Vol. 14(6), pp. 345-353, 7 February, 2019
DOI: 10.5897/AJAR2018.13696
Article Number: B2C30D260194
ISSN: 1991-637X
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African Journal of Agricultural Research

Full Length Research Paper

Biomass accumulation and potassium concentrations in tissue of Teff (*Eragrostis tef Zucc.* Trotter) at three growth stages in Vertisols and Nitisols of the Central Highlands of Ethiopia

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Received 31 October, 2018; Accepted 17 January, 2019

Understanding the physiology and time-course of above ground biomass (AGBM) and potassium (K) accumulation pattern in plants and removal from soil is essential to simultaneously increase crop yield and synchronize K demand and K supply, thereby predict crop yield. It is also an essential criterion for optimizing fertilizer practices, and may help to enhance soil and crop quality. A pot experiment was conducted using teff (*Eragrostis tef Zucc. Trotter*) to determine AGBM, K concentration and uptake at three growth stages. Two soil types (Vertisols and Nitisols) and four K levels were used. Soil samples (120) were collected at planting and three stages while plant samples (160) were collected at the three growth stages. Above ground biomass increased as growth stage advances regardless of K levels in both soil types. Maximum AGBM was observed at tillering stage and at 120 kg K ha^{-1} and was higher in Vertisols at all growth stages. The study concluded that sufficient supply of nutrients from soil/fertilizers at early growth stages is required for higher yields. The study suggested that determining the right rate for different soil and crops is required. Repeating the experiment at field condition to draw sound conclusions was also recommended.

Key words: Growth stages, potassium concentration, biomass, teff, Vertisols, Nitisols, Central Highlands.

INTRODUCTION

Teff (*Eragrostis tef Zucc.* Trotter) is a major cereal crop indigenous to Ethiopia (Demissie, 2011; Seyfu, 1997) but is a minor cereal crop worldwide (Schneider and Anderson, 2010; Yigzaw et al., 2001). In other countries like Australia, South Africa, and United States, it is principally used as a forage crop for animal feed. Teff is a warm-season, annual grass that has rapid seed germination and seedling development. It is also well adapted to dry climates. In Ethiopia, teff performs well in 'Weina Dega' agro-ecological zones or medium altitude with ranges of 1,700 to 2,400 m above sea level. Depending on variety and altitude, teff requires 90 to 130

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days for growth (Gebretsadik et al., 2009). Teff has large area coverage annually in Ethiopia and it was first (24%) in area coverage and second in production (17.29%) in 2016/2017 cropping season. An area of 3.02 million ha was cultivated and yielded 5.02 million metric tons (Central Statistics Agency of Ethiopia (CSA), 2017).

Potassium (K) is an essential element for crop growth. It plays a vital role as macronutrient in plant growth and sustainable crop production. Adequate K nutrition enhances the efficiency of photosynthetic apparatus (Wang et al., 2012; Zhao et al., 2001) and promotes plant roots (Zia-Ul-Hassan and Arshad, 2010). However, K has been given less attention than nitrogen (N) and phosphorus (P) with respect to increasing cereal production because the effect of K on increasing cereal production is more gradual compared with N and P, especially in K-enriched soils (Niu et al., 2011). Potassium uptake and availability for plant growth and development vary depending on environmental conditions associated with a particular set of growing conditions. The soil itself contributes greatly to K availability. Availability and uptake of potassium (K) is often complicated by many interacting components. Two factors that have predominating effects are the soil and plant characteristics involved. A third factor is improved fertilizer and management practices, which can be used to modify the inherent characteristics of soils and plants involving K uptake (Mallarino and Murrell, 1998).

Vertisols and Nitisols are the major crop growing soils in Ethiopia. Vertisols cover 12.6 million ha, or about 10% of the country. In addition, there are 2.5 million ha of soils with vertic properties. About 70% of these soils are in the highlands and about 25% (1.93 million ha) of the highland Vertisols are cropped (Debele, 1985). Different reports provide different area estimates of Nitisols in the Ethiopian highlands (Zewdie, 2013). The most recent survey puts the extent of Nitisols to cover about one million ha that account for 31% of the agricultural lands in the Ethiopian highlands (Elias, 2016). The soils are particularly extensive in the south-western and north-central highlands representing 64 and 25% of the agricultural landmass, respectively (Elias, 2017).

Like other cereals, the development of the above ground organs of teff, the dynamics of biomass accumulation, the yield and other traits are all fundamentally influenced by ecological conditions (Fufa et al., 2001), variety traits and the technology used to manage them (Teklu and Tefera, 2005). Of the many factors involved, the most decisive ones are the water supplies, the yield potential and the nutrient supplies (Assefa et al., 2011; Tulema et al., 2005). The amounts, dynamics and within-plant distribution patterns of biomass accumulation and nutrient uptake vary with growth stage of the plant (Karlen and Whitney, 1980; Lal et al., 1978), and are affected by crop species, cultivars and soil-climatic conditions (Gawronska and Nalborczyk, 1989).

In small grains, seed yield is closely related to total biomass production (Reynolds et al., 1999; Vandenboogaard et al., 1995). Grain yield has usually been positively correlated with total DM production and nutrient accumulation in crops (Rhoads and Stanley, 1981). Meanwhile, DM accumulation and nutrient accumulation vary with growth stage of crops (Jones et al., 2011; Miller and Jacobsen, 2004). Cereal crops generally followed a similar pattern of biomass and nutrient accumulation in the growing season, which increased continuously with growing time, maximum biomass accumulation rate and amount usually occurred at late boot stage (46 to 47 Days after emergence (DAE)) and ripening stage (Malhi et al., 2006).

Teff crop was generally fertilized by farmers in Ethiopia using either nitrogen only or nitrogen (N) and phosphorus (P) fertilizers, mainly as urea and Di-ammonium phosphate (DAP) fertilizers. Intensive farming of cereal crops to produce more food often compels the use of additional nutrients, besides N and P, in Ethiopia in recent years. Response to application of nutrients such as K, S, Zn and other micronutrients are reported (Astatke et al., 2004; Haile and Boke, 2011; Mulugeta et al., 2017,2018) and soils are also showing deficiency of these nutrients (Ethiopian Soils Information System (EthioSIS), 2016).

The increased focus on optimizing yield response to nutrient inputs and the need to ensure balanced nutrition has increased demand for information on biomass accumulation, nutrient concentration and nutrient sufficiency levels of crops and on the relationship of biomass accumulation and nutrient uptake to seed yield. However, there is little information available to date, on the accumulation and distribution of biomass and nutrients of teff throughout the growing season in Ethiopia. For whole and seasonal mineral nutrients requirements of crops, fertilizer scheduling and synchronizing nutrient supply with nutrient demand of the crops, it is essential to determine the exact amount of nutrient uptake over the growing season. The availability of K may further be conditioned by the demand of K at different growth stages, the information on which is not available for teff in Ethiopia (Mulugeta et al., 2018).

The objective of this study was therefore to determine the dynamics of biomass accumulation in the plant biomass, changes in nutrient concentration during the growing period, and the nutrient uptake of teff grown in a fertilization experiment in two different soil types collected from central highlands of Ethiopia.

MATERIALS AND METHODS

A pot experiment was conducted using teff (*E. tef*, variety-Kuncho) as test crop in a lath house in the period between October 2015 and February 2016 at the Debre Zeit Agricultural Research Center (08° 46’10.10’’ N and 38° 59’56.13’’ E) and an altitude of 1889 m.a.s.l. Sixty surface representative soil samples were obtained by composing 10 to 12 random cores from the top 20 cm from major soil types varying in available K, pH and texture across 20 teff growing districts of Ethiopia to be used as test soils in this experiment. The soils were collected from areas identified as low, medium and high based on their available K status by the national soil fertility status mapping report (Ethiopian Soils Information System (EthioSIS), 2013). The samples were mixed, air-dried, and passed through 1 cm sieve to remove gravel and debris and prepared for pot trials. A portion of the sample was ground and sieved through a 2 mm sieve for physical and chemical analyses. The particle size distribution was done by the HORIBA-Partica (LA-950V2) laser scattering particle size distribution analyzer (Agrawal et al., 1991) and LA-950 software version 7.01 for Windows (Horiba Ltd, NextGen® 2010). Soil pH and electrical conductivity (EC) were measured using 1:2.5 and 1:5 soil: water ratios, respectively. Exchangeable K, Ca, and Mg and available P, Sulfate-S and extractable Zn were extracted following Mehlich-3 (M-3) procedure (Mehlich, 1984). Organic carbon was predicted from mid infrared spectra of soil samples using OPUS version 7.0 software (Bruker® Optic GmbH, 2011) with 32 scans and spectral range of 7400 to 600 cm^{-1} (wave numbers) including part of NIR region.

The pot trial was conducted by using a total of 3 kg of the dried soil sample in a plastic pot having 16 cm top and 14 cm bottom diameters. Four levels of potassium: 0, 60 120 and 180 kg ha^{-1} K, were applied as potassium chloride (60% K_2O) replicated three times in a completely randomized design. There were thus 12 pots per soil and a total of 720 experimental pots. To ensure that K was the only nutrient element limiting teff production, optimum and uniform doses of N, P, S and Zn were applied at the rates of 120, 60, 15 and 3 kg ha^{-1}, respectively, as NPSZn compound fertilizer (12-45-0 + 5S+1Zn). Of the nutrients supplied, 100% of P, K, S and Zn and 30% of N were applied as basal fertilizers before planting while 70% of N was applied as urea 30 days after planting to all pots. All the nutrients were applied as solution. Teff was planted in each pot, managed well and harvested at maturity and the required data were collected and analyzed. Based on the data, the critical limits of potassium in soil was determined graphically by plotting percentage yield against soil available K using the procedure of Cate and Nelson (1971). Out of these soils collected from 60 locations, soils collected from 10 locations, five each for Vertisols and Nitisols, were selected and the soil of each pot was thoroughly mixed and the old roots sieved out and refilled to their respective pots in 5 replications for both soils making a total of 40 pots as experimental unit.

The lath house experiment was conducted between November 2016 and February 2017 at the Debre Zeit Agricultural Research Center. Three kilograms of the dried soil sample was placed into a plastic pot (16 cm top and 14 cm bottom diameter). To ensure that K was the only nutrient element limiting teff production, optimum and uniform dose of N, P, S and Zn (120, 60, 15 and 3 kg ha^{-1}), respectively were applied as NPSZn compound fertilizer (12-45-0+5S+1Zn). In this experiment, similar doze and type of nutrients were applied, except for K. Plants growing in the soil of the previous check pots had to draw further K from the soil while the plants growing in the formerly fertilized soils had largely profited from the residual effect of the previously applied nutrient. Of the nutrients supplied, 100% of P, S and Zn and 30% of N were applied as basal fertilizers before planting while 70% of N was applied as urea 30 days after planting to all pots. All nutrients were applied as nutrient solution. The soil samples collected from each pot were mixed, air-dried and sieved to pass through a 1 cm screen for pot trials. A portion of the sample was ground and sieved through a 2 mm screen for physicochemical analysis. About 30 uniform seeds were sown in each pot. Soil moisture was maintained at nearly 60% field capacity throughout the experiment. Watering and intercultural operations like weeds control and plant protection measures were employed uniformly in each pot whenever required. The plant samples were collected by mowing close to the surface from 1/3 of the pot area in each stage at three separate growth stages. The first sampling occurred at tillering; the second at heading, and the last at the maturity stage for determinations of biomass and K concentration. Similarly, soil samples were collected at planting and the three growth stages. Accordingly, 160 soil and 120 plant samples were collected and analyzed. For the soil samples, exchangeable K, Ca, and Mg and available P, Sulfate-S and extractable Zn were extracted following Mehlich-3(M-3) procedure (Mehlich, 1984).

Plant nutrient concentrations were assessed on the harvested product. The teff plant samples were washed with distilled water to remove the dust and soil particles from the samples. The sun-dried plant samples were kept in paper bags and then dried at 65°C in an oven to constant weight. The dried samples were weighed for their dry matter (DM) yield. The dried plant samples were separately powdered in a warring stainless-steel grinder. Dry powdered plant samples were ashed in a muffle furnace at 500°C and then the ash was extracted in 10 ml of 6N HCl and dried on hot plate for 15 min at 140°C. The ash was dissolved in 10 ml of 1N HCl and K content in filtered digest was analyzed with Inductive Couple Plasma (ICP). Total K uptake was calculated by the following formula as used by Sharma et al. (2012).

K uptake (kg ha^{-1}) = (% K in the plant × Total dry matter (kg ha^{-1}) / 100

Data were analyzed by analysis of variance using SAS software version 9.2 (SAS Institute Inc, 2008) and graphs were developed using Excel. The differences between treatments were tested using the least significant difference (LSD) test at the 0.05 probability level.

RESULTS AND DISCUSSION

Soil properties

The results revealed that soil texture varied from clay loam to clay, with the clay content varying from 29 to 75.0% with a mean clay content of 45% and the sand content varies from 13 to 31% with a mean value of 24% (Table 1). These values show that the clay fraction of the soil sample was higher than silt then much higher than sand in that order.

The soil pH values ranged from 5.0 to 7.8 with a mean value of 6.0 indicating the soils were mostly acidic in reactions. Some of the tested soils had pH < 5.5 (Table 1) showing the characteristics of a highly weathered tropical soil. The pH also shows that these soils are suitable for crop production (Quirine et al., 2005; Redmon and Mcfarland, 2013). In accordance with the ratings of (Ethiopian Soils Information System (EthioSIS), 2016), the available P ranged from very low to medium, exchangeable K from low to high, while available S and extractable Zn were low and medium, respectively (Table 1). The data also showed that the experimental soils were variable not only in their K status but also in other physical and chemical parameters.

The result also showed that the predominant exchangeable cation, which accounts for more than 80% of the exchange complex was Ca^{++} followed by Mg^{++}, K^{+} and Na^{+}. Exchangeable Ca, Mg and K content in the studied soils ranged from 2072.5 to 11548.6 mg kg^{-1} and

Table 1. Physico-chemical properties of the experimental soils (Vertislos and Nitosols) collected from 60 locations in central highland of Ethiopia.

Soil type	Site	Soil parameters									
		Sand	Clay	Textural class	pH	Av. P	Exch. K	Exch. Ca	Exch. Mg	Sulfate S	Extract. Zn
		(%)			(1:2.5)	(mg kg^{-1})- Mehlich-3					
Nitisols	1	31	29	Clay loam	5.8	14.7	175	2651.1	488.1	13.13	7.68
	2	25	38	Clay loam	5.1	6.2	179	2370.0	563.7	11.86	5.21
	3	29	42	Clay	5.9	5.7	186	1419.3	356.4	14.31	3.01
	4	24	44	Clay	5.0	10.5	198	2369.3	482.0	16.93	4.07
	5	26	43	Clay	6.5	7.9	216	2357.7	590.3	12.49	4.77
Vertisols	1	23	47	Clay	5.7	22.1	245	2072.5	473.3	12.12	5.15
	2	26	36	Clay loam	5.1	5.7	252	2268.1	450.9	11.57	5.18
	3	13	75	Clay	7.8	37.5	345	11548.6	874.7	19.14	6.98
	4	19	57	Clay	7.2	40.1	415	10955.2	797.9	17.18	8.19
	5	22	36	Clay loam	5.7	42.1	699	4741.5	1031.6	11.92	4.36

Av= Available; Exch.= exchangeable; Extract = extractable.

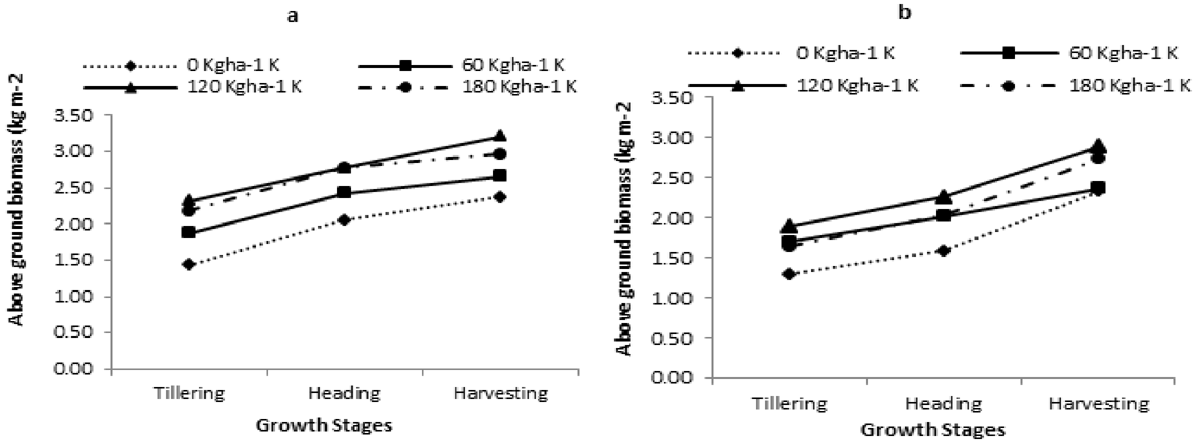

Figure 1. Changes of biomass (kg DM m^{-2}) of teff with growth stage in the pot experiments at Debre Zeit, on a) Vertisols and b) Nitisols.

356.4 to 1031.6 mg kg^{-1}and 175 to 699 respectively. Similarly, available P ranged from 5.7 to 42 .1 mg kg^{-1}. The available P content of vertisols was much higher than nitisols in the test soils. Sulfate S and extractable Zn varied from 11.86 to 19.14 mg kg^{-1} and 3.01 to 8.19 mg kg^{-1}. Vertisols have higher values of most of the parameters except pH than nitisols indicating that vertisols have better inherent soil fertility condition than nitisols (Mamo et al., 2001).

Aboveground biomass

Determination of above ground biomass indicated that biomass accumulation increased with plant age, the maximum being at late growth stage (Figure 1). Similar results were reported by Malhi et al. (2006) in their studies on wheat, barley and oat crops reported that the biomasses of the crops reached their estimated maximum at ripening growth stage. Gawronska and Nalborczyk (1989) also observed similar seasonal biomass accumulation among different winter rye (*Secale cereale* L.) cultivars, despite considerable differences in morphology and absolute values of biomass.

Biomass accumulation increased with increasing K level up to 120 kg K ha^{-1} and decreased afterwards (Figure 1) and was significantly (p<0.0001) different from the other K levels (Table 2). Generally, higher biomass

Table 2. Aboveground biomass, and soil and plant K concentration and K uptake of teff at different growth stages in Vertisols and Nitisols of central highlands of Ethiopia.

Parameter	Soil K concentration (mg kg^{-1})	Aboveground biomass K concentration (%)	Aboveground biomass (kg m^{-2})	Aboveground biomass K uptake (kg ha^{-1})
Treatment (T)	***	***	***	***
Soil type (ST)	***	***	***	***
T × ST	NS	NS	NS	NS
Stage (S)	***	***	***	NS
T × S	NS	NS	NS	NS
ST × S	NS	NS	NS	NS
T × ST × S	NS	NS	NS	NS
CV	9.92	12.04	16.04	19.77
LSD	14.47	0.06	0.18	23.08
Treatments				
0 kg ha^{-1} K	262.78^{c}	0.91^{c}	1.84^{c}	155.34^{c}
60 kg ha^{-1} K	273.01^{bc}	1.09^{ab}	2.17^{b}	230.15^{b}
120 kg ha^{-1} K	287.41^{b}	1.14^{a}	2.56^{a}	283.14^{a}
180 kg ha^{-1} K	314.59^{a}	1.05^{b}	2.39^{a}	241.38^{b}
LSD	0.0648	0.1845	23.08	10.235
Soil type				
Vertisols	358.47^{a}	1.10^{a}	2.42^{a}	263.14^{a}
Nitisols	210.42^{b}	0.99^{b}	2.06^{b}	191.87^{b}
LSD	10.24	0.05	0.13	16.32
Stage				
Tillering	268.18^{b}	1.32^{a}	1.79^{c}	238.08^{a}
Heading	292.64^{a}	1.01^{b}	2.24^{b}	227.96^{ab}
Maturity	292.52^{a}	0.81^{b}	2.69^{a}	216.47^{b}
LSD	12.54	0.06	0.16	19.99

Significant at *P ≤ 0.01, **P ≤ 0.001, ***P ≤ 0.0001; NS: Not significant; LSD- least significant difference; CV- coefficient of variations; Means followed by same letter(s) within a column do not differ at P ≤ 0.05.

was observed in Vertisols than Nitisols and the effect of K application had similar trend for both soil types for pots that received K. In pots that did not receive K, biomass increment was not similar to those that received K, especially in Nitisols. This result indicated that potassium application in Nitiosls has much significant effect than Vertisols. This might be attributed to the low initial soil K level in Nitisols, which ranged from 175 to 216 mg kg^{-1} soil, while the range was from 245 to 699 mg kg^{-1} in Vertisols (Table 1) indicating that soils with low K status respond more to application of the nutrient as compared to those with high K status. The findings were in line with the results of Meena et al. (2015) on sorghum and Zou and Lu (2008) on rapeseed, which showed higher response to K in soils with low K status and low response in high K status soils.

Besides, the higher production of dry matter and absorption of K by the teff plant from K fertilized pots as compared to control indicated that teff has greater potential to produce better grain yield when appropriate rate of K is applied under optimum nutrition of other nutrients for its proper growth and development.

Potassium concentration in the plant

Maximum concentrations of K were attained at the tillering stage in both soils for all treatments and the contents decreased with advanced plant age (Figure 2 and Table 2). Potassium fertilizer application increased K concentrations at all the stages over the control. Average maximum K concentration was obtained with application of 120 kg K ha^{-1} in Vertisols and 60 kg K ha^{-1} in Nitisols. The concentration of potassium was rapidly decreased with plant age (Figure 2) and the values appeared to be affected by K fertilization. This is in line with results of

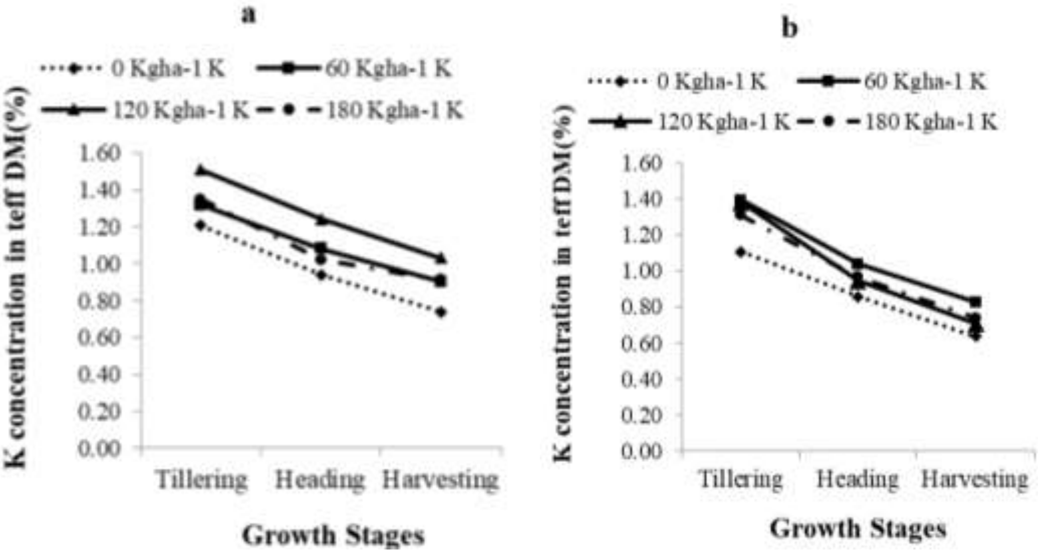

Figure 2. Changes of K concentration in teff biomass (%) at different growth stages in the pot experiments at Debre Zeit, on a) Vertisols and b) Nitisols.

Rhue et al. (1986) and Westermann et al. (1994) which indicated decreases in K concentration as growing season advances.

There are two viewpoints about plant nutrient concentration at different growth stages: (1) decreasing plant nutrient concentrations with increasing DMY may result in a dilution effect and (2) decreasing DMY with increasing plant nutrient concentrations may be due to toxicity effects. Our results showed that DMY increased with application of K because of accelerated plant growth, but K concentration of plant decreased, probably because of the dilution effect. For instance, Izsáki and Kádi (2013) reported a 33% K dilution in 30 days in Jerusalem Artichoke (*Helianthus tuberosus* L.). Besides, the high nutrient concentration in younger tissues is related to water content of the tissue as young tissues are rich in nutrients which are dissolved in water, mainly in the vacuole and in the cytosol (Mengel and Kirkby, 2001).

Potassium uptake by the aboveground biomass

The results indicated that the K uptake by the biomass of teff was significantly (p<0.0001) affected by the different treatments (Table 2). Mean potassium uptake was 191.87 kg ha^{-1} in Nitisols and 263.14 kg ha^{-1} in Vertisols. The highest K uptake was observed at the application of 120 kg K ha^{-1}, which was statistically different from other treatments (Table 2). The lowest K uptake was recorded in the control (without K application). Potassium uptake by teff follows a pattern similar to dry weight accumulation, except that dry matter continued to increase until maturity, whereas maximum K accumulation was reached at tillering after which there was a decrease. Similar result was reported by Akporhonor et al. (2005) on maize. Potassium uptake showed different trends across growth stages in the two soils (Figure 2). In Nitisols, K uptake was the highest at tillering stage, decrease at heading and showed a slight increase at maturity (Figure 3b), while in Vertisols the highest K uptake was at tillering and gradually decreased afterwards (Figure 3a).

A comparison of the two soil types showed that the uptake of K was significantly (p<0.0001) higher in Vertisols than Nitisols (Table 2). This could be explained by the higher aboveground biomass yield and K concentration of teff in Vertisols as compared to Nitisols. Besides, the higher K uptake in Vertisols could be associated with the soil moisture content, as availability of K is strongly related to soil water content (Olivera et al., 2004).

Potassium concentration in the soil

The soil analytical data showed that the soil K content significantly (P < 0.0001) increased with increasing K rates at all growth stages, and the difference between the soil types was also significant. Potassium concentration was higher in Vertisols than Nitisols (Table 2). The two soils vary in their K status a different growth stages may be based upon whether fixation or release dominates, which in turn is dependent upon the types of clays and the amount of weathering they have undergone (Laboski and Carrie, 2006). Besides, soil test levels were higher in fertilized pots than the unfertilized and increased with increasing K rates (Figure 4).

The concentration of soil K showed inverse relationship

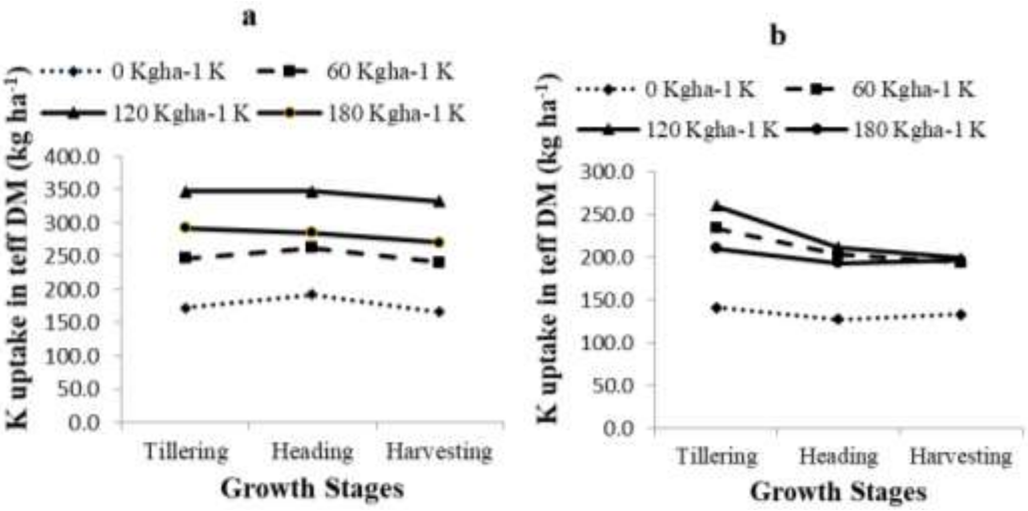

Figure 3. Changes of K uptake in soils (kg ha^{-1}) at different growth stages in the pot experiments at Debre Zeit, on (a) Vertisols and (b) Nitisols

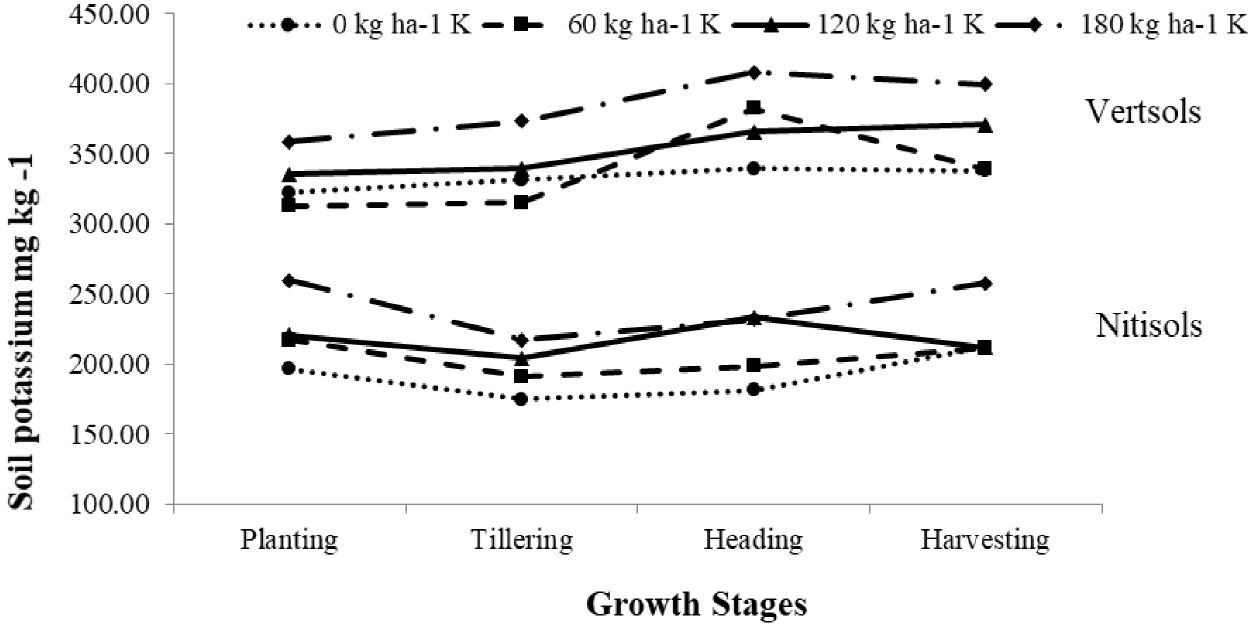

Figure 4. Changes of K concentration in soils (mg kg^{-1}) at different growth stages in the pot experiments at Debre Zeit, on Vertisols and Nitisols.

with plant K concentrations and plant age. As the plant gets older, teff plant K concentration decreased, whereas the soil K level increased. These could be due to moist condition of the soil that allows continuous release of K from the soil during the growing season, as well as the decreased uptake of K with advanced growth stage (Sangakkara et al., 2001).

Usually, soil and plant nutrient concentrations, for most nutrient elements, are positively correlated such that a greater concentration of available nutrient in the soil would be reflected in the plant-tissue nutrient contents. However, one of the reasons why concentrations of some plant nutrients do not mirror soil concentrations is that the plant nutrient concentration reflects not only soil nutrient concentration but also plant age and availability of other nutrients (Mengel and Kirkby, 2001). For short-season crops, there is evidence that a large proportion of the total K uptake occurs during early stages of growth and the K availability at this stage determines the final yield (Costigan et al., 1983).

Conclusion

Measuring aboveground biomass and nutrient concentrations may help us understand the fertility requirements of teff and lead to better fertilization programs for the crop. The results of our experiment revealed that application of K fertilizer increased the aboveground biomass, plant and soil K concentration and K uptake by teff. The K concentrations in the plants were maximum at tillering in both soil types and decreased with advanced growth stages. Both above ground biomass accumulation and plant K uptake generally followed a similar pattern in the growing season, whereby both increased continuously with growing age, with a much faster increase at early growth stages than at late growth stages. Potassium application significantly affected biomass accumulation, K concentration in the plant and K uptake, the highest being at 120 kg K ha^{-1}. Higher yield was obtained on vertisols than nitisols. On the other hand, plant K concentration was not positively related to the soil K content, which might be due to other factors affecting its availability. The findings suggest that the supply of nutrients from soil and fertilizers must be sufficient at early growth stages to ensure that plants have higher nutrient uptake rate at tillering for optimum development and thereby higher yields. The findings on K fertilization at different stages are new for teff as well as for cereals in Ethiopia. Thus, the present recommendation to apply nutrients at early stage of growth will provide useful information both on the time and levels of potassium application for teff. However, we suggest repeating the experiment under field conditions to draw sound conclusions.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

ACKNOWLEDGEMENTS

Financial support was provided by the International Potash Institute (IPI)/Israel Chemicals Limited (ICL) and Agricultural Transformation Agency (ATA). The authors are also thankful to the Debre Zeit Agricultural Research Center for allowing the lath house for the study.

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