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Evaluation of the effect of N-fertilization levels on teff (*Eragrostis tef*) yields expressed with nitrogen indices

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Abstract

Kakabouki, I., Folina, A., Karydogianni, S., Zisi, C. & Papastylianou, P. (2021). Evaluation of the effect of N-fertilization levels on teff (*Eragrostis tef*) yields expressed with nitrogen indices. *Bulg. J. Agric. Sci., 27 (4)*, 736–743

Teff (*Eragrostis tef* (Zucc.) Trotter) cultivation is a valuable crop for its various uses, such as grain and straw as well as animal feed. Teff cultivation is affected by different factors; one of the main is being N fertilization. Nitrogen indicators have been used in this study to evaluate whether the different amounts of nitrogen applied can be absorbed by plants. The aim of this study was to investigate the appropriate amount of nitrogen for Mediterranean conditions in order to be effective in teff crop in variety Kora. Two similar experiments were performed in the present study, in Western Greece in Agrinio during 2016-2017. The experiments were followed a randomized complete block design (RCBD), with four replications and four different nitrogen treatments (0 kg N/ha (control), 40 kg N/ha, 80 kg N/ha and 120 kg N/ha). There were measured several agronomic characteristics (root density (cm 100/cm^3), total yield (kg/ha)). Some nitrogen indicators were also measured such as the nitrogen use efficiency (NUE), the nitrogen harvest indexes (NHI) and the nitrogen agronomic efficiency (NAE). According to our results in both years, the agronomic characteristics had their highest values during the application of the highest amounts of nitrogen. However, between the two years, there were statistically significant differences. In terms of indicators, it turned out that the most effective amount of nitrogen was 80 kg N/ha and 120 kg N/ha.

Keywords: Teff; fertilization; NUE; NHI; NAE; seed yield
Abbreviations: NUE – Nitrogen Use Efficiency; NHI – Nitrogen Harvest Index; NAE – Nitrogen Agronomic Efficiency

Introduction

While Teff (*Eragrostis tef*) is considered as an important crop for each grain production in many areas, it has recently become more known for its beneficial properties and its demand has increased. In Greece, it has been systematically included in human diet for the last 10 years, while it is also considered as an important animal feed (Roussis et al., 2019). In Ethiopia, teff is grown for grain and straw and is a crop of great economic importance (Gebretsadik et al., 2009; Mirutse et al., 2009). Crop yields better in altitudes higher to to 2400 m above sea levels (Derib et al., 2018). Teff has great variability in the same area and even in the same field and can grow satisfactorily in different soils (Gebretsadik et al., 2009; Girma et al., 2012).

A number of factors affect Teff performance. Teff is sensitive to the presence or absence of nitrogen and phosphorus (Girma et al., 2012). The yield of straw increased significantly with the use of both N and P fertilizers (Ayalew et al., 2011). The application of N fertilizer significantly increases the yield and yield components of teff, while some researchers report that cultivation requires minimal fertilizer

(Twidwell 2002; Gebretsadik et al., 2009; Giday et al. 2014). Roseberg et al. (2005) note that the plant does not need more than 90-100 kg N/ha during the growing season. On the other hand, Ayalew et al. (2011), in an area of Ethiopia, do not recommend adding fertilizer because it does not significantly affect yield. Another suggestion for fertilizing of teff cultivation and increasing its yield is the combination of inorganic and organic fertilization (Agegnehu et al., 2014). The combination of organic and inorganic fertilizers can increase all yield components with the ratio of inorganic fertilizers be superior (Assefa et al., 2016). On the contrary, according to Bilalis et al. (2017) organic fertilization give very good results compared to inorganic. In addition to fertilizers, some researchers report that a determinant of teff yield is tillage while others state that it is not affected (IAR, 1998; Gebretsadik et al., 2009). Also, the crop has a high adaptability to rainfall, with the presence or absence of rain there can be satisfactory production (National Soil Service, 1994). The plant densities were exanimated as a factor that can affect yields but has not been shown to significantly affect (Bilalis et al., 2017).

In addition to yield, inorganic fertilization affects the quality traits of teff. As N fertilization increases, so does forage crude protein (Girma et al., 2012). N and P are key elements that determine quality characteristics (Girma et al., 2012). Mirutse et al. (2009) noted that N uptake is significant related to N applied. Micronutrient uptake of the plant was increased by inoculation of the root with mycorrhiza (Mamo et al., 1987).

The root system of teff is important because gives drought resistance once it has developed, that is, after 2-3 weeks (Norberg et al., 2008). A major yield constraint is lodging which is the result of falling shoots and root. Van et al., 2010 note that teff is more susceptible to root lodging than to shoot lodging. Teff's root system is shallow and the resistance to lodging depends on the anchorage strength of the root system (Stallknecht et al., 1993; Van et al., 2010). Fertilization is very significant for lodging and shoots and root. Hence, attention should be paid to the nitrogen units applied because a high plant can be created and in combination with its slender stem to be more prone to lodging.

In addition to N units important for cereal is how much nitrogen is ultimately stored in the grains. Globally, in cereal crops, less than 50% of applied N is transferred to the grains (Johnson et al., 2003). Important for excess mineral N is the management of N fertilizers (Johnson et al., 2003). In global level, for the same as now yields, a 1% increase in NUE would be worth $ 2 346 584.62 in N fertilizer savings if yields were maintained (Johnson et al., 2003). Factors that affect NUE, and consequently N losses, are the N source, the method of fertilizer application and the cultivation system (Raun et al., 1999).

Our research has two objectives studies. The literature examines N units and what is the optimum rate of N for the cultivation of teff. Therefore, the first objective concerns the investigation of the desired rate applied N in the Mediterranean conditions, given the increase in the demand for human nutrition. Also, most researchers are considering the reaction of cultivation to N units in relation to the economic cost of fertilization. In addition, it is important how the teff plants use the applied N and how much is saved in the grains, which are used for consumption as flour or the seed itself and in the leaves, as animal feed. In semi-arid climate of Greece, teff fertilizer response and exploitation are not well documented for yield and quality. In identifying and evaluating the cultivar practices of teff for growth in Greece through nitrogen indices, we aimed to introduce teff as an alternative crop to create an ecological and healthy profile. The hypothesis of this experiment is that a higher rate of N the crop can take advantage of it and we can have higher yield and better nitrogen use efficiency in the aboveground part of the plant.

Materials and Methods

Experimental Design

Two same experiments with teff crop (variety Kora) were carried out in Western Greece, in Agrinio (38°35′18 N, 21°25′40 E, with altitude 53m), during 2016-2017. The soil was clay loam, with pH (1:1 H_2O) 6.72 and 2.78 % organic matter (Wakley & Black, 1934). The experiments were established in an area of 320 m^2 (16 plots x 20 m^2 each plot), according to a randomized complete block design (RCBD), with four replications and four different treatments, with different amounts of ammonia nitrate (NH_4NO_3), (0 kg N/ha (control), 40 kg N/ha, 80 kg N/ha and 120 kg N/ha).

The sowing took place on March 13, 2016 and on March 11, 2017, for the first and second experiments respectively, by hand in rows 20 cm apart, at a density of 700 seeds per meter^2 and a depth of 1 cm. The harvest day was on July 9, 2016 for the first experiment and on July 7, 2017 for the second. Meteorological data, mean temperature and precipitation during the experimental period are shown in the Figure 1. Weeds were controlled, when it was necessary, by hand hoeing. An overhead sprinkler system was set up on the field. Irrigation was carried out 5 times during the experimental period. The total quantity of water applied was 250 mm.

Measurements

The same measurements were made for the two experiments. The measurements made concerned the agronomic

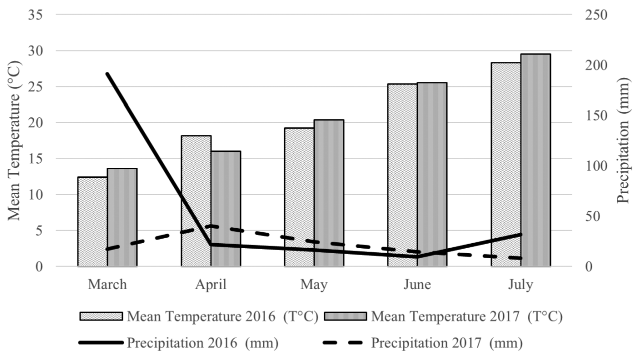

Fig. 1. Meteorological data, mean temperature and precipitation, during the experimental periods (March 2016 – July 2016 and March 2017 – July 2017)

characteristics of the plants (root density, Leaf Area Index (LAI), plant height, 1000 seed weight, dry matter (DM) yield and the total yield), as well as certain nitrogen indicators (Nitrogen percentage in seeds, Nitrogen uptake in seeds, Total Nitrogen uptake, Nitrogen Use Efficiency (NUE), Nitrogen Harvest Index (NHI), Nitrogen Agronomic Efficiency (NAE) and Effect of uptake).

As for the root density (cm 100/cm^3) root samples were collected on the date of harvest and from the 0-25 cm layer using a cylindrical drill (25 cm long, 10 cm in diameter). For each sample, roots were separated from soil after standing for 24 h in water *$(NaPO_3)_6$ *Na_2CO_3. For the density determination of the roots, the samples were placed in a high-resolution scanner using DT software (Delta-T Scan version 2.04; Delta-T Devices Ltd, Burrwell, Cambridge, UK). In addition there were determined the LAI, using SunScan (Delta-T Devices Ltd), and the plants' height (cm) on the harvest day. There were weighted 1000 seeds (mg) per plot. Dry Matter yield in upper parts, Stover, (kg/ha), were measured after drying for 72 h at 75°C. The harvest was done in 13% moisture content, when it was measured the total yield (kg/ha).

As for the determinations, the samples were chosen randomly within each plot and all of them were ground to fine powder, according to the Kjeldahl method (Bremner, 1960) using a Buchi 316 device.

Nitrogen uptake in seeds (kg/ha) and total nitrogen uptake (kg/ha) were estimated by equation 1 and equation 2 respectively.

$$\text{N-uptake seed} = \text{N \% in seeds} * \text{Dry matter yield upper parts} \quad (1)$$

$$\text{N-uptake total} = \text{N yield upper parts (kg/ha)} * \text{N yield seed (kg/ha)} \quad (2)$$

Moreover, Nitrogen Use Efficiency (NUE) was estimated by the following equation (eq.3).

$$\text{NUE} = (\text{total N uptake (kg/ha)}_{\text{fertilizer}} - \text{total N uptake}_{\text{control}} \text{(kg/ha))/ kg N/ha} \quad (3)$$

Nitrogen Harvest Index (NHI) is an indicator which is defined as a ratio of the concentration of N in seeds (N uptake in seeds) to the total N in the plant (total N uptake) (eq. 4).

$$NHI = \textit{N uptake seed (kg/ha)/ total N uptake (kg/ha)} \quad (4)$$

Nitrogen Agronomic Efficiency (NAE), is an indicator which shows the amount of seed produced per kg of N fertilizer (eq. 5).

$$\text{NAE} = (\text{seed yield}_{\text{fertilizer}} - \text{seed yield}_{\text{control}})\text{/N kg of fertilizer} \quad (5)$$

Furthermore was determined the Effective of Uptake which shows the ration of yield to total nitrogen uptake (eq. 6).

$$\text{Effective of Uptake} = \text{Yield (kg/ha)/ total N uptake (kg/ha)} \quad (6)$$

Statistical Analysis

Analysis of variance was carried out on data using the Statistica (Stat Soft, 2011) logistic package as a Completely Randomized Design. The Analysis of Variance (ANOVA) used a mixed model, with years and replications as random effects and fertilization as fixed effects. Differences between means were separated using Tukey's test. Correlation analyses were used to describe the relationships between growth parameters and yield components using Pearson's correlation. All comparisons were made at the 5% level of significance ($p \leq 0.05$).

Results

In Table 1 are presented the agronomic characteristics. In the root density, the values ranged from 27.08 to 52.25 cm/cm^3 in the first year and from 34.68 to 55.10 cm/cm^3 in the second year. The N80 had not statistically significant difference with the control and the N40 had not statistically significant difference with the N120, in the both years. The highest value was 55.10 cm/cm^3 in N120, in the second year and the lowest was 27.08 cm/cm^3 in the control in the first year. Also, in the LAI (Leaf Area Index), the highest value was 3.47 in the N120 in the first year and the lowest was 2.78 in the control, in the second year. The N40 had not statistically significant difference with the control and the N80 had not statistically significant difference with the N40 and N120, in the both years.

Moreover, in the plant height the values ranged from 55.58 to 67.93 cm in the first year and from 56.23 to 71.83 cm in the second year (Table 1). The N40 had not statistically significant difference with the control, but in the second year had statistically significant difference between

Table 1. The agronomic characteristics of teff as effected by fertilizer treatments

	Root density, cm 100/cm^3	LAI	Plant height, cm	1000 seed weight, mg	DM yield upper parts STOVER, kg/ha	Yield, kg/ha
			Year A			
Control	27.08^a	2.92^a	55.58^a	256.79^a	2318.25^a	417.25^a
N40	35.15^b	3.10^{ab}	59.48^{ab}	266.58^{ab}	2420.10^{ab}	484.50^b
N80	44.65^a	3.24^{bc}	64.35^{bc}	275.38^{bc}	2496^{bc}	569.25^c
N120	52.25^b	3.47^c	67.93^c	286.63^c	2571^c	621^d
			Year B			
Control	34.68^a	2.78^a	56.23^a	266.09^a	2292^a	433.25^a
N40	47.03^b	3.02^{ab}	63.38^b	277.30^b	2406.75^{ab}	477.75^a
N80	52.73^a	3.19^{bc}	66.63^{bc}	282.72^a	2496^{bc}	555.75^b
N120	55.10^b	3.42^c	71.83^c	291.03^b	2556.75^c	598^b
F_{fert}	*7.78****	*19.06****	*24.49****	*13.50****	*17.64****	*82.19****
F_{year}	*4.56**	*ns*	*4.97**	*6.38**	*ns*	*ns*
$F_{fert\ x\ year}$	*ns*	*ns*	ns	ns	ns	ns

F-test ratios are from ANOVA. Different letters within a column indicate significant differences according to Tukey's test (α = 0.05) *Significance levels:* * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns, not significant ($p > 0.05$)

them. The highest value was 71.83 cm in the N120 in the second year and the lowest was 55.58 cm in the control in the first year.

Furthermore, in the 1000 seed weight the first year, statistically the same was true of LAI. But in the second year, the control had not statistically significant difference with the N80 and the N40 had not statistically significant difference with the N120. The values ranged from 256.79 to 286.63 mg in the first year and from 266.09 to 291.03 mg in the second year. The highest value was 291.03 mg in the N120 in the second year and the lowest was 256.79 mg in the control in the first year. In the dry matter in upper parts the values ranged from 2318.25 to 2,571 kg/ha in the first year and from 2292 to 2556.75 kg/ha in the second year (Table 1). The N40 had not statistically significant difference with the control, in the both years. The highest value was 2571 kg/ha the N120, in the first year and the lowest was 2292 kg/ha in the control in the second year. Also, in the yield the all treatments had statistically significant difference between them in the first year. On the other hand, in the second year, the control had not statistically significant difference with the N40 and the N80 had not statistically significant difference with the N120. The highest value was 621 kg/ha in the N120 and the lowest was 417.25 kg/ha in the control in the first year (Table 1).

Moreover, in the percentage of nitrogen in upper parts, the control had not statistically significant difference with the N80 and the N40 had not statistically significant difference with N120, in the first year (Table 2). On the contrary, the second year the N40 had not statistically significant difference with the N80. The values ranged from 1.33 to 1.55% in the first year and from 1.29 to 1.37% in the second year. The highest value was 1.55% in the N120, in the first year and the lowest was 1.27% in the control in the second year. In the first year the values were higher than in the second year. Also, in the percentage of nitrogen in the seeds, the N40 had not statistically significant difference with N80 and N80 had not statistically significant difference with the N120. On the other hand, in the second year the control had not statistically significant difference with the N40. The highest value was 2.1% in the N120, in the second year and the lowest was 1.80% in the control, in the first year (Table 2). Furthermore, in the nitrogen uptake in upper parts the control had not statistically significant difference with the N80 and the N40 had not statistically significant difference with the N120, in the first year.

In the second year the control had not statistically significant difference with the N120. The highest value was 39.76 kg/ha in the N120 in the first year and the lowest was 29.51 kg/ha in the control, in the second year. Also, in the nitrogen uptake in seed, the N80 had not statistically significant difference with the N120, in the first year, in the second year the control had not statistically significant difference with the N40. The values ranged from 7.52 to 13.17 kg/ha in the first year and from 8.36 to 12.94 kg/ha in the second year. In the nitrogen total uptake the control had not statistically signifi-

Table 2. The nitrogen indicators as effected by fertilizer treatments (NUE nitrogen use efficiency; NHI nitrogen harvest index; NAE nitrogen agronomic efficiency)

	N in upper parts, %	N in seeds, %	N uptake in upper parts, kg/ha	N uptake in SEED, kg/ha	N_{total} uptake, kg/ha	NUE	NHI	NAE	Eff of uptake (seed yield/ N_{total} uptake)
Year A									
Control	1.33[a]	1.80[a]	30.79[a]	7.52[a]	38.31[a]	ns	0.20[a]	ns	10.97[ns]
N40	1.42[b]	1.96[b]	34.30[b]	9.50[b]	43.80[ab]	0.05[a]	0.22[a]	1.68[a]	11.12[ns]
N80	1.45[a]	2.07[bc]	36.16[a]	11.80[c]	47.96[bc]	0.05[a]	0.25[b]	1.90[b]	11.95[ns]
N120	1.55[b]	2.12[c]	39.76[b]	13.17[c]	52.93[c]	0.05[a]	0.25[b]	1.70[a]	11.83[ns]
Year B									
Control	1.27[ns]	1.93[a]	29.51[a]	8.36[a]	37.87[a]	ns	0.22[a]	ns	11.44[ns]
N40	1.29[a]	2[ab]	30.96[ns]	9.56[a]	40.52[ab]	0.03[a]	0.24[b]	1.11[a]	11.80[ns]
N80	1.37[a]	2.07[bc]	34.29[ns]	11.52[b]	45.80[bc]	0.04[b]	0.25[a]	1.53[a]	12.16[ns]
N120	1.39[ns]	2.16[c]	34.99[a]	12.94[c]	47.93[c]	0.04[b]	0.27[b]	1.37[b]	12.52[ns]
F_{fert}	*ns*	*27.04******	*7.08******	*80.84******	*23.03******	*36.16******	*8.05******	*27.49******	*ns*
F_{year}	*7.50**	*5.22**	*5.73**	*ns*	5.85*	8.78**	ns	4.44*	ns
$F_{fert\ x\ year}$	ns	ns	ns	ns	ns	ns	ns	ns	ns

F-test ratios are from ANOVA. Different letters within a column indicate significant differences according to Tukey's test (α = 0.05). *Significance levels:* * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns, not significant ($p > 0.05$)

cant difference with the N40 and the N40 had not statistically significant difference with the N80, in the both years. The highest value was 52.93 kg/ha in the N120, in the first year and the lowest was 37.87 kg/ha in the control, in the second year (Table 2). In nitrogen uptake efficiency (NUE), in the first year the treatments had not statistically significant difference between them. In the second year, the N80 had not statistically significant difference with the N120. The highest value was 0.05 in the first year and the lowest was 0.03 in the N40 in the second year. In nitrogen harvest index (NHI), the control had not statistically significant difference with the N40 and the N80 had not statistically significant difference with the N120 in the first year.

On the contrary, in the second year the control had not statistically significant difference with the N80 and the N40 had not statistically significant difference with the N120. In the nitrogen agronomic efficiency (NAE), the N40 had not statistically significant difference with the N120 in the first year.

In the second year the N40 had not statistically significant difference with the N80. The highest value was 1.90 in the N80 in the first year and the lowest was 1.11 in the N40, in the second year. Additional, in the effective of uptake all treatments in both years were not statistically significant, but the highest value was 12.52 in the N120, in the second year and the lowest was 10.97 in the control, in the first year (Table 2).

Discussion

Nitrogen generally affects the agronomic characteristics of plants. Sharma (1973) reported that the addition of nitrogen results in an increase in plant height as well as an increase in leaf count.

Murtada (2004) mentioned that the Teff consists of large crown and many tillers resulting in a shallow diverse root system. In our study, in the root density, higher amounts of nitrogen showed an increase in root density. And this is evident from the positive correlation between root density and N uptake in upper parts ($r = 0.58$, $p = 0.01$) as well as with the N total uptake ($r = 0.60$, $p = 0.01$), (Table 3). In contrast, Svoboda & Haberle (2006) report that in higher amounts of nitrogen the root density decreased. Ishaq et al. (2001) and Oussible et al. (1992) report that any value in the resistance of the penetration meter above 2.0 MPa results in a significant reduction in the development of the root growth.

Concerning the leaf area index (LAI), the highest amount of nitrogen had the maximum values of LAI. LAI had positive correlation with root density ($r = 0.71$, $p = 0.001$), with the nitrogen in upper parts ($r = 0.53$, $p = 0.01$) and with N

Table 3. Correlation matrix between agronomic characteristics and nitrogen indicators

	Root density, cm 100/cm	LAI	Plant height, cm	1000 seed weight, mg
Root density, cm 100/cm^3	1	0.69 ***	0.71***	0.80***
LAI	0.69 ***	1	0.77 ***	0.66***
Plant height, cm	0.71 ***	0.77***	1	0.78***
1000 seed weight, mg	0.80***	0.66***	0.78***	1
DM yield upper parts STOVER, kg/ha	0.78***	0.92***	0.83***	0.76***
N in upper parts, %	0.43*	0.53**	0.13^{ns}	0.16^{ns}
Yield, kg/ha	0.24^{ns}	0.57**	0.59**	0.43*
N in seeds, %	0.48*	0.59**	0.76***	0.63***
N uptake in upper parts, kg/ha	0.58**	0.70***	0.35^{ns}	0.36^{ns}
N uptake in SEED, kg/ha	0.32^{ns}	0.60**	0.66***	0.51*
N_{total} uptake, kg/ha	0.60**	0.79***	0.51**	0.47*
NUE	-0.52**	-0.07^{ns}	-0.13^{ns}	-0.46*
NHI	-0.14^{ns}	0.04^{ns}	0.36^{ns}	0.21^{ns}
NAE	-0.44*	-0.07^{ns}	-0.10^{ns}	-0.40^{ns}
Eff of uptake (seed yield/ N_{total} uptake)	-0.38^{ns}	-0.21^{ns}	0.11^{ns}	-0.02^{ns}

Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns, not significant ($p > 0.05$)

total uptake (r = 0.79, p = 0.001) as shown in Table 3. Which means that as the amount of nitrogen applied increases, so does the leaf area index. Gasim (2001) reported that the number of leaves per plant was higher in nitrogen application compared to the control.

Moreover the plant height, increased as the nitrogen increased. Similar results are shown by Roussis et al (2019), where inorganic fertilization was the result of higher Teff plants. Giday et al. (2014) notes that as the applied dose of nitrogen increased, the height of the Teff plants increased. The plant height had positive correlation with the LAI (r = 0.77, p = 0.001) as like as with the dry matter yield upper parts stove (r = 0.83, p = 0.001) (Table 3).

As for the weight of a thousand seeds, there were statistically significant differences between the operations where the highest amounts of nitrogen were recorded and the largest weight of the kilograms of seeds. Contrary, Roussis et al. (2019) reported that there was no difference between treatments, but the highest weight appeared in inorganic fertilization. The high concentration of nitrogen in the seeds affects the weight of a thousand seeds and this is proved by the positive correlation that exists between the percentage of nitrogen in the seeds and the weight of thousands of seeds (r = 0.63, p = 0.001) as shown in Table 3.

Giday et al. (2014) stated that the dry matter yield in above ground part of the plant (stover) was increased as the applied nitrogen increased. Similar results were recorded in our study where the highest value appeared in the highest dose of nitrogen in both years of experiment. The dry matter yield in upper parts affects important agronomic characteristics of the plant such as LAI, plant height, the root density, as well as the weight of a thousand seeds as shown in Table 3.

Several studies have shown a positive relationship between yield and increasing levels of nitrogen fertilization (Geleto et al., 1995; Giday et al., 2014). Similar results were recorded in both years where the experiment was performed. The highest yield was in the highest dose of nitrogen.

According to our results (Table 2), the percentage of nitrogen content in the upper parts showed its highest value in the highest amount of nitrogen while the lowest was in the control. In addition there were positive correlated with the leaf area index (Table 3) (r = 0.53, p = 0.01). As for the nitrogen in the seeds in this study, it was statistically higher at application of 120 kg N per hectare. According to Kidanu (1999) applied nitrogen fertilizer improves the N content in grain and straw of both in wheat and teff cultivation.

Nitrogen uptake in the upper parts and in the seeds as well as the total N uptake showed their highest value in the higher amount of nitrogen. Moreover, there was a positive correlation between total N uptake and the LAI (r = 0.79, p = 0.001). Several studies have reported that applied nitrogen was associated with N intake (r = 0.90, p = 0.01) as there was a negative correlation between applied and total nitrogen (Kakabouki et al., 2019; Mirutse et al., 2009).

The main role of nitrogen indicators is to see how effectively nitrogen is used by plants. Nitrogen Use Efficiency (NUE) is an indicator that refers to the amounts of nitrogen that can be used effectively by plants. Thus, the higher the NUE value, the higher the nitrogen absorption of the crop. In the present study has revealed the same value in all nitrogen treatments except control. According to Table 3 it was negatively correlated with root density (r = -0.52, p = 0.01). Girma & Raun (2011) reported that nitrogen fertilizers play an important role in improving NUE in teff cultivation.

Furthermore, the nitrogen harvesting index (NHI) refers to the amounts of nitrogen uptake added to the seeds. In this study, NHI showed its highest value at both 80 kg N and 120 kg N per hectare. In addition, according to Gebretsadik et al. (2009), the highest harvest index (0.304) was at the 69 kg N per hectare application.

Nitrogen Agronomic Efficiency (NAE) is the indicator that informs us about the effect of applied N on seed yield. The higher is this index, the higher is the yield of the seeds. In this study, there was a negative correlation between it and root density (r = -0.44, p = 0.005) (Tabe 3). Also, NAE was higher at 80 kg N applied per hectare. The effective of uptake indicator refers to the amounts of nitrogen uptake involved in seed yield. According to the results of the present study (Table 3), there were no statistically significant differences between fertilizer treatments for this indicator. Thus, the different amounts of nitrogen applied did not significantly affect seed yield.

Conclusion

In conclusion, different doses of nitrogen fertilization had different effects on agronomic characteristics and nitrogen indicators for the teff crop. The highest plant height, yield and values in nitrogen indicators recorded in the highest doses of nitrogen in the both years. With the indicators' values, we conclude that the 80N and the 120N amounts were the most efficient. There have been differences between the two years, mainly between treatments.

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