting interval increased from every 10<sup>th</sup> to 30<sup>th</sup> days, the protein content decreased. This might be due to higher maturity by harvesting less frequently such as every 30<sup>th</sup> day cutting treatment. Protein content at the most frequent cutting treatment (12 cuttings during growing season) was significantly ( $F = 113.9; P < 0.001; F = 101.3; P < 0.001$  in Athens and Agrinio, respectively) higher than other cutting frequency treatments. This might be due to a lower maturity stage for the most frequently harvesting treatment (i.e., every 10th day) than rest of cutting intervals.

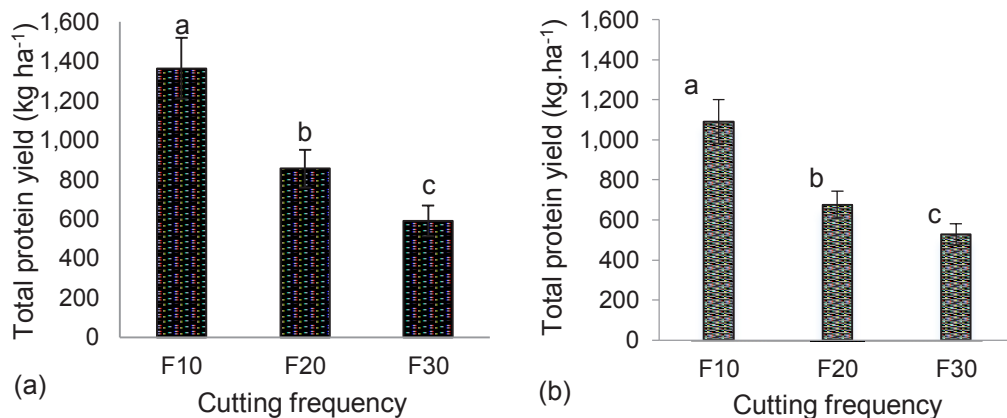
**Table 2.** Effects of cutting frequency (F10: 10 days' interval, F20: 20 days' interval, F30: 30 days' interval) on height (cm), total dry matter (DM) yield (kg ha<sup>-1</sup>), protein (% DM), ether extract: EE (% DM), acid detergent fiber: ADF (% DM) and neutral detergent fiber: NDF (% DM) of teff, in Athens and Agrinio area

Cutting frequency	Athens			Agrinio		
	Height (cm)	Total DM yield (kg ha <sup>-1</sup> )	Protein (% DM)	Height (cm)	Total DM yield (kg ha <sup>-1</sup> )	Protein (% DM)
F10	41.51 a	6778 a	18.93 a	38.42 a	6322 a	17.25 a
F20	59.83 b	4989 b	17.53 b	57.61 b	4355 b	15.52 b
F30	73.06 c	3656 b	16.63 c	69.45 c	3708 b	14.21 c
$F_{cutting\ frequency}$	85.01***	19.43**	113.9***	64.82***	11,21*	101.3***
	EE (% DM)	ADF (% DM)	NDF (% DM)	EE (% DM)	ADF (% DM)	NDF (% DM)
F10	2.06 c	26.12 ab	56.79 a	2.00 c	25.61 ab	54.47a
F20	2.23 b	26.66 a	57.95 b	2.17 b	27.01 a	58.02b
F30	2.27 a	25.65 b	56.99 a	2.30 a	23.22b	55.03 a
$F_{cutting\ frequency}$	1496.9***	13.24**	14.75**	711,2***	10.87*	10,11*

F-test ratios are from ANOVA. Significant at \*, \*\* and \*\*\* indicate significance at  $P = 0.05, 0.01$  and  $0.001$ , respectively and ns: not significant ( $P > 0.05$ ). Mean values within each column followed by different letters, differ significantly according the LSD test ( $P \leq 0.05$ ).

The results of the present study are suitable to previous studies; on *Festuca scabrella* (Willms & Beauchemin, 1991) was noted that the levels of protein content increased by proliferate the frequency of cuts. Moreover, in the research study of Puteri et al. (2015) investigating the productivity and nutritional quality of sorghum at different cutting rates appeared that as the interval between the cuts raised, the protein levels reduced. Decline of protein content levels has been recorded in many studies (Kidunda et al., 1990, Seyoum et al., 1998, Zewdu et al., 2002) and is predominantly attributed to the dilution of the protein content of the feed crops by the rapid accumulation of cell carbohydrates in the late stages of growth (Bayble et al., 2007). On the other hand, Baghdadi et al. (2017) noticed that crude protein of silage could be affected and increased by the increase of plant-available nitrogen.

The total protein yield is a function of total dry matter yield and protein content. Besides that, as expected, in Athens area, total protein yield ranged from 1,283.03 to 607.92 kg ha<sup>-1</sup> for the F10 and F30 treatment, respectively, (Fig. 2, a) and in Agrinio area ranged from 1,090.55 to 526.9 kg ha<sup>-1</sup> (Fig. 2, b) for the F10 and F30 treatment, respectively. For both areas, there is significant differences among values of the three cutting frequencies. Moreover, the correlations between the mean total protein yield (kg ha<sup>-1</sup>) and dry matter (kg ha<sup>-1</sup>) of the two experimental areas in F10, F20 and F30 treatments were also calculated (Table 3). The F30 treatment displayed no significant linear regression ( $y = ax + b$ ;  $R^2 = 0.26$ ,  $p > 0.05$ ). Contrastingly, in F10 and F20 treatments identical correlations noticed with  $R^2 = 0.49$  ( $p < 0.01$ ) and  $R^2 = 0.47$  ( $p < 0.05$ ), correspondingly. During the time of teff's biomass increased simultaneously the total yield protein increased. The equation slope of F20 was higher ( $a = 4.4$ ) than F10 ( $a = 1.7$ ). That result led to the conclusion that cutting every 20 days, protein yield growth rate is higher than cutting every 10 days.



**Figure 2.** Effects of cutting frequency (F10: 10 days' interval, F20: 20 days' interval, F30: 30 days' interval) on total protein yield (kg ha<sup>-1</sup>) of teff plant a) in Athens and b) in Agrinio area. Values belonging to the same characteristic with different letters within a column denote significant differences on cutting treatments (LSD test,  $P < 0.05$ ). Vertical bars indicate standard deviation.

**Table 3.** Line correlation equations between protein yield (kg ha<sup>-1</sup>) and total dry matter yield (kg ha<sup>-1</sup>). Significant at \*, \*\* and \*\*\* indicate significance at  $P = 0.05$ ,  $0.01$  and  $0.001$ , respectively and ns: not significant ( $P > 0.05$ )

<i>Treatments</i>	<i>Equation</i>	<i>Slope</i>	<i>R<sup>2</sup></i>	<i>P- Level</i>
F10	$y = 1.713x + 271.79$	1.7	0.4898	**
F20	$y = 4.4053x + 203.74$	4.4	0.4733	*
F30	$y = -2.8924x + 1340.5$	-2.8	0.2569	ns

In addition, it has been observed that as the interval between the cuts increases, the percentage of the strain increases while the protein concentration decreasing and the cell wall contents increasing (fibrous substances, NDF and ADF) (Bach & Munck, 1985).

ADF and NDF are important components of forage and are frequently used as a factor to define forage quality (Collins & Fritz, 2003). Analysis of variance revealed that cutting frequency affected both ADF and NDF (Table 2), though the differences among the treatments were significant differences between values on F10 and F30, in both areas.

NDF levels in teff biomass were significantly higher in F20 (57.95% DM), followed by F30 (56.99% DM) and F10 (56.79% DM) treatments in Athens, and the same trend was found in Agrinio with the values being 58.02% DM at F20, 55.03% DM at F30, and 54.7% DM at F10 (Table 2) with significant differences among them. In the F30 treatment, there was an increase in NDF levels in the second and third cutting, and a decrease in the fourth cutting (data not shown). In correspondence with the results of this research, the research by Staniar et al. (2010) found that NDF levels increased during the second cutting and decreased on the third one.

The response of neutral detergent fiber (ADF) was similar to the above-mentioned for NDF, with the highest values observed in F20 treatment (26.66% DM and 27.01% DM in Athens and Agrinio, respectively), followed by F10 and F30 treatments. Willms & Beauchemin (1991) indicated that the levels of ADF content decreased by increasing the frequency of cuts. In the present study, the levels of NDF and ADF are acceptable and lower than Staniar et al. (2010) approach for ruminants. Moreover, these authors observed that the fiber constituents, NDF and ADF, increased as the cutting interval and stage of maturity increased. For most forages, as the plant cell walls thicken with advancing plant maturity, the amount of fiber content (cell wall constituents) is generally increased (Van Soest et al., 1991).

The ether extract has a heterogeneous composition and is formed by lipids (galactolipids, triglycerides, and phospholipids) and all other non-polar compounds, such as phosphatides, steroids, pigments, fat-soluble vitamins, and waxes. Its amount in forage is generally low, with values usually less than 3% of the dry matter (Coleman & Henry, 2002). According to Table 2, ether extract was increased as the cutting interval increased from every 10<sup>th</sup> to 30<sup>th</sup> days. As mentioned above, this might be due to higher maturity by harvesting less frequently such as every 30<sup>th</sup> day cutting treatment. A significant increase in the NDF, ADF, and ether extract (EE) contents of tumbleweed (*Gundelia tournefortii* L.) were reported with increasing maturity of plants (Kamalak et al., 2005).

## CONCLUSIONS

The analysis of the results revealed that the highest total yield of dry weight biomass was observed in F10 (10 days' interval) treatment, while the lowest was observed in F30 (30 days' interval) treatment for both sites. In general, F10 treatment exhibited the highest levels of quantitative and qualitative characteristics. In terms of qualitative characteristics, the highest fat levels and lowest ADF levels was found in F30 treatment, the highest protein levels and the lowest NDF levels in F10 treatment, and the highest levels of fibrous substances, ADF and NDF, in F20 treatment. Despite its versatility in adapting to extreme environmental conditions, the productivity of teff is low and is similar to the quantity produced by natural grasslands of Greece at annual basis (1.5 tonnes ha<sup>-1</sup>). Although, the high ADF, NDF and relatively high CP content characterized teff biomass can meet the requirements of lactating animals. In conclusion, teff could be successfully integrated into Mediterranean grasslands with the prospect for improving their nutritional quality and the possibility for increasing protein yield through the application of frequent cuttings.

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