Appraisal of mineral content of *desho* grass (*Pennisetum pedicellatum* Trin.) as affected by stage of maturity and agro-ecologies in Ethiopia

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Abstract: Ash determination of forages may not exactly tell the mineral status of forage crops as livestock feed. Therefore, it is important to determine common minerals to have useful information for livestock nutrition as this helps to mitigate mineral deficiency of farm animals rely on that particular forage. The aim of the research was to determine the mineral content of desho grass harvested in different harvesting dates and altitudes for ruminant livestock production in the highlands of Ethiopia. The samples of desho grass were collected from different harvesting dates and altitudes to see the concentration of common macro and micro minerals. The samples were analyzed for common macro-minerals (Ca, K, P, Mg and Na) and micro minerals (Mn, Fe, Cu and Zn). The results indicated most of the concentration macro minerals were not significant (P>0.05) due to altitude factor except Mg and P which were significant. In terms of harvesting dates, only Mg and Ca were significant (P<0.05) while other minerals were non-significant. The analysis of minerals in the current study indicated that desho grass contains most of required minerals for herbivores which depend on it. However, for high producing animals adequate supplementation of both macro and micro minerals could be advantageous.

Keywords: Ash, Desho grass, macro minerals, mincro minerals

1. Introduction

Mineral elements are inorganic nutrients derived by plants through their roots which are the contact points with the soil. The mineral elements absorbed by plants are then converted into plant products. The latter are then fed to livestock for conversion into animal products (Payne, 1994; Martin and Robertsa, 2000). These mineral elements are believed to have one or more catalytic functions in the cell (Biswas and Mukherjee, 1995). Minerals are dietary essentials for animals and herbage content of minerals below the requirement of animals adversely affects both intake and digestibility (Crowder, 1985). Grazing and browsing animals usually obtain from feed resources they directly get from the environment. Mineral requirement of animals is influenced by type and level of production, age, level and chemical form of elements and management practices (Little, 1982). The availability of minerals in feed resources depends on various factors such as stage of maturity of plants and method of feeds prepared, soil type and environmental factors in which feeds produced (Khan *et al*., 2005). The interaction of different factors make complex the situation for livestock producers not easily determine the optimum amount of minerals required for their stock (Dost, 2001).

Though there are efforts to understand sources and optimum amount of energy and protein nutrients for livestock nutrition in the tropics have been given more emphasis thus far. However, optimal production and productivity of livestock is only possible if there is an adequate supply of minerals (Khan *et al*., 2004). Forages are important sources of minerals for grazing or forage feed livestock. Hence, the feeding value of a given forage source depends on its chemical composition and nutritional content and palatability. As a result, information of forage constituents of animal feed is central to animal production and productivity. The nutritional value of forage is independently and as a group affected by a variety of factors, including variety, soil, climatic, kind and stage of utilization, management and stage of growth. Nutrients composition of forages also varies from time to time and location to location (De Leeuw, 1979).

Desho grass *(Pennisetum pedicellatum* Trin), belongs to the *Poaceae* family and tribe *Paniceae*. The species belonging to the genus, Pennisetum, constitute a heterogeneous assemblage ranging from diploids to octoploids with either sexual or apomictic reproductive behavior having annual, biennial or perennial life cycle (Martel *et al*., 1997). The grass provides high yields green herbage ranging between 30-109 t/ha (Ecocrop, 2010) and compares favorably with Sorghum bicolor or other Pennisetum species. It responds well to fertilization and could be combined with fodder legumes either in mixtures or in rotational cropping. In short rotation with maize or groundnuts, it yields better than traditional forage grasses, especially when fertilized, while the roots and stubbles also increase soil fertility. To obtain the highest yield, *desho* grass should be cut 4 months after sowing at 8 cm from ground level (Leta *et al.*, 2013). *Desho* grass is used in temporary pastures or in cut-and carry systems since it provides ample quantities of good quality green forage and stands several cuts a year. The grass is also useful for hay and silage preparation (Ecocrop, 2010).

Desho grass is native to tropical Africa and now widespread within 20°N and 20°S. The grass mainly found on disturbed land, road edges and recent fallows, in areas where annual rainfall ranging between 600 mm and 1500 mm with a rainy season of 4-6 months and average daily -temperatures of about 30- 35°C. *Desho* grass thrives on a wide range of soils (including degraded sandy or ferruginous soils) provided they are well drained. However, the grass is susceptible to water logging and frost but has some drought tolerance (Ecocrop, 2010; FAO, 2010). *Desho* grass is used as a soil stabilizer.

Once planted, *desho* grass maintenance activities such as applying fertilizer, weeding and gap filling, are required to ensure proper establishment and persistency of *desho* grass (Solomon *et al.*, 2010). Fertilizer should be applied throughout the plot one month after planting. It is recommended to use organic compost in the form of animal manure, leaf litter, wood ash, food scraps, and/or any other materials rich in biodegradable matters (Danano, 2007). After this initial treatment, fertilizer is only applied sporadically when *desho* plants are struggling to grow or where replanting has taken place. Weeding and gap filling are continuous activities in *desho* grass production. After 2 to 3 years, maintenance inputs decrease substantially or cease altogether as the grass cover closes up and the plot becomes a sustainable fodder source. Past interventions have shown that *desho* based grazing land management practices are best implemented when communal grazing land is re-distributed into small plots (less than 0.5 ha) that are convenient for individual use, development and management (Danano, 2007).

According to McDonald *et al*. (2010), plants and plant products from the main supply of nutrients to animals, and the composition of plants will influence the animal's mineral intake. Thus, the species and stage of maturity of the plant, the type of soil and climate, and the seasonal conditions are important factors. Indeed much knowledge into the mineral element content of the grass *Pennisetum pedicellatum* in their natural environment in the tropics including Ethiopia is not available as the grass is not highly researched. The study was conducted to determine the effects of altitude and stages of maturity on mineral composition of desho grass (P. *pedicellatum* Trin.*) in Ethiopia.*

2. Materials and Methods

2.1 Description of the experimental sites

The agronomic component of this study was conducted in two agro-ecologies (mid altitude and high altitude) using a rain fed system. The mid altitude area was represented by Andassa Livestock Research Center located at 11^0 2900 N and 37^0 2900 E at an altitude of 1730 m above sea level. Farta District Office of Agriculture (2014) provided summary climatic data for the area which receives about 1434 mm of rainfall annually. Mean annual temperature varies from a maximum of 29.5 ^{0}C to a minimum of 8.8 ^{0}C. The soil type is dark clay and seasonally waterlogged with 3.4% organic matter, 0.17% total nitrogen and pH of 6.9. The highland area was represented by Farta district, Tsegure Eyesus Kebele (Kebele is the local administration in Ethiopia) at a site called Melo located near Debre Tabor Town, at $11^0$11' N and 38^0E and at an altitude of 2650 m above sea level. The soils of Melo site are characterized by clay and sand mixture with chemical composition of 2.26% organic matter, 0.11% total nitrogen and pH of 5.47. The mean annual rainfall is about 1570 mm and the mean maximum and minimum annual temperatures were reported to be 21.5 ^{0}C and 9.6 ^{0}C respectively.

2.2 Land preparation and planting

The agronomic characteristics of the grass were studied at Andassa Livestock Research Center, located in West Gojam and in Farta district of South Gondar Zone of the Amhara Regional State. Andassa Livestock Research Center (ALRC) is located at $11^0$29" N and $37^0$29" E at an altitude of 1730 m.a.s.l. The study area receives about 1434 mm of rainfall annually. The mean annual temperature vary from a maximum of 29.5^{0}C in March to a minimum of 8.8^{0}C in January. The soil of the center is dominantly dark clay soil, which is water logged in the rainy season and crack during dry period (ALRC, 2014). The highland of Farta district called Melo site, is located near Debre Tabor Town. The area is located at latitude and longitude of $11^0$11’ N latitude, 38^oE longitude and at an altitude of 2650 meters above sea level. The major soils of the district comprises of 20% black, 30% red, and 50% brown. The mean annual rainfall is 1570 mm and the mean minimum and maximum annual temperature is 9.6 ^{0}C and 21.5 ^{0}C, respectively (FDoA, 2014). The laboratory chemical analysis was conducted at International Livestock Research Institute, Animal Nutrition Laboratory (Addis Ababa). The feeding and digestibility trial was done at sheep research farm of Zenzelma Campus, Bahir Dar University.

A total area of 81 m^2 was selected from each of the mid land and high land locations. These were ploughed in May and harrowed in June 2014. The prepared experimental land was divided in to three blocks each of which comprised three plots (3 x 3 m^2 each). *Desho* grass obtained from Southern Nationals and Nationalities by CASCAPE (Capacity Building for Scaling up of Evidence Based Best Practices in Agricultural Production in Ethiopia) project was planted using vegetative root splits in rows on a well-prepared soil. Soil samples were taken from each plot before planting and analyzed for major elements such as N, P, C, OM, pH, and texture. The spacing between rows and plants were 50 and 10 cm, respectively. Land preparation, planting, weeding and harvesting was made according to the recommendations by Leta *et al*. (2013).

2.3 Mineral analysis

The concentration of Ca, Mg, Fe, Zn, and Mn were determined by atomic absorption spectrophotometry (Perkin-Elmer AAS Analyst 100, USA) while flame photometer was used for K and Na analysis. Phosphorus concentration was determined colorimetrically (AOAC 1990).

2.4 Statistical analysis

All data was analyzed with General Linear Model (GLM) procedure of SAS (2007) for least square analysis of variance. Mean comparisons were done using Duncan's Multiple Range Test (DMRT) for variables whose F-values declared a significant difference. Differences were considered statistically significant at 0.01% and 0.05% significance level. The statistical model for the analysis of data was:

$Y_{ijk}= \mu +Al+H_i+Al*H+e_{ijk}$

Where, yijk=all dependent variables (morphological data and chemical composition) collected μ = overall mean

H_i = the effect of i^{th} harvesting days (90, 120 and 150 days)

H_i*Al_j= the interaction of harvesting day and altitude

e_{ijk} = random error

The data were analyzed using the General Linear Model (GLM) of SAS 9.2 (2002). Turkey's honest significant test was employed for separation of treatment means.

3. Results and Discussion

3.1 Mineral composition of desho grass

3.1.1 Calcium (ca) content

The result of Ca content of the *Pennisetum pedicellatum* Trin. grass in the current study was higher than the reports of Heuze *et al*. (2015), Imoro *et al* (2012) for the same species but lower than the reports of Aguiar *et al*. (2006) for pangola grass. The calcium content of desho grass in the current study is higher than the requirement of a 3.7 g/Kg DM for a 20 kg live weight sheep grows 100 g/ day and 2.6.g/ Kg DM for growing 500 kg cattle (Underwood and Suttle, 1999). Forages are generally satisfactory sources of calcium (Ca) for grazing livestock, particularly when they contain leguminous species. Minson (1990) gives the average published values as 14.2 and 10.1 g Ca kg per kg dry matter (DM) for temperate and tropical legumes and 3.7 and 3.8 g Ca kg21 DM for the corresponding grasses. Forage calcium requirements of grazing animals are influenced by animal type and level of production, age and weight (McDowell, 1985). However, it has been suggested that ruminants with high production of milk or any product may increase up the level of 1.2 to 2.6 g/kg for lactating animals. Generally, Sykes and Field (1972) suggested that levels of 2.5 g/kg are adequate in most circumstances. The minimum calcium and phosphorus requirements generally recommended for the maintenance of domestic livestock under range conditions are 0.32% and 0.17%, respectively and beef cattle require 0.16% to 0.60% calcium and 0.16% to 0.43% phosphorous of dry matter ration, depending on sex, age, and growth condition (NRC, 1970).

Though phosphorus is very critical in dairy diets (Hersom, 2010), calcium and phosphorus have integrated functions in animals and the absorption as well as intake of calcium and phosphorus must be adequate since the absorption of these two important minerals depends on their combined ratio. Variations in the levels of Ca between the present findings and those already reported in the literature could be partly due to mature forage specie, composition of forages and environmental conditions.

3.1.2 Phosphorous (P) content

The mean phosphorous content found in the current study was in agreement with the phosphorous content for Pangola grass (Heuze *et al*. 2015) but higher than reports of Aguiar *et al* (2006) for *Pennisetum pedicellatum* and *Pennisetum gaucum*. Phosphorous content of desho grass was within the range of the general requirement of livestock. The phosphorus status of forages varies widely and is influenced primarily by the phosphorus status of the soil, the stage of maturity of the plant and the climate. On average, phosphorus concentrations increase by 0.03–0.05 g kg21 dry matter (DM) mg21 extractable soil phosphorus (Minson, 1990; Jumba *et al*., 1995). Temperate forages generally contain more phosphorus (P) than tropical forages (3.5 vs. 2.3 g P kg21 DM) and legumes slightly more than grasses (3.2 vs. 2.7 g P kg21 DM) (Minson, 1990), but there are exceptions. Tropical legumes, such as *Stylosanthes*, grow vigorously on soils that provide insufficient phosphorus for other species, but their phosphorus status remains low (often < 1.0 g P kg21 DM). Distribution of phosphorus between leaf and stem is relatively uniform, but there is a marked reduction in whole-plant phosphorus concentrations as the forage matures, particularly during the dry season.

3.1.3 Magnesium (Mg) content

The mean magnesium content of desho grass in the current study was 4.22 g/kg. The result is lower than the reported in Gana (Imoro *et al*., 2012). The magnesium content of herbage plants varies with the species and with the soil and climatic conditions in which the plants are grown. In temperate pastures, leguminous species are usually richer than grasses in magnesium (Mg), as they are in calcium (Thomas *et al*., 1952; Turner *et al*., 1978). The finding is in agreement with the results of Minson (1990) 2.6 and 2.8 g Mg per kg DM reported for temperate and tropical grasses.

3.1.4 Manganese (Mn) content

The function of manganese (Mn) in the animal body is related to manganese deprivation has been shown to impair immunity (Hurley and Keen, 1987) and central nervous system (CNS) function (Hurley, 1981). The available Mn in desho grass was within the recommended dose 16 mg/Kg DM of feed for sheep and cattle. However, the result of manganese in the current study was lower than Zafar *et al*. (2009).

3.1.5 Zinc (Zn) content

The mean zinc concentration of desho grass was 18.34 mg/kg which was lower than most pastures the mean zinc concentration in pastures is 36 mg kg21 dry matter (DM);values vary widely (range 7 to 100 mg kg21 DM), but a high proportion lie between 25 and 50 mg kg2

DM (Minson, 1990). The requirement of Zn for ruminants is with the range of 18–42 mg Zn kg21 DM, which appears adequate. Also, Zn concentration was found adequate for growing ruminants suggested by Zafar *et al*. (2009).

3.1.6 Iron (Fe) content

The mean iron (Fe) concentration of desho grass in the current study was 319.65 mg/kg which is much higher than the recommended adequate level for grazing animals (McDowell, 1985; Khan *et al*., 2005). High Fe of desho grass in the current study is in agreement with earlier reports of other countries (Khan *et al*., 2003; Zafar *et al*., 2009). Most plant materials used in the feeding of farm animals contain large, though variable, concentrations of iron, depending on the plant species, the type of soil on which the plants grow and the degree of contamination by soil. Experiments with weaned growing–finishing lambs show that 10 mg Fe kg21 DM is inadequate and that their minimum requirements lie between 25 and 40 mg kg21 DM (Lawlor *et al*., 1965).

3.2 Effect of location on mineral concentration of *desho* grass

The effect of altitude on mineral concentration of desho grass is presented in Table 1. The result indicated all of the micro minerals analyzed from desho grass were not significant (P>0.05). From the macro minerals calcium (ca) was not significant (P>0.05) due to altitude however magnesium (Mg) and phosphorous (P) were significantly affected (P<0.05) by differences in environment.

Table 1: Mineral composition of *desho* grass

	Minerals					
Location	Fe (mg/Kg)	Zn (mg/Kg)	Mn (mg/Kg)	Mg (g/Kg)	Ca (g/Kg)	P (g/Kg)
Mid	386.7^{a}	19.1^{a}	81.8^{a}	5.1^{a}	3.9^{a}	2.9^{b}
High	252.6^{a}	17.6^{a}	58.5^{a}	3.3^{b}	3.4^{a}	2.3^{a}
Mean	319.7	18.3	70.2	4.2	3.7	2.6
SD	186.6	2.4	27.3	1.3	0.8	0.5

SE= standard Error; Means under each row with different superscripts are significantly different (P<0.05).

3.3 Effect of stage of maturity on mineral concentration of *desho* grass

The effect of stage of maturity (early, mid and late) on mineral concentration of desho grass is presented in Table 2. The result indicated all of the micro minerals analyzed from desho grass were not significant (P>0.05) due to differences in stage of maturity. The magnesium and calcium concentrations of desho grass however, were decreased (P<0.05) as the time of harvesting increased. This may be due to the fact that grasses vary in their genetic capacity to take up minerals from the soil and in their mineral requirements for growth. The concentration of minerals in forages is determined largely by its stage of growth. The result of this finding is in agreement with reports on macro-minerals in Napier grass which declined with advancing stage of growth (Minson, 1990; Kariuki *et al*., 1999).

Table 2: Mineral composition of *desho* grass

	Minerals					
Maturity stage	Fe (mg/Kg)	Zn (mg/Kg)	Mn (mg/Kg)	Mg (g/Kg)	Ca (g/Kg)	P (g/Kg)
Early (90 days)	398.3[a]	19.3[a]	80.2[a]	5.2a	4.4[a]	2.7[a]
Mid (120 days)	282.2[a]	18.5[a]	76.2[a]	3.9[b]	3.7[b]	2.6[a]
Late (150 days)	278.5[a]	17.2[a]	54.0[a]	3.6[b]	3.1[b]	2.5[a]
Mean	319.7	18.3	70.2	4.2	3.7	2.6
SE	186.6	2.4	27.3	1.3	0.8	0.5

SE= standard Error; Means under each row with different superscripts are significantly different (P<0.05).

The results of this study are in agreement with different workers (Underwood, 1981; Little, 1982; Kariuki *et al*., 1999) who stated that mineral concentration in forages decline significantly with maturity, but the rate and extent of this decline varies with time of year, soil type, soil nutrient levels and seasonal conditions. Kariuki *et al*. (1998) also reported that grass harvested at younger stage contains satisfactory levels of calcium (Ca) and phosphorus (P) that can sustain acceptable growth performance of animals (Kariuki *et al*., 1998).

Different workers in Ethiopia on other species grasses (Zinash *et al*., 1995; Diriba, 2000; Adane, 2003) reported that the ash concentration of the grasses declined significantly as cutting interval increased. Moreover, Hassan *et al*. (1990) reported that ash content of grass significantly declined as days of harvesting increased from 2 to 8 weeks. Taye (2004) reported the highest ash content of Napier grass at shortest days of harvesting after planting. Bana grass harvested at 10 weeks of age contained 9.3% ash (Gwayumba *et al*., 2002). Schreuder *et al*. (1993) reported that bana grass harvested at 9, 12, 18 and 22 weeks of age produced 17.2, 15.5, 15.4 and 15.3 % ash, respectively. Total ash was also influenced by the available plant density per unit area. This implies that the mineral content in the plant tissue decreases and the uptake gradually increases with increment of plant density mainly for dilution of minerals account of higher population of grasses in the higher planting density resulted in inter and intra-specific competition. When mineral nutrients in herbage are marginal in respect of animal requirements, changes in concentrations brought about by climatic, managerial or seasonal influences and plant maturity are significant factors in incidence of deficiency state in livestock which wholly or largely depend on plants (Underwood, 1981).

Taking the common macro minerals, calcium and phosphorus content of grasses was affected by days of harvesting (Kariuki *et al*., 1999). The highest calcium (0.80%) and phosphorus content (0.21%), and the lowest calcium (0.53%) and phosphorus content (0.17%) of Napier grass were obtained at 68 and 114 days of harvesting, respectively (Tessema *et al*., 2002). In contrast, Wirch *et al*. (2000) on similar grass reported that there were no significant differences in calcium and phosphorus content at 30 and 40 days of harvesting interval. Overall the here was significant difference ($P<0.05$) in calcium content (Ca) of *desho* grass harvested at different dates after harvesting and significantly higher percentage composition of calcium was recorded from the grass harvested at 90 and 120 days after planting). On the contrary, phosphorus content (P) of the grass showed variation with change in altitude rather ($P>0.05$) than with variation. Among macro minerals, phosphorous and calcium are the most important nutrients required for normal animal performance. The P content of the *desho* grass planted in the mid altitude was (2.86g/kg) significantly higher than that planted in the high altitude (2.32g/kg), which may be due to the variation in soil characteristics and climatic condition which determine the uptake of soil nutrients by the plants. Deficiencies of minerals in livestock nutrition likely to affect production of pasture based livestock under extensive livestock production systems unless mineral content and overall nutrient content status of such pastures are monitored.

4. Conclusion

Knowing only the ash content of forage grass materials does not provide sufficient information to rely solely upon whereas the amount of the respective minerals present often gives information that is more useful. This study was primarily aimed at giving an insight into the identification of mineral content of *desho* grass harvested in different stages and altitudes. Most of the mineral components were above the requirement of animals as recommended by NRC. The results of this study revealed that the content of minerals in *desho* grass was affected by both location and stage of maturity. Moreover, though the finding of this research indicated that almost all of the minerals were within the range of required levels of livestock. Thus, to have more crucial information on bioavailability of mineral elements, further study on animals fed *desho* grass based diet and the recommended levels of mineral nutrients needed in their diet. As a conclusion, further study should be conducted on multiplications and using different fertilizer types and rates to find the maximum amount of each mineral from the grass for better livestock production in the area.

Conflict of interest

The author declares that there is no conflict interest regarding the publication of this paper in the journal.

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