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Research Article

Yield, Yield Components, and Nutritive Value of Perennial Forage Grass Grown under Supplementary Irrigation

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There is a distinct seasonality in the availability of feeds in the highlands of Ethiopia, reaching a peak and low levels towards the end of the rainy and dry season, respectively. Consequently, this trial was conducted to assess the yield performance and nutritive value of nine perennial grasses accessions from seven grass species under supplementary irrigation to produce feed year-round. The evaluated grasses species were two *Urochloa* (*U. decumbens* cv. ILRI-10871 and ILRI-13205), two *Setaria* (*S. sphacelata* cv. ILRI-143 and ILRI-6543), one *Phalaris* (*Phalaris aquatica* cv. Sirrosa), coloured Guinea (*Panicum coloratum* cv. Coloratum), Desho (*Pennisetum glaucifolium* cv. Kindu kosha), Napier (*Pennisetum purpureum* cv, ILRI-16791), and Rhodes (*Chloris gayana* cv. Massaba) variety. The experiment was carried out in a randomized complete block design. The chemical compositions of the grasses were scanned by, the near infrared spectroscopy (NIRS). Results indicated that the plant height, dry matter, and crude protein yield were significantly affected by year, species ($P < 0.001$), and their interaction ($P < 0.05$). Moreover, species were significantly influenced *in vitro* dry matter digestible yield, relative feed value, and nutrient content (DM, CP, NDF, ADF, ADL, and IVDMD). Napier grass had superior in dry matter, crude protein, and *in vitro* dry matter digestible yield than the other perennial grasses species tested together. Thus, among the tested grasses species, Napier grass showed outstanding potential as a forage plant followed by Phalaris and Desho grass under supplementary irrigation in the central highland of Ethiopia.

1. Introduction

The most serious challenges with livestock feeding occur in developing countries, especially during the long dry season, when there is insufficient plant biomass leftover from the wet season to maintain native livestock species [1]. The availability of feeds in Ethiopia's highlands has a particular seasonality, with peak levels towards the end of the rainy season and severely low levels towards the end of the long dry period when green forage is sparse. This latter part of the year is additionally the time when the quality of available feeds is at its lowest, mainly composed of low-quality crop residues [2]. The combination of feed scarcity and low feed quality during the dry season makes it difficult for livestock owners to meet their animals' energy and nutrient requirements [3]. As a result, the livestock population frequently suffers from cyclic loss of body condition as a result of seasonal feed production patterns [4], affecting the supply and pricing of livestock products in the local market [5]. Thus, silage conservation and the cultivation of adapted forage under supplementary irrigation are significant options for addressing the animal feed shortfall in the dry season.

In Ethiopia's highlands, small-scale irrigation has the potential to enable crop-livestock intensification [6, 7]. To improve farm productivity and provide resilience to the detrimental effects of climate change, the country is currently focusing on expanding small and medium-scale irrigation agriculture in rural areas [8]. Farmers in the highlands have different levels of experience irrigating their land with shallow wells, streams, rivers, and ponds for vegetable and other crop production [9]. As a result of these irrigation practices, feed biomass is produced as a byproduct (grass along water canals and field plots, inedible vegetable

trash, and green crops collected) that can be used as supplemental feed [10].

Despite the paucity of green fodder during dry years, production of improved forage utilizing irrigation alongside food crops is nonetheless not commonly practiced. This could be due to a lack of knowledge or the perception that producing fodder using irrigation is not economically viable. However, due to the better price of animal products during the dry season and the scarcity of fodder, irrigated fodder production combined with livestock production may allow farmers to target market niches that provide additional income and diversify their livelihoods. Hence, the water requirements of forage crops vary with the environmental conditions.

Many researchers have reported on the adapting and yielding abilities of various perennial grass species under rain-fed circumstances in Ethiopia's central highlands [11, 12]. Among the perennial pasture species tested so far, *Phalaris* (*Phalaris aquatica* cv. Sirrosa), Rhodes (*Chloris gayana* cv. Massaba), and coloured Guinea (*Panicum coloratum* cv. Coloratum), Napier (*Pennisetum purpureum* cv. ILRI-16791), common *Setaria* (*Setaria sphacelata* cv. ILRI-143 and 6543), and Desho (*Pennisetum glaucifolium* cv. Kindu kosha/DZF-591) are very well adapted grasses to mid and high altitude areas up to 2400 m above sea level. Despite their significant potential for forage production under rain-fed conditions, there is no research result on the performance and comparative advantage of these grasses species under supplementary irrigation in the central highlands of Ethiopia. Thus, the objectives of the study were to assess the yield, nutritive value, and relative feed value performance of irrigated perennial grasses forage species.

2. Materials and Methods

2.1. Description of Study Area. The experiment was conducted at the Holetta Agricultural Research Center, Ethiopia, during the main cropping seasons of 2017 to 2020 under supplementary irrigation conditions. Holetta Agricultural Research Center is located at 9°00′N latitude, 38°30′E longitude at an altitude of 2400 m.a.s.l. It is 34 km west of Addis Ababa on the road to Ambo. The soil type of the area is predominantly red Nitosol. The long-term (30 years) average annual rainfall and temperature of the study area are 997 mm and 14.6 cm, respectively. While the soil a characteristic and monthly temperature and rainfall are presented in Tables 1 and 2.

2.2. Experimental Design and Layout. This experiment was arranged in a randomized complete block design. The experimental unit that had been cultivated during the previous season was identified within the irrigation scheme. The land was plowed, cleared of all weeds, and harrowed by tractor to a fine tilth. The seeds were grown in a nursery, and the vegetative parts were obtained from the nursery. Vegetative parts in the form of root splits were used for planting which was accomplished at the beginning of the main rainy season (May 25, 2017). The root splits were planted with the intra- and inter-row spacing of 0.25 m and 0.5 m for *Urochloa*, Desho, and *Setaria* and 0.5 m and 1 m for Napier grass respectively. *Panicum*, *Phalaris,* and Rhodes grass were sown at a 5 kg ha^{-1} seeding rate and 20 cm between rows with drilling. The plot size was 7.2 m^2 (4 × 1.8 m). The spacing between plots and blocks was 1 m and 1.5 m, respectively. Phosphorus fertilizer was uniformly applied to all plots at planting in the form of diammonium phosphate (DAP, 18% N; 20% P; 1.5% S) at the rate of 100 kg/ha. After every harvest, the plots were top-dressed with 100 kg urea (46% N/ha) of which one-third was applied at the time of harvest (after two weeks of harvest), and the remaining two-third was applied during the active growth stage of the plant, during the midgrowing season.

2.3. Experimental Materials and Irrigation. The study involved nine perennial forage grasses *Urochloa* (*U. decumbens* cv. ILRI-10871 and ILRI-13205), *Phalaris* (*Phalaris aquatica* cv. Sirrosa), Rhodes (*Chloris gayana* cv. Massaba), coloured Guinea (*Panicum coloratum* cv. Coloratum), Napier (*Pennisetum purpureum* cv. ILRI-16791), common Setaria (*Setaria sphacelata* cv. ILRI-143 and 6543), and Desho (*Pennisetum glaucifolium* cv. Kindu kosha/DZF-591). Seeds of the *Urochloa*, *Panicum*, *Phalaris*, and *Setaria* species were obtained from the International Livestock for Africa (ILCA), while Desho and Napier grass was obtained from the Debre Zeit and Bako Agricultural Research Center, respectively. Desho grass was released by Debre Zeit Agricultural Research Center. From the time of seeding to maturity, the experimental plots were uniformly irrigated. Up to emergence, the water was applied twice a week, in the morning at 6:00–7:30 a.m. Following emergence, water application was reduced to every once per two weeks.

2.4. Data Collection. This experiment involved two phases, namely, establishment (May 25, 2017, to May 2018) and productive phases (May 2018 to January 2020). The weeding management was twice per year, and particularly the plots were freed from the weeds when the fertilizer applied. Data were collected on plant height at harvesting and forage dry matter yield. Plant height was measured from the ground to the highest leaf at the time of the forage harvesting stage. Plant height was recorded from 6 randomly selected plants within the sampling area. For the determination of biomass yield, *Panicum*, *Phalaris*, *Rhodes*, and *Setaria* grass species were harvested at the 10% blooming stage of the whole plots (7.2 m^2) areas. Desho and *Urochloa* were harvested at >100 cm height, and Napier grass was at >1.75 m. The plot was cut three per year (at July, November, and April). For data analysis, the production phases were classified to establishment phase (the first year) and production phase (the subsequent years of the first year or establishment year). The combined analysis is the result of through the experimental period (average of production and establishment phase). The weight of the total fresh biomass yield was recorded from each plot in the field, and a 500 g sample was taken from each plot to the laboratory to determine dry matter yield. The dry matter content was determined by oven-drying at 65°C for

Table 1: Properties of soils in the study area.

Parameter	Values	Method of analysis
pH (1 : 2.5 H_2O)	4.94	Potentiometric method
Organic carbon (%)	1.79	Dichromate oxidation method [13]
Total nitrogen (%)	0.20	Kjeldhal method [14]
Available P (ppm)	5.60	Olsen method [15]
CEC (meq/100 g)	18.24	NH_4OAc method (pH = 7)
Na^+ (meq/100 g)	0.16	NH_4OAc method [16]
K^+ (meq/100 g)	5.03	NH_4OAc method [16]
Ca^{2+} (meq/100 g)	29.50	NH_4OAc method [16]
Mg^{2+} (meq/100 g)	13.75	NH_4OAc method [16]
P (mg kg^{-1})	5.6	NH_4OAc method [16]
Texture		
Sand (%)	18	Boycouos hydrometric method
Silt (%)	15	Boycouos hydrometric method
Clay (%)	67	Boycouos hydrometric method

Table 2: Monthly rainfall and average temperature during the growing season.

Month	Rainfall (mm)				Temperature (°C)			
	2017	2018	2019	2020	2017	2018	2019	2020
January	0.0	5.0	80.1	0.0	15.6	15.1	17.6	14.9
February	30.2	64.0	2.6	0.0	14.3	15.6	16.3	15.4
March	24.0	22.5	53.4	73.2	15.8	16.3	16.8	16.9
April	56.4	118.5	80.1	92.4	16.5	16.8	17.8	17.1
May	129.6	161.4	109.2	100.6	17.0	16.9	17.2	16.9
June	74.6	193.9	187.4	126.1	14.9	15.6	16.2	16.1
July	177.4	225.5	249.0	280.3	14.3	15.3	16.9	15.6
August	217.3	234.1	356.1	334.2	14.6	15.1	15.1	15.2
September	244.0	101.0	187.0	216.2	14.4	15.4	14.3	14.9
October	29.0	10.0	7.8	31.6	15.9	14.3	13.2	14.3
November	0.0	3.4	28.2	8.0	13.2	14.0	14.3	13.2
December	0.0	0.0	3.6	3.2	12.2	13.5	13.9	12.5
Total/average	982.5	1139.3	1344.5	1265.8	14.9	15.3	15.8	15.3

72 hours. The oven-dried samples were ground to pass through a 1 mm sieve size for laboratory analysis. Before scanning, the samples were dried at 60°C overnight in an oven to standardize the moisture, and then 3 g of each sample was scanned by near infrared spectroscopy (NIRS) with an 8 nm step. The samples were analyzed on a % dry matter (DM) basis for ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and in vitro dry matter digestibility (IVDMD) using a calibrated NIRS (Foss 5000 apparatus and Win ISI II software). The digestible yield was determined by multiplying IVDMD with total biomass yield and then divided by 100%. Crude protein yield was calculated with the following formula:

$$\text{CPY} = \frac{\text{crude protein percentage} * \text{dry matter yield}}{100}. \quad (1)$$

2.5. Relative Feed Value. Relative feed value (RFV) is a forage quality index that is used to rank feeds according to their overall nutritive value. This ranking is made relative to the typical nutritive value of full bloom alfalfa hay, containing 41% ADF and 53% NDF on a DM basis and having an RFV of 100 and is considered to provide the average score. Though RFV has no units, it compares the potential of two or more like forages based on energy intake. Thus, it serves as an index of forage quality for comparing forage lots. Forages with RFV greater than 100 are of higher quality than full bloom alfalfa hay and forage with a value lower than 100 are of lower value than full bloom alfalfa. Relative feed value (RFV) was calculated from the estimates of dry matter digestibility (DMD) and dry matter intake (DMI) [17].

$$\begin{aligned} \text{DMD\%} &= 88.9 - (0.779 \times \%\text{ADF}), \\ \text{DMI as \% of BW} &= \frac{120}{\%\text{NDF}}, \\ \text{RFV} &= \frac{\%\text{DMD} * \text{DMI}}{1.29}, \end{aligned} \quad (2)$$

where ADF: acid detergent fiber (% of DM); NDF: neutral detergent fiber (% of DM); DMI: dry matter intake (% of body weight).

2.6. Statistical Analysis. Analysis of variance (ANOVA) procedures of the SAS general linear model (GLM) was used to analyse the quantitative data (SAS, 2002). LSD test at 5% significance was used for comparison of means. The data were analyzed using the following model:

$$Y_{ijk} = \mu + S_i + Y_j + SY_{ij} + B_k + e_{ijk}, \quad (3)$$

where Y_{ijk} = dependent variables; μ = grand mean; S_i = effect of species i; Y_j = effect of year j; SY_{ij} = interaction effect of species and year ij; B_k = effect of block k; and e_{ijk} = random error effect of species i, year j, interaction of year and species ij, and block k.

3. Results and Discussion

3.1. Effect of Species, Year, and Their Interaction on Agronomic Traits. The effects of species, year, and their interaction on the plant height, dry matter, and crude protein yield of perennial grass species under supplementary irrigation are presented in Table 3. The result of the analysis showed that plant height at forage harvesting, dry matter, and crude protein yield were significantly influenced by species, year ($P > 0.001$), and interaction of species and year ($P > 0.05$). While species and year had significant ($P > 0.001$) influence on *in vitro* dry matter digestible yield perennial grass under supplementary irrigation. This result might be due to the variation of environmental conditions (rainfall, temperature, etc.) and genetic differences. The significant difference in agronomic traits between the experimental years indicating those experimental years had a different distribution of rainfall and temperature. Indeed, the rainfall pattern and temperature were slightly different among the experimental years. *In vitro* dry matter digestible yield was not significantly influenced by the interaction of year and species.

The significant effect of year and species interaction on the forage dry matter, crude protein, and *in vitro* dry matter digestible yield implies that there is a change of ranking order of species/accessions over years due to the nonuniformity of growing conditions (rainfall, temperature, etc.) during the experimental years. This might be due to different species/accessions exhibit a highly specific response to particular environmental conditions (soil, rainfall, and temperature), while others are uniform in performance over a range of environmental conditions.

3.2. Plant Height. The mean plant height at forage harvesting of the perennial forage grass species evaluated under supplementary irrigation at Holetta is described in Table 4. The plant height at forage harvesting was significantly different among perennial forage species across the experimental years. Napier (ILRI-16791) has significantly (2017 ($P < 0.001$), 2018, 2019, and 2020, ($P < 0.001$)) taller plant height than the other evaluated perennial grass species. This result might be attributed to the morphological and physiological growth habits of the Napier grass species (Napier grass had a vertical growth habit than the other evaluated grass species). Plant height can be attributed to the morphological and physiological differences among the cultivars [18].

During the establishment year (2017), *Urochloa decumbens* had a significant ($P < 0.01$) shorter plant height than the other grass species except for Desho grass. The nonsignificant difference in plant height at forage harvesting of Desho and *Urochloa* grass species might be due to the relative morphological and physiological growth habits of these species. Napier grass had taller plants ($P < 0.01$) than other grass species. *Setaria sphacelata* accessions had ($P < 0.01$) a taller plant height than *Urochloa decumbens* accessions.

The result of the combined analysis showed that plant height at forage harvesting was significantly influenced by grass accessions. *Urochloa decumbens* (ILRI_10871 and ILRI_13205) had significantly ($P < 0.001$) shorter height than the other evaluated perennial grasses species. The result might be due to the morphological growth habit of this species, *Urochloa decumbens* growth pattern was creeping rather than erect. During the production phase, plant height at forage harvesting was significantly ($P < 0.001$) affected by forage species, and Napier (ILRI_16791) grass had a taller plant height than the other grass species.

The analysis result of the productive phase (2018–2019) showed that plant height at forage harvesting was significantly ($P < 0.001$) influenced by species. Taller plant height was recorded for Napier grass than the other tested perennial grass species. Setaria accessions had a taller ($P < 0.001$) plant height than *Urochloa* accessions. This might be due to the fact that Setaria inflorescence growth habit is taller than the *Urochloa* inflorescence. Also, the result might be due to the difference in other morphological and physiological growth habits among these species. Moreover, it might be because relatively less number of tillers and leaves in Setaria in which the nutrients are used for height increment rather than tiller production [19]. Contrary to this, the short plant height observed in *Urochloa* could be due to the production of a high number of the tiller, which could share the available soil nutrient that could be used for growth. The plant height at forage harvesting did not significantly ($P > 0.05$) different among the accessions within the species.

The plant height recorded for Napier grass in this experiment was lower than the value (2.78) reported by [20] for Napier grass under supplementary irrigation at Wondo Genet. This variation could be due to the difference of evaluated genotypes and environmental conditions of the study area. However, the mean plant height of Napier grass (16791) obtained in this study was higher than the value reported by [21] for Napier grass (16791) evaluated under rain-fed conditions at Holetta. This result might be due to the advantage of supplementary irrigation and differences among the experimental years in temperature and variation in both amount and distribution of annual rainfall. Management and harvesting stage might be also other factors that contribute to the variation of the value of the two reports.

The mean combined analysis value (70.60 cm) of plant height obtained for *Urochloa decumbens* accessions (ILRI_10871 and ILRI_13205) in this study was concurrent with the value (70.10 cm) reported by [22] for *Urochloa decumbens* accessions (ILRI_10871 and ILRI_13205) under rain-fed conditions at Holetta. Conversely, according to the result of combined analysis, the mean plant height recorded for Desho (88.94 cm) and *Setaria sphacelata* accessions (104 cm) in this study was slightly lower than the value

Table 3: Species and year effect on the plant, dry matter, and crude protein yield of perennial grass evaluated under irrigation.

Parameters	Species	Year	S × Y	Mean	CV
Plant height (cm)	***	***	*	103.61	17.70
Dry matter yield (t/ha)	***	***	*	15.13	31.38
Crude protein yield (t/ha)	***	***	*	0.88	21.38
In-vitro dry matter digestible yield (t/ha)	***	***	ns	6.14	36.23

CV = coefficient variation; * = $P < 0.05$; *** = $P < 0.001$; S × Y = species and year interaction; t/ha = tonnes per hectare.

Table 4: Plant height (cm) of perennial forage grass species evaluated under supplementary irrigation.

Species	Year				Productive phase	Combined analysis
	2017	2018	2019	2020		
U. decumbens ILRI_10871	56.67^{d}	107.23^{bc}	55.73^{e}	63.30^{d}	75.42^{e}	70.73^{e}
U. decumbens ILRI_13205	41.63^{d}	102.77^{bc}	65.57^{de}	71.87^{cd}	80.07^{de}	70.46^{e}
Desho grass (var. Kindu kosha)	78.90^{cd}	125.53^{b}	81.53^{cd}	69.80^{d}	92.29^{cde}	88.94^{d}
P. purpureum cv. ILRI_16791	177.77^{a}	167.78^{a}	172.77^{a}	149.43^{a}	163.30^{a}	166.90^{a}
P. coloratum cv. Coloratum	112.20^{bc}	113.33^{bc}	112.23^{b}	109.60^{b}	111.70^{b}	111.80^{bc}
P. aquatica cv. Sirrosa	128.90^{b}	124.73^{b}	109.73^{b}	103.50^{b}	112.70^{b}	116.70^{b}
C. gayana cv. Massaba	116.10^{bc}	85.88^{c}	96.53^{bc}	97.27^{b}	93.23^{cde}	98.95^{cd}
S. sphacelata ILRI_143	111.67^{bc}	106.40^{bc}	92.23^{bc}	94.30^{bc}	97.64^{bcd}	101.20^{bcd}
S. sphacelata ILRI_6543	105.00^{bc}	111.93^{bc}	104.33^{bc}	105.77^{b}	107.30^{bc}	106.80^{bc}
Mean	103.20	116.18	98.96	96.09	103.7	103.6
CV	24.41	15.67	13.97	14.29	18.78	20.8
P value	0.0002	0.0032	<0.0001	<0.0001	<0.0001	<0.0001

CV : coefficient variation. Means with the different letter are significantly different.

reported by [20] for Desho (91.24 cm) and *Setaria sphacelata* accessions (114.79 cm) under the rain-fed condition at Holetta. This variation might be due to differences among the experimental years in temperature and variation in both amount and distribution of annual rainfall and difference of morphological and physiological growth response of these grass species to supplementary irrigation and rain-fed conditions. According to annual Basque Research [23], plants growing underwater in limiting conditions tend to grow taller to scramble for below nutrients around the growing environments.

3.3. Forage Dry Matter Yield. Forage dry matter yield performance of the tested perennial grass species/accessions across the experimental years is indicated in Table 5. The result of the experimental year's analysis revealed that forage dry matter yield was significantly ($P < 0.05$) influenced by species. The variation in dry matter yield observed among the grass species in the current study might be attributed to the variations in the genetic makeup of the species, soil, and environmental adaptability. The better ($P < 0.05$) dry matter yield was obtained from Napier grass across the experimental years except during the establishment phase (2017). This result suggests that Napier grass had better response to supplementary irrigation for forage dry matter yield than the other evaluated grass species.

During the establishment phase (2017), *Phalaris* grass had more ($P < 0.05$) dry matter yield than *Urochloa*, Desho, and *Setaria* grass species. This suggests that *Phalaris* was fast to establish and respond to supplementary irrigation than these species. The result would also suggest that *Phalaris* grass had a superior response to the agronomic management than these species under supplementary irrigation at the establishment phase. However, the dry matter yield of *Phalaris* grass was nonsignificantly ($P > 0.05$) different from the dry matter yield of Napier, *Panicum*, and Rhodes grass.

The result of the combined analysis showed that forage dry matter yield was significantly ($P < 0.001$) affected by species. Napier grass had better ($P < 0.001$) dry matter yield than the other grass species, and this might be due to the genetic difference of these grass species. Although, the result might be due to the fact that Napier grass had a taller plant height than the other grass species. This is because longer plants possess relatively more leaves and branches that may increase biomass yield [22]. Desho grass showed better ($P < 0.001$) dry matter yield than *Setaria* accessions and *Urochloa decumbens* (ILRI_10871). However, the dry matter yield was not significantly ($P > 0.05$) influenced by accessions within the species.

The result of productive phase analysis revealed that species significantly ($P < 0.001$) influence the forage dry matter yield. Napier grass gave the highest ($P < 0.001$) forage dry matter yield than other evaluated perennial grass species. The result might be due to the fact that forage dry matter yield is directly related to plant height at the forage harvesting stage because when the plant height at forage harvesting increases forages dry matter yield also increases. Desho grass has a better dry matter yield ($P < 0.001$) than *Panicum*, *Setaria* accessions, and *U. decumbens* (ILRI_10871). However, the forage dry matter yield of Desho grass was nonsignificantly ($P > 0.05$) different from *Phalaris*, Rhodes, and *Urochloa* (ILRI_13205) grass species. The forage dry matter yield was not significantly ($P > 0.05$) affected by accessions within the *Urochloa* and *Setaria* grass species.

Table 5: Forage dry matter yield (t/ha) of perennial forage grass species evaluated under irrigation supplementation.

Species	Year				Productive phase	Combined analysis
	2017	2018	2019	2020		
U. decumbens ILRI_10871	1.46^{c}	9.75^{c}	15.24^{b}	12.76^{b}	12.58^{c}	9.80^{c}
U. decumbens ILRI_13205	0.51^{c}	12.34^{bc}	23.94^{b}	15.19^{b}	17.15^{bc}	12.99^{bc}
Desho grass (var. Kindu kosha)	4.59^{bc}	23.37^{b}	27.92^{b}	18.85^{ab}	23.38^{b}	18.68^{b}
P. purpureum cv. ILRI_16791	4.79^{abc}	40.07^{a}	42.34^{a}	24.95^{a}	35.79^{a}	28.04^{a}
P. coloratum cv. Coloratum	9.51^{ab}	17.41^{bc}	16.80^{b}	15.95^{b}	16.72^{c}	14.92^{bc}
P. aquatica cv. Sirrosa	11.89^{a}	19.91^{bc}	18.80^{b}	12.07^{b}	16.92^{bc}	15.67^{bc}
C. gayana cv. Massaba	8.75^{ab}	17.71^{bc}	17.91^{b}	15.33^{b}	16.99^{bc}	14.93^{bc}
S. sphacelata ILRI_143	1.26^{c}	14.52^{bc}	14.96^{b}	13.15^{b}	14.21^{c}	10.97^{c}
S. sphacelata ILRI_6543	1.08^{c}	12.73^{bc}	15.53^{b}	11.32^{b}	13.19^{c}	10.16^{c}
Mean	4.87	18.65	21.49	15.51	18.55	15.13
CV	16.94	36.47	38.33	32.09	38.02	62.30
P value	0.0248	0.0016	0.0123	0.082	<0.0001	0.0002

CV : coefficient variation. Means with the different letter are significantly different.

In contrast to the dry matter yield (28.04 t ha^{-1}) of Napier grass obtained in this study, [21] reported a lower value (10.51 t ha^{-1}) of dry matter yield for this Napier grass accessions under rain-fed conditions at Holetta. The variation of this result might be due to the amount and distribution of rainfall and temperature differences of the study years. Although, the difference in forage dry matter yield among reports could be attributed to the stage of maturity at the time of harvesting, management, and the effect of supplementary irrigation. This is because supplementary irrigation increases the harvesting frequency that may increase the biomass yield of the grass. The forge dry matter yield obtained from Napier grass in this study was greater than the overall mean value (17.36 t ha^{-1}) reported by [20] for Napier grass accessions under supplementary irrigation. This variation could be due to the differences in edaphic, climatic, and biotic conditions of the study area and the genetic difference of the tested accessions.

The forage dry matter yield obtained for *Urochloa* (11.40 t ha^{-1}) and *Setaria* (10.57 *t* ha^{-1}) in this study was lower than the value reported by [20] for these *Urochloa* (16.59 t ha^{-1}) and *Setaria* (12.23 *t* ha^{-1}) accessions under rain-fed conditions. This result suggests that *Urochloa* and *Setaria* grass species did not express their yield performance under supplementary irrigation. Although, this result suggests that supplementary irrigation is not conducive to harvest better forage biomass yield from the *Urochloa* and Setaria grass species under the environment receiving 1183.025 mm annual rainfall. This is due to the fact that *Urochloa* grass is more tolerant to drought than moisture stress/access problems. *U. decumbens* are drought-resistant and resilient in infertile soils and produce high herbage yield with relatively low levels of fertilizer inputs [24].

Forage dry matter yield value (18.68 t ha^{-1}) of Desho (DZF_591/Kindu kosha) grass obtained in this study was lower than the value (24.27 t ha^{-1}) reported in [22] for Desho grass variety (DZF_592/Kulumsa) under rain-fed conditions at Holetta. This variation might be due to differences among the experimental years in temperature and variation in both amount and distribution of annual rainfall. Although, the difference in forage dry matter yield among reports could be attributed to the stage of maturity at the time of harvesting, management, a genetic difference of the tested variety, and the effect of supplementary irrigation.

The forage dry matter yield trend over the production years of each evaluated forage grass species is indicated in Figure 1. As shown in Figure 1, forage dry matter yield increased with production years for the first three consecutive years (2017 to 2019) for each evaluated grass species and decreased at the fourth year. This suggests that the evaluated forage grass species express their production potential for the first three years, and this might be because they used soil nutrient content effectively for the first three years.

The increment and decrement of dry matter yield of each evaluated forage species were consistent with increment and decrement of the annual rainfall of the experimental years. This might be due to the evaluated grass species can access more water and more efficient at converting available water into plant dry matter [25]. Reference [26] showed a significant reduction in plant fresh and dry biomass, chlorophyll pigments, and photosynthetic and transpiration rates, while an increase in shoot N, P, K+, and root K+ was observed under water deficit conditions. Reference [27] also reported that yields were reduced by water deficit.

3.4. Crude Protein Yield. The crude protein yield of perennial grass under supplementary irrigation is indicated in Table 6. The result of the production phase and combined analysis showed that crude protein yield was significantly ($P < 0.001$) influenced by species. Napier (ILRI-16791) grass was more ($P < 0.001$) crude protein yielder than the other evaluated perennial grass species. Setaria grass species gave lower ($P < 0.001$) crude protein yield than Napier and *Phalaris* grass species.

The result of establishment year (2017) showed that crude protein yield was significantly ($P < 0.05$) influenced by species. In the establishment year (2017), *Phalaris* was a more crude protein yielder followed by *Panicum*, Rhodes, and Napier grass species. This result was consistent with the dry matter yield. Hence, in the establishment year, *Phalaris* grass has more dry matter yield than the other evaluated grass species.

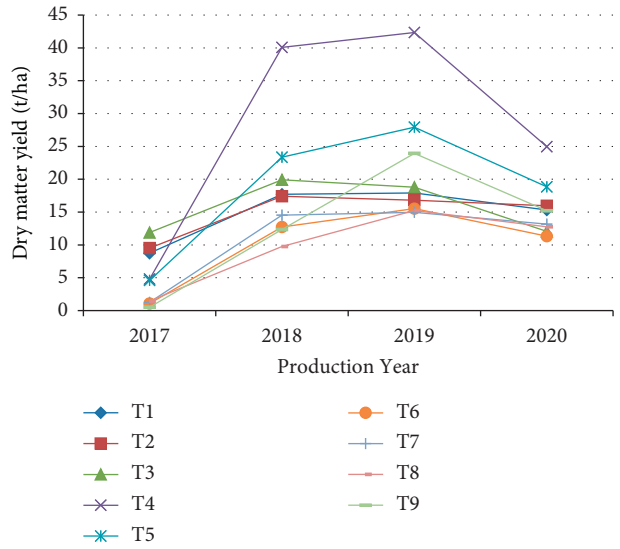


Figure 1: Forage dry matter yield performance of different (t/ha) perennial species under irrigation supplementation.

Table 6: Crude protein yield (t/ha) of perennial forage grass species evaluated under irrigation supplementation.

Species	Year				Productive phase	Combined analysis
	2017	2018	2019	2020		
U. decumbens ILRI_10871	0.08^{b}	0.53^{b}	0.85^{b}	0.70^{b}	0.69^{c}	0.54^{bc}
U. decumbens ILRI_13205	0.03^{b}	0.74^{b}	1.42^{b}	1.01^{b}	1.06^{bc}	0.78^{bc}
Desho grass (var. Kindu kosha)	0.21^{b}	1.03^{b}	1.23^{b}	0.83^{b}	1.03^{bc}	0.82^{bc}
P. purpureum cv. ILRI_16791	0.34^{ab}	2.80^{a}	2.95^{a}	1.75^{a}	2.50^{a}	1.96^{a}
P. coloratum cv. Coloratum	0.57^{ab}	1.03^{b}	0.99^{b}	0.93^{b}	0.98^{bc}	0.88^{bc}
P. aquatica cv. Sirrosa	0.89^{a}	1.47^{b}	1.40^{b}	0.89^{b}	1.25^{b}	1.16^{b}
C. gayana cv. Massaba	0.48^{ab}	0.89^{b}	0.90^{b}	0.78^{b}	0.86^{bc}	0.76^{bc}
S. sphacelata ILRI_143	0.06^{b}	0.70^{b}	0.73^{b}	0.64^{b}	0.69^{c}	0.53^{c}
S. sphacelata ILRI_6543	0.06^{b}	0.64^{b}	0.77^{b}	0.57^{b}	0.66^{c}	0.51^{c}
Mean	0.30	1.09	1.25	0.90	1.08	0.88
CV	10.14	14.35	17.80	11.48	15.75	69.39
P value	0.034	0.0006	0.0072	0.0431	<0.0001	<0.0001

CV : coefficient variation. Means with the different letter are significantly different.

Crude protein yield was significantly influenced by species in 2018 ($P < 0.001$), 2019 ($P < 0.01$), and 2020 ($P < 0.05$) production year. Moreover, the result of the production phase and combined analysis showed that crude protein yield was variable ($P < 0.001$) among the grass. Napier grass species has more crude protein yield than the other evaluated grass species across the production year. The crude protein yield value was consistent with the dry matter yield. Moreover, crude protein yields difference between the species is a reflection of the difference in crude protein content existing among the species. This could be due to the crude protein yield of the species mathematically derived from dry matter yield and crude protein content of species.

3.5. In Vitro Dry Matter Digestible Yield. The *in vitro* dry matter digestible yield (IVDMD) of evaluated perennial grass species under supplementary irrigation is indicated in Table 7. The result of establishment year (2017) analysis showed that IVDMD yield was significantly ($P < 0.01$) influenced by species differences. While IVDMD significantly influenced by species in 2018 ($P < 0.01$) and 2019 ($P < 0.05$) production years. Though species did not significantly ($P > 0.05$) influenced the IVDMD in the 2020 production year. In the establishment year (2017), *Phalaris* had higher IVDMD followed by *Panicum*. Despite the lowest IVDMD percentage, in the 2018 and 2019 production years, Napier has more IVDMD yield than other investigated grass species. This might be due to significantly higher ($P < 0.001$) dry matter yield of Napier than the other evaluated grass species.

The result of the production phase and combined analysis showed that species had a significant ($P < 0.001$) effect on the IVDMD yield. Napier had a higher IVDMD yielder than the other evaluated grass species, and this might be due to the Napier had significantly higher ($P < 0.001$) dry matter yield than the other evaluated grass species. Likewise, this could be due to the IVDMD yield of the species mathematically derived from dry matter yield and IVDMD content of species. Hence, the *in vitro* dry matter digestible

Table 7: *In vitro* digestible dry matter yield (t/ha) of perennial forage grass species evaluated under irrigation supplementation.

Species	Year				Productive phase	Combined analysis
	2017	2018	2019	2020		
U. decumbens ILRI_10871	0.64^{b}	4.32^{c}	6.74^{b}	5.66	5.57^{c}	4.34^{cd}
U. decumbens ILRI_13205	0.22^{b}	5.37^{bc}	10.41^{ab}	6.96	7.66^{bc}	5.63^{bcd}
Desho grass (var. Kindu kosha)	1.78^{b}	9.46^{bc}	11.40^{ab}	7.69	9.52^{bc}	7.58^{bc}
P. purpureum cv. ILRI_16791	1.92^{b}	15.79^{a}	16.87^{a}	9.90	14.19^{a}	11.12^{a}
P. coloratum cv. Coloratum	3.41^{ab}	6.46^{bc}	6.06^{b}	5.84	6.12^{bc}	5.44^{bcd}
P. aquatica cv. Sirrosa	6.15^{a}	10.31^{b}	9.72^{b}	6.25	8.76^{b}	8.11^{ab}
C. gayana cv. Massaba	3.14^{ab}	6.36^{bc}	6.54^{b}	5.59	6.16^{bc}	5.41^{bcd}
S. sphacelata ILRI_143	0.45^{b}	5.23^{bc}	5.33^{b}	4.74	5.10^{c}	3.94^{cd}
S. sphacelata ILRI_6543	0.38^{b}	4.53^{bc}	5.51^{b}	4.02	4.69^{c}	3.61^{d}
Mean	2.01	7.54	8.73	6.27	7.53	6.14
CV	13.67	10.51	14.16	5.67	11.96	64.82
P value	0.0065	0.0039	0.0289	0.148	<0.0001	0.0001

CV : coefficient variation. Means with the different letter are significantly different.

yield is determined by multiplying IVDMD with total dry matter yield and then divided by 100% which is positively correlated.

3.6. Relative Feed Value. The calculated value of related feed value (RFV) for evaluated forage grasses is presented in Table 8. The RVF was significantly ($P < 0.05$) different among the evaluated grass species. *Phalaris* had a higher relative feed value followed by *Urochloa* accessions. The result was negatively steady with the ADF and NDF content because the RFV is derived from ADF and NDF. Hence, *Phalaris* had low ADF and NDF content than the other evaluated grass species, and RFV is negatively correlated with the ADF and NDF value. The RFV of evaluated grass species was ranged from 115.07 to 127.29. In fact, the magnitude of the index is higher than a standard value of 100 implying the higher nutritional value of evaluated grass species. Likewise, the overall mean RFV index for the evaluated grass species in this study falls within the range of 103–124 that leguminous hays of second-grade quality are required to have [28, 29].

Table 8: Relative feed value (%) of perennial forage grass species evaluated under irrigation supplementation.

Species	Relative feed value
U. decumbens ILRI_10871	122.92^{ab}
U. decumbens ILRI_13205	122.10^{abc}
Desho grass (var. Kindu kosha)	118.29^{bc}
P. purpureum cv. ILRI_16791	119.90^{bc}
P. coloratum cv. Coloratum	119.81^{bc}
P. aquatica cv. Sirrosa	127.29^{a}
C. gayana cv. Massaba	115.07^{c}
S. sphacelata ILRI_143	118.91^{bc}
S. sphacelata ILRI_6543	117.70^{bc}
Mean	120.22
CV	3.17
P value	0.0468

CV : coefficient variation. Means with the different letter are significantly different.

3.7. Nutritional Content. The nutrient content of investigated perennial grass species under supplementary irrigation is indicated in Table 9. Dry matter, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), and *in vitro* dry matter digestible were found to be varying among the species under investigation. However, species did not significantly ($P > 0.05$) influence the ash content. Dry matter percentage was significantly ($P < 0.001$) different among the species, and this might be contributed to differences in growth habit and rate, which are refered through the phenotypic and genotypic differences. Phalaris had lower ($P < 0.001$) dry matter content than the other evaluated perennial grass species.

Crude protein content (CP%) was significantly ($P < 0.01$) influenced by species and, however, was not significantly ($P > 0.05$) influenced by accessions of *Urochloa* and *Setaria*. Higher CP content was recorded for *Phalaris* followed by Napier, *Urochloa*, and *Panicum* grass species, and this result suggests that these species were leafier than the other species at a time of harvest. This might be due to the level of CP is greater in leaves than stems [30]. In this study, forage materials from all the grass species except *Phalaris* had <7%, and this value is slightly below the 7% CP required for microbial protein synthesis in the rumen that can support at least the maintenance requirement of ruminants [31]. Thus, the CP content obtained from the investigated perennial grass except for *Phalaris* is unable to meet the minimum crude protein requirements (7%) for maintenance of animals and rumen microbes [32]. The CP% for *Urochloa*, Desho, and *Setaria* species was slightly comparable with the observation of [20] at Holetta under rain-fed conditions. Reference [33] reported that the feeds that have <12%, 12–20%, and >20% CP are classified as low, medium, and high protein sources, respectively. Based on this classification, all evaluated grass species were classified as low protein feed sources.

Ash content of the investigated perennial grass was not significantly ($P > 0.05$) affected by species. Species had a significant ($P < 0.05$) effect on the NDF content of perennial grass species. *Phalaris* proved to be inferior to all in terms of ANDF, and it was followed by *Urochloa* grass. The mean

Table 9: Nutrient content of perennial forage grass species evaluated under supplementary irrigation at Holetta.

Species	DM	Ash	CP	NDF	ADF	ADL	IVDMD
U. decumbens ILRI_10871	89.87^{a}	16.17	5.49^{bc}	67.07^{bc}	38.61^{abc}	5.95^{ab}	44.56^{b}
U. decumbens ILRI_13205	89.74^{a}	17.44	6.27^{ab}	66.70^{bc}	36.87^{bc}	5.00^{c}	43.66^{b}
Desho grass (var. Kindu kosha)	89.45^{ab}	15.30	4.38^{c}	69.66^{ab}	40.96^{ab}	5.24^{bc}	41.05^{bc}
P. purpureum cv. ILRI_16791	89.73^{a}	16.83	6.98^{a}	68.87^{abc}	41.99^{a}	6.47^{a}	38.54^{bc}
P. coloratum cv. Coloratum	88.71^{b}	15.59	5.81^{abc}	68.79^{abc}	42.03^{a}	6.42^{a}	38.09^{bc}
P. aquatica cv. Sirrosa	87.87^{c}	12.91	7.08^{a}	64.89^{c}	35.33^{c}	4.03^{d}	52.22^{a}
C. gayana cv. Massaba	89.90^{a}	13.76	5.18^{bc}	71.62^{a}	41.59^{a}	5.98^{ab}	37.36^{bc}
S. sphacelata ILRI_143	89.81^{a}	15.91	4.85^{bc}	69.33^{ab}	39.45^{ab}	5.25^{bc}	35.93^{c}
S. sphacelata ILRI_6543	89.94^{a}	15.91	5.01^{bc}	70.04^{ab}	40.86^{ab}	5.67^{abc}	35.60^{c}
Mean	89.43	15.46	5.65	68.62	39.85	5.58	40.67
CV	0.49	12.28	12.91	3.13	5.28	8.72	9.00
P value	0.0002	0.215	0.003	0.049	0.012	0.0003	0.0007

CV : coefficient variation; DM : dry matter; CP : crude protein; NDF : neutral detergent fiber; ADF : acid detergent fiber; ADL : acid detergent lignin; IVDMD : *in vitro* dry matter digestible; Means with the different letter are significantly different.

NDF content of evaluated perennial forage grass species under supplementary irrigation was higher than the average values (66.2%) of NDF for tropical grasses reported by some authors [34, 35]. Furthermore, it falls within the limit (65% and above) classified as low-quality roughages [36] except *Phalaris* (64.89%).

ADF was significantly ($P < 0.05$) influenced by species difference, and *Phalaris* recorded the lowest ADF content. This might be due to the effect of genotypic and phenotypic characteristics of the evaluated grass species. Likewise, the result of this study was supported by [37, 38], who reported that the nutrient composition of forage crops can be varied with genotypic characteristics, harvesting stages, and environmental conditions. Reference [39] reported that the digestibility of feeds is related to the fiber because the indigestible portion has a proportion of ADF and the higher the value of ADF is, the lower the feed digestibility is. Accordingly, *Phalaris* can be more digestible and of higher intake than the other evaluated perennial grass species except for *Urochloa* accessions.

The ADL content of evaluated perennial grass species showed a significant ($P < 0.05$) difference. The lowest ADL content was recorded from *Phalaris* followed by *Urochloa* accessions. Reference [34] reported a lignin content value above 6% to affect the digestibility of forage negatively, and the evaluated grass species had lower than this value except for Napier and *Panicum* species.

The calculated value of *in vitro* dry matter digestibility was significantly ($P < 0.001$) influenced by species. *Phalaris* (Sirrosa) proved to be superior to all investigated grass species in terms of *in vitro* dry matter digestible content. *In vitro* dry matter digestibility content of perennial grass also showed a highly significant decline with an increment of NDF, ADF, and ADL. This could be due to fact that an increase in NDF, ADF, and ADL result in the deposition of lignin in the cell wall and an increase in the proportion of stem which becomes less digestible compared to the leaf portion at high fiber and lignin content [34]. The result of this study was consistent with [40] who reported that forage with high IVDMD levels had lower concentrations of the NDF fraction, which is more slowly degraded in the rumen, impacting microbial synthesis and animal performance.

4. Conclusion

Based on the results, it can be concluded that species can significantly affect plant height at forage harvesting, forage dry matter yield, crude protein yield, *in vitro* dry matter digestible yield, dry matter percentage, relative feed value, ash, crude protein, and fiber contents of the evaluated perennial grass species under supplementary irrigation. However, these parameters did not significantly differ among the accessions of *Urochloa* and *Setaria*. Therefore, based on dry matter yield, *in vitro* dry matter digestible and crude protein yield data, Napier grass from the evaluated grass species is recommended followed by *Phalaris* and Desho grass species for the study area and similar agroecologies as alternative forage grass. The final remark is that further works should be done on performance of animals fed with these grass species to reach firm recommendations.

Data Availability

The data used to support the findings of this study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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