Registration of New Napier Grass Varieties: Zehone-02 and Zehone-03

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Abstract

Background: Napier grass is a pioneer perennial forage crop and performs well in diverse environments. It produces a high biomass yield and could be also categorized as high-quality forage, which is highly palatable when young and leafy.

Objective: To register and release high yielding, stable, and disease tolerant Napier grass varieties.

Materials and Methods: Ten Napier grass varieties including a standard check (ILRI-16984) were tested for forage dry matter yield, herbage quality, pest and disease reaction, and other agro-morphological characteristics across three locations (Holetta, Debrezeit, and Hawassa Agricultural Research Centers) during the main cropping seasons of 2011–2014. Based on the overall performance, three superior varieties (16791, 15743, and 16819) were selected and verified with the standard check at Holetta, Kulumsa, and Wondo-genet Agricultural Research Centers during the main cropping season of 2016.

Results: The results indicated that the candidate varieties had significant forage dry matter yields, crude protein contents, and digestible yields advantages over the standard check. Among the varieties, Zehone-02 (16791) had the highest advantages of forage dry matter yield, crude protein content, and digestible yield over the standard check and other candidate varieties. Moreover, the candidate varieties had advantages of leaf to stem ratio, crude protein content, and *in vitro* organic matter digestibility over the standard check. Based on the criteria of the Eberhart and Russell regression model, Zehone-02 (16791) and Zehone-03 (16819) varieties had better mean forage dry matter yield but less stable when compared to the standard check.

Conclusions: Among the tested candidate varieties, Zehone-02 (16791) variety was released for its better forage dry matter yield, while Zehone-03 (16819) variety for its thin-stemmed nature stature. Therefore, both Napier grass varieties (Zehone-02 and Zehone-03) were released in 2017 for production in the mid and high altitude areas and similar agro-ecologies in the country.

Keywords: Adaptation; Agro-morphological characteristics; Dry matter yield; Quality attributes; Reaction; Yield stability

1. Introduction

Napier grass [*Pennisetum purpureum* (L.) Schumach], also known as elephant grass, originated in sub-Saharan tropical Africa (Clayton *et al*., 2013) and occurs naturally throughout tropical Africa and particularly in East Africa (Lowe *et al*., 2003; Mwendia *et al*., 2006). It is a pioneer forage crop species and performs well in low, mid, and highland areas of Ethiopia (Tessema Zewdu, 2005). According to Fekede Feyissa *et al.* (2005), Napier grass grows best at high temperatures but can tolerate low air temperatures under which the yield can be reduced and ceases to grow at a temperature below 10 °C. Napier grass is propagated vegetatively by using stem cuttings, root splits, or shoot tips (Tessema Zewdu, 2008) which usually vary across agro-ecologies (Getnet Assefa and Gezahagn Kebede, 2012). For best establishment and productivity, it should be planted at the distance of 1 m between rows and 0.5 m between plants (Tessema Zewdu, 2008). However, the spacing could vary based on the climatic conditions of the area. Narrower spacing is often used for moisture-stressed areas when compared with high moisture areas (Gezahagn Kebede *et al*., 2017). Amongst the improved forage crops promoted in Ethiopia, Napier grass could play an important role in providing a significant amount of biomass yield of 20 to 30 t DM ha^{-1} $year^{-1}$ with good agronomic and management practices (Farrell *et al*., 2002). Napier grass can provide a continual supply of green forage throughout the year and best fits all intensive small-scale farming systems (Alemayehu Mengistu, 1997).

The yield performance of Napier grass genotypes is heavily influenced by agro-ecology, climatic

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conditions, management practices, and edaphic factors. Genotypic variation in growth characteristics of Napier grass has also been reported (Mwendia *et al.*, 2006) and growth and morphological characteristics are correlated with dry matter yield and nutritional quality (Tudsri *et al.*, 2002). The cultivation of high-quality forages with high yielding ability and adaptability to biotic and abiotic environmental stresses is one of the possible options to increase livestock production under smallholder farmers' conditions (Tessema Zewdu, 1999). Despite the huge livestock population in the country, the productivity of animals in Ethiopia is lower than the regional and continental average. Among the factors contributing to low productivity, the availability of poor-quality feed resources remains to be the major bottleneck to livestock production. Because most smallholder livestock producers predominantly own small and fragmented pieces of land, grasses such as Napier grass offer a best-fit alternative to other feed options, as these are high-yielding forage plants that require a minimum amount of inputs and acreage. The yield of Napier grass mainly depends on the type of cultivar used which in turn is influenced by both the environment and management practices employed. To improve livestock production, sustainable solution to seasonal deficiencies in feed availability and quality are required through proper management and utilization of developed forage crops.

The number of released Napier grass varieties is too small in the country. So far, only one Napier grass variety (ILRI-16984) has been released by Holetta Agricultural Research Center in 1984 (MoA, 2017) which produces low yield and quality when compared to the yields and quality of the current released varieties. Livestock production is highly constrained by the low quantity and quality of feed in Ethiopia particularly in the drier seasons. Napier grass variety, which produces better forage yield and quality per unit area, is a prerequisite to reduce the feed shortage problem of the country. So, testing the adaptability and yield potential of Napier grass varieties across various agro-ecological zones is very important to identify the best-bet varieties for efficient utilization. Accordingly, two Napier grass varieties, named Zehone-02 (16791) and Zehone-03 (16819) have been officially released owing to their better yield potential and quality to address the feed demand of mixed crop-livestock farming systems. Therefore, this paper presents the forage yield performance, herbage qualities, agro-ecological adaptation, reaction to major diseases and pests, and other morpho-agronomic and management recommendations for the recently developed and released Napier grass varieties (Zehone-02 and Zehone-03) in Ethiopia.

2. Varietal Evaluation

Ten Napier grass varieties including the standard check (ILRI-16984) were considered to select the best performing varieties for release. The experiment was conducted under field conditions at Holetta, Debrezeit, and Hawassa during the main cropping seasons of 2011 to 2014. The varieties were planted at the beginning of the main rainy season in three agricultural research centers. The varieties were planted in a 4 m x 4 m plot using a randomized complete block design (RCBD) with three replications and the varieties were assigned randomly to plots within the block. Root splits at Holetta and stem cuttings at Debrezeit and Hawassa were planted in four rows per plot. Stem cuttings with three nodes were planted to the depth of 15 to 20 cm at an angle of 45°. A total of 32 root splits/stem cuttings were planted per plot with the intra and inter-row spacing of 0.5 and 1 m, respectively. There was an alleyway of 2 m width between blocks and 1m width between plots. A blanket basal fertilize was uniformly applied to all plots in the form of Diammonium phosphate (DAP) at the rate of 100 kg ha^{-1}. After every harvest, the plots were top-dressed with 50 kg ha^{-1} N in the form of urea, of with one-third applied at the first shower of rain and the remaining two-third applied during the active vegetative growth stage of the plant. Plots were hand-weeded during the establishment and subsequent years.

Based on the overall performance, three best performing Napier grass varieties (16791, 15743, and 16819) were selected for a variety verification trial with a standard check (ILRI-16984) at Holetta, Kulumsa, and Wondo-genet agricultural research centers in the 2016 cropping season. The varieties were planted per plot with the intra and inter-row spacing of 0.5 and 1 m apart, respectively on a plot size of 10 m x 10 m. At planting, the recommended fertilizer rate was uniformly applied on the plots at each location. The National Variety Release Committee (NVRC) evaluated the varieties under field conditions in October 2016 and based on the results of their evaluation, two varieties (16791 and 16819) were released in April 2017 to be used by various end-users. The mean plant heights of the varieties over locations are shown in Table 1.

Table 1. Average plant height (cm) of Napier grass varieties as compared to the Standard check tested at Holetta, Debrezeit, and Hawassa in the 2013–2014 cropping seasons.

Variety	Location for varietal evaluation			Mean
	Holetta	Debrezeit	Hawassa	
16791	124.8^{a}	172.8^{a}	158.8^{a}	152.1^{a}
15743	115.8^{a}	132.8^{b}	149.5^{ab}	132.7^{b}
16819	88.3^{b}	124.3^{b}	139.5^{c}	117.4^{c}
ILRI-16984 (standard check)	106.6^{ab}	125.0^{b}	144.7^{bc}	125.4^{bc}
Mean	108.9	138.7	148.1	131.9
CV (%)	10.7	5.4	3.3	7.9
LSD	23.3	14.9	10.0	10.1

Note: *Means followed by different letters within a column are significantly different from each other at P< 0.05. CV = Coefficient of variation (%); and LSD = Least significant difference at 5% probability level.*

3. Agro-Morphological Characteristics

The registered varieties are well adapted to mid and highland areas ranging in altitude from 1500 to 2500 meters above sea level. The varieties performed very well in the areas with annual rainfall ranging from 700 to 1200 mm. The released varieties, named Zehone-02 (16791) and Zehone-03 (16819), have better performance when planted in red nitosol areas.

Napier grass is propagated vegetatively by using stem cuttings, root splits, or shoot tips, which usually vary across agro-ecologies. For best establishment and productivity, it should be planted at the distance of 1m between rows and 0.5 m between plants, giving a population of 20,000 plants ha^{-1}. Stem cuttings with three nodes are planted to the depth of 15 to 20 cm at an angle of 45^{o}. Application of the recommended DAP fertilizer rate at planting and split application of urea fertilizer using the recommended rate after every harvest is very important to boost the yield and quality of napier grass varieties.

The released varieties should be harvested at 1 to 1.5 m height to get optimum biomass yields and herbage quality. The recorded numbers of tillers are 32 and 38 and the leaf to stem ratio is 1.12 and 1.17 for Zehone-02 and Zehone-03 varieties, respectively. The mean forage dry matter (DM) yield (14 and 10 t ha^{-1}), crude protein (CP) yield (0.9 and 0.7 t ha^{-1}), and digestible yield (6.8 and 4.9 t ha^{-1}) are recorded for Zehone-02 and Zehone-03 varieties, respectively. Zehone-03 variety has lower neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) indicating better *in vitro* organic matter digestibility (IVOMD) when compared to Zehone-02 variety. Generally, both released varieties (Zehone-02 and Zehone-03) have similar crude protein (CP) content but Zehone-02 variety has relatively higher ash content. A summary of agro-morphological characteristics of the released two Napier grass varieties is indicated in Table 2.

4. Yield Performance and Stability

Combined analysis indicated that forage DM yield varied significantly among the tested varieties (Table 3). Forage DM yield ranged from 8.0 to 13.0 t ha^{-1} with a mean of 9.9 t ha^{-1}. Generally, Zehone-02 variety produced the highest forage DM yield followed by 15743 and Zehone-03 while the standard check (ILRI-16984) gave the lowest DM yield. Forage DM yield differences occurred due to variations among the tested varieties and testing environments. The rank of the varieties for forage DM yield did not vary across the test environments indicating nonoccurrence of the varietal interaction for this trait across the test environments (Figure 1). When genotypes perform consistently across locations, breeders can effectively evaluate genotypes with a minimum cost in a few locations for the ultimate use of the resulting varieties across wider geographic areas. However, with high genotype by location interaction effects, genotypes selected for superior performance under one set of environmental conditions may perform poorly under different environmental conditions. The result indicated that the candidate varieties have forage DM yield, CP yield, and digestible yield advantages over the standard check (Table 4). Generally, Zehone-02 variety gave the highest forage DM yield, CP yield, and IVOMD yield advantages over the standard check followed by 15743 and zehone-03 varieties.

Table 2. Agronomical and morphological characteristics of 16791and 16819 varieties of Napier grass.

Characteristics	16791	16819
Species	*Pennisetum purpureum*	*Pennisetum purpureum*
Variety name	Zehone-02	Zehone-03
Adaptation	For red nitosol areas	For red nitosol areas
Altitude (m.a.s.l.)	1500–2500	1500–2500
Rainfall (mm)	700–1200	700–1200
Seeding rate (number ha^{-1})	20,000 plants	20,000 plants
Intra row spacing (cm)	50	50
Inter row spacing (cm)	100	100
Planting materials	Root splits/ stem cuttings	Root splits/ stem cuttings
Planting date	Mid-June to mid-July	Mid-June to mid-July
Fertilizer rate (kg ha^{-1})		
DAP	100 kg DAP or 46/18 kg N/P_2O_5	100 kg DAP or 46/18 kg N/P_2O_5
Urea	108.7 kg urea or 50 kg N	108.7 kg urea or 50 kg N
Time of fertilizer application		
DAP	At planting	At planting
Urea	1/3 at the start of rain and 2/3 at active growth stage	1/3 at the start of rain and 2/3 at active growth stage
Plant height at forage harvest (cm)	100–150	100–150
Number of tillers per plant	32	38
Leaf to stem ratio	1.12	1.17
Yield per cut (t ha^{-1})		
Forage Dry matter	12–16	8–12
CP yield	0.79–1.05	0.54–0.85
Digestible yield	6.63–7.05	4.56–5.25
Fodder quality (g kg^{-1} DM)		
Ash	149.5	147.9
CP	60.5	60.5
NDF	778.4	728.5
ADF	492.8	461.4
ADL	67.3	67.2
IVOMD	510.3	512.0
Year of release	2017	2017
Breeder/maintainer	HARC/EIAR	HARC/EIAR

Note: *m.a.s.l. = Meters above sea level; DAP = Diammonium phosphate; NDF = Neutral detergent fiber; ADL = Acid detergent lignin; ADF = Acid detergent fiber; IVOMD= In vitro organic matter digestibility; HARC = Holetta Agricultural Research Center; and EIAR = Ethiopian Institute of Agricultural Research.*

Table 3. Average forage dry matter yield (t ha^{-1}) of Napier grass varieties as compared to the standard check tested at Holetta, Debrezeit Hawassa in the 2013–2014 cropping seasons.

Variety	Location for varietal evaluation			Mean
	Holetta	Debrezeit	Hawassa	
16791	10.5	14.9^{a}	13.5^{a}	13.0^{a}
15743	8.9	11.9^{b}	8.6^{b}	9.8^{b}
16819	7.4	11.3^{bc}	8.0^{b}	8.9^{bc}
ILRI-16984 (standard check)	7.0	9.4^{c}	7.6^{b}	8.0^{c}
Mean	8.5	11.9	9.4	9.9
CV (%)	18.4	8.1	10.1	14.5
LSD	3.1	1.9	1.9	1.4

Note: *Means followed by different superscript letters within a column are significantly different from each other at P< 0.05. CV = Coefficient of variation (%); and LSD = Least significant difference at 5% probability level.*

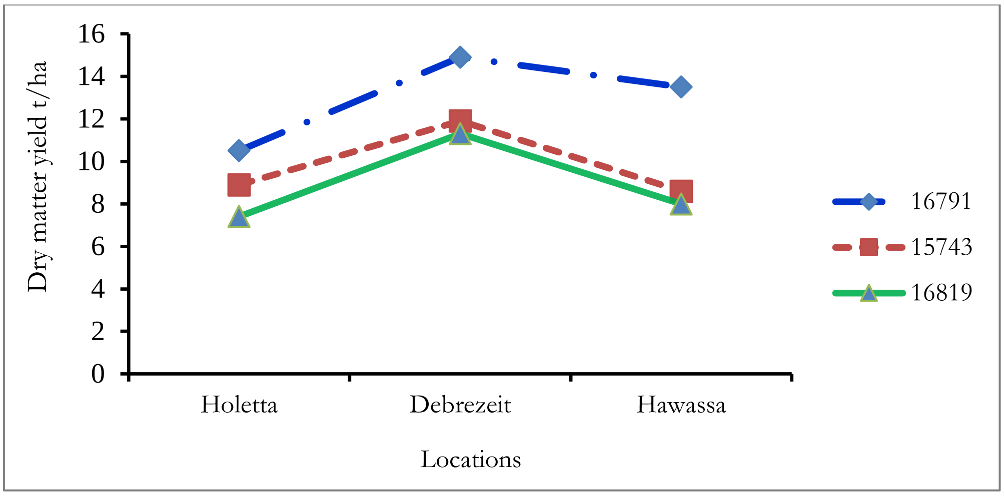

Figure 1. Forage dry matter yield performance of candidate varieties across the test environments.

According to Eberhart and Russell's (1966) model, genotypic performance is generally expressed in terms of three parameters; mean yield, regression coefficient (b_i), and the deviation from regression (S^2d_i). According to this model, a genotype should have a high mean yield, $b_i = 1$ and $S^2d_i = 0$ to decide its stability. According to Finlay and Wilkinson (1963), b_i approximating close to 1.0 indicates average stability, but always be associated and interpreted with the genotype mean yield to determine adaptability. When the regression coefficients for genotypes are approximate to 1.0, deviation from regression close to zero, and are associated with high mean yield, genotypes are adapted to all environments. However, when associated with low mean yield, genotypes are poorly adapted to all environments. The standard check (ILRI-16984) has a minimum deviation from regression and regression coefficient close to 1.0. Based on the criteria of the Eberhart and Russell (1966) regression model, the standard check variety can be considered as more stable but gave the lowest forage DM yield. On the other hand, varieties Zehone-02 (16791), 15743, and Zehone-03 (16819) have high mean forage DM yield but less stable when compared to the standard check.

Table 4. Forage dry matter, crude protein, and *in vitro* organic matter digestible yields advantage of Napier grass varieties over the standard check.

Variety	DM yield	% increase	CP yield	% increase	IVOMD yield	% increase
16791	13.0	62.5	0.79	71.7	6.63	66.6
15743	9.8	22.5	0.57	23.9	5.02	26.1
16819	8.9	11.3	0.54	17.4	4.56	14.6
ILRI-16984 (standard check)	8.0	–	0.46	–	3.98	–

Note: *DM = Dry matter; CP = Crude protein; and IVOMD = In vitro organic matter digestibility.*

5. Reaction to Diseases and Pests

The varieties (16791, 15743, 16819, and standard check) were tested for their diseases and pests reaction starting from the initial stage of evaluation to verification stage and found to be resistant/moderately resistant to major diseases which can affect the varieties (Figure 2). The diseases' effect on the performance of Napier grass varieties were recorded as 0-10% resistant, 11-30% moderately resistant, 31-60% moderately susceptible, and 61-100% susceptible. Accordingly, the released varieties (Zehone-02 and Zehone-03) were found to be resistant to the recorded major diseases (rust, and root rot diseases) as compared to the standard check variety and other candidate variety during the experimental periods. Generally, no pests' problem was recorded during the experimental periods. The resistance reaction of the varieties could be integrated with other diseases management strategies for better results.

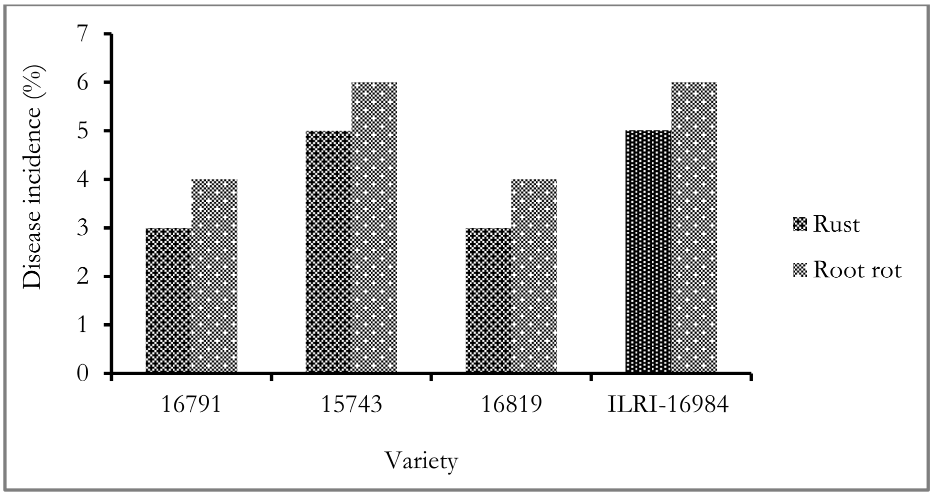

Figure 2. Overall mean response of Napier grass varieties for rust and root rot diseases.

6. Quality Attributes

The chemical compositions and *in vitro* organic matter digestibility of Napier grass varieties are presented in Table 5. The ash content of the candidate Napier grass varieties showed a difference, ranging from 133.7 to 149.5 g kg^{-1} DM. High ash contents in forage plants could be an indication of high mineral concentration. The concentration of minerals in forage varies due to factors like plant developmental stage, morphological fractions, climatic conditions, soil characteristics, and fertilization regime. The crude protein (CP) content of the candidate varieties ranged from 57.7 to 60.5 g kg^{-1} DM. Under high temperatures in the tropics, there is rapid growth and development of grasses resulting in a high rate of decline in the proportion of leaves than stems, which reduce CP content and digestibility. The *in vitro* organic matter digestibility (IVOMD) content of the tested candidate varieties ranged from 510.3 to 512.0 g kg^{-1} DM. The decline in digestibility as Napier grass matured may be attributed to the observed declines in CP content, and an increase in detergent fibers and degree of lignification. The neutral detergent fiber (NDF) content ranged from 728.5 to 778.4 g kg^{-1} DM. The decline in digestibility may, therefore, have been mainly due to the fiber chemistry and anatomical structure of the cell wall rather than its content. The candidate varieties had advantages over the standard check variety in terms of leaf to stem ratio, CP, and IVOMD (Table 6). The result showed that Zehone-03 variety had the highest leaf to stem ratio (23.2%) advantage followed by Zehone-02 (17.9%) and 15743 (16.8%) over the standard check. Similarly, Zehone-03 and Zehone-02 varieties had the same highest CP (6.0%) content while Zehone-03 and 15743 varieties had the same highest IVOMD (2.9%) content advantages over the standard check.

Table 5. Chemical compositions and *in vitro* organic matter digestibility of Napier grass varieties.

Variety	DM (g kg^{-1})					
	Ash	CP	NDF	ADF	ADL	IVOMD
16791	149.5	60.5	778.4	492.8	67.3	510.3
15743	133.7	57.7	767.7	479.5	66.6	512.0
16819	147.9	60.5	728.5	461.4	67.2	512.0
ILRI-16984 (Standard check)	149.4	57.1	785.5	464.0	85.1	497.4

Note: *DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; and IVOMD = In vitro organic matter digestibility.*

Table 6. Leaf to stem ratio, crude protein, and *in vitro* organic matter digestibility advantages of Napier grass varieties over the standard check.

Variety	LSR	% increase	CP	% increase	IVOMD	% increase
16791	1.12	17.9	60.5	6.0	510.3	2.6
15743	1.11	16.8	57.7	1.1	512.0	2.9
16819	1.17	23.2	60.5	6.0	512.0	2.9
ILRI-16984 (Standard check)	0.95	–	57.1	–	497.4	–

Note: *LSR = Leaf to stem ratio; CP = Crude protein; and IVOMD = In vitro organic matter digestibility.*

7. Adaptation

The released Napier grass varieties, Zehone-02 (16791) and Zehone-03 (16819), are adapted to mid and high-altitude areas of the country. The varieties performed very well in areas with altitudes ranging from 1500 to 2500 meters above sea level, which have an annual rainfall of 700 to 1200 mm. It could also be possible to extend the production of both varieties to other areas with similar agro-ecologies after doing adaptation trials. Both varieties produce higher dry matter yield when recommended fertilizers are applied at the appropriate rates. For better performance, the varieties should be planted in mid-June to mid-July under rain-fed conditions and any time when irrigation water is available. The released varieties have fast growth and better forage dry matter yield performances in the mid-altitude areas when compared to high altitude areas of the country.

8. Conclusion

The new Napier grass varieties performed differently in terms of agronomic performance, yield stability, and nutritive values across the test environments. This may be attributed to variations in edaphic, climatic, and biotic factors across the locations. Measured agronomic traits such as tillering performance, plant height, leaf to stem ratio, forage DM yield showed variations among the tested varieties and the environments. The varieties also showed variations in forage DM yield stability across the test environments during the experimental periods. Different stability parameters and models indicating that the standard check (ILRI-16984) variety is considered more stable when compared to other varieties evaluated in the study. On the other hand, varieties such as Zehone-02 and Zehone-03 were found to be less stable varieties across the test environments but gave better DM yield performance. The crude protein (CP) and *in vitro* organic matter digestibility (IVOMD) were higher in the high-altitude area while CP yield, digestible yield, and most fiber components were relatively higher in the mid-altitude areas indicating that temperature and amount of rainfall and its distribution hurt the feed quality of Napier grass varieties. Generally, Zehone-02 and Zehone-03 varieties have better mean DM yield performance but less stable when compared to other varieties included in the study. Therefore, Zehone-02 (16791) variety was released for its better forage DM yield while Zehone-03 (16819) variety for its thin-stemmed stature, which could be considered as different merit, which varies, from the candidate varieties and other varieties released so far. Generally, thin-stem varieties have better nutritional qualities and conserved as hay when compared to bold-stem varieties. However, bold-stem varieties can be conserved in the form of silage for efficient utilization. Therefore, both Napier grass varieties (Zehone-02 and Zehone-03) have been released in 2017 for production in the mid and high-altitude areas and similar agro-ecologies in the country. The planting materials of both Napier grass varieties are maintained by the feed and nutrition research section of Holetta Agricultural Research Center.

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