

Effect of sowing seasons and harvests stage on morphological characteristics, yield potential, nutritive value, and digestibility of Rhodes grass (*Chloris gayana* L.)

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Abstract

Rhodes grass (*Chloris gayana* L.) is a multi-cut, C₄ specie and widely cultivated grass under tropical and subtropical climatic conditions, famous for its ability to tolerate harsh dry summer condition, soil salinity, and light frost of winter season. The study was aimed to investigate the effect of different sowing season and harvest on biomass yield, nutrient composition, digestibility (*in vitro*) and morphological characteristics of *C. gayana*. The seeds were in 20 plots (5 m × 15 m) under randomize complete block design (RCBD) and seed rate of 8 kg/ha during each sowing season. The sowing was undertaken through broadcasting method in four different seasons/year (winter, spring, summer, autumn). The samples were collected at the three successive harvest/cuts (1st cut 70 days after sowing (DAS), 2nd cut after 40 days, and third cut at 40 days after the second cut) for fresh matter (FM) and dry matter (DM) yields and samples were studied using PROC MIXED procedure. Higher variation was observed ($P < 0.05$) for germination rate (%), tillers/ plant (no.) and maximum height of plant (cm) during spring season. The significant variation for FM (18.85 vs 11.83 tons ha⁻¹), DM (5.20 vs 3.35 tons ha⁻¹), and *in vitro* digestibility (61.0 vs 54.4 g/100 g) were observed during spring season compared to rest of the seasons. The harvest numbers also displayed significant variation for FM, DM yield, nutrient composition, and *in vitro* digestibility of Rhodes grass. Advancing from first harvest towards the third harvest there was an increase in the yield (tons ha⁻¹) of FM (11.54 vs 17.56), DM (3.01 to 4.94). The highest value for crude protein (CP) (0.51 vs 0.25 tons ha⁻¹) and nutrient detergent fibre (3.32 vs 2.10 tons ha⁻¹) were observed during the

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third harvest and the lowest value were recorded during the first harvest. The current study displayed that Rhodes grass should be sown during spring season for maximum yield including biomass yield, nutritive value, and *in vitro* digestibility. Moreover, advance harvests i.e., second, third etc., may improve biomass yield, and fibre digestibility of the Rhodes grass.

Keywords: climatic conditions; cultivated grass; drought resistance; fodder quality; food security

Introduction

The livestock sector in Khyber Pakhtunkhwa (KP), a northwest province of Pakistan, including the tribal districts plays a crucial role in region's economy, having approximately 26.85 million livestock. The small-scale subsistence livestock farming, providing employment to more than 70% of the total population (approximately 35.53 million people) and contributes 56% of total province economy (Government of Khyber Pakhtunkhwa, 2019). The reliance on livestock farming highlights the sector's importance for rural livelihoods. During the prolonged summer dry months (May to July) and in the winter months (October to January) the availability of green fodder decreases sharply and farmers mostly rely on dry forages and concentrate feeds. The high costs of concentrate feeds items increase the cost of production and smallholder subsistence farmers could not afford costly feed for a longer duration (Khan *et al.*, 2012; Khan *et al.*, 2015). Therefore, animals are mainly kept on low quality pastures or stall-fed with poor quality crop residues i.e., maize stover, rice and wheat straw are insufficient to meet the nutritional needs of dairy animals (Khan *et al.*, 2012). The poor-quality forages and feed reduce livestock productivity and poor digestibility (Khan *et al.*, 2015). Furthermore, the scarcity and high cost of traditional feed supplements i.e., wheat bran, oil and seed cakes, exacerbate the situation and increase the production cost. To address these challenges, there is a pressing need to introduce the high quality, drought resistant forage varieties with ability to sustain under harsh climatic conditions of KP. Varieties i.e., Mott grass, Napier grass, Sadabahar, *Moringa oleifera*, rye grass and Rhodes grass holds potential for providing sustainable green fodder during critical periods of feed scarcity. In addition, these forages have ability to grow under various soil types, climatic conditions, offering a solution to the seasonal forages deficit and improving the overall productivity and sustainability of livestock sector (Khan *et al.*, 2015).

Rhodes grass (*Chloris gayana* L.) is a multi-cut, C4 specie and an important cultivated grass widely grown in the tropical and subtropical areas. It is known for its ability to withstand in dry harsh summer condition, soil salinity, and light frost in the winter season (Ponsens *et al.*, 2010). According to studies, Rhodes grass grows best on loamy, fertile soil ranging from sandy to clay loams, although it can also survive on soils with low fertility and poor drainage (Kobayashi *et al.*, 2004; Takao *et al.*, 2012). Rhodes grass is drought resistant, can withstand high temperature, and can easily be grow on sandy soils (Liphshitz *et al.*, 1974; Skerman *et al.*, 1990). Like, other tropical and subtropical grasses, Rhodes grass can survive temperatures ranging 5-50 °C (Mazahrih *et al.*, 2016). Previous studies have reported that optimum temperature for Rhodes grass production is 35 °C, with photosynthesis peaking and a six-fold increase in production occurring when temperature range between 20 and 30 °C (Jones *et al.*, 1969; Sweeney *et al.*, 1975; Ivory *et al.*, 1976). Additionally, the lower critical daily threshold temperature for the grass growth at 8 °C and tolerant to frost than other grass species (Bogdan, 1977; Arshad *et al.*, 2014).

According to the early published data, Rhodes grass was initially introduced to Punjab in 2011 and later spread to the Sind province, Pakistan. However, it has not yet been introduced to the northern parts of Pakistan. Rhodes grass can be cultivated for various purposes including hay, green fodder, and pasture crop, and can be grown in a variety of soil types and climatic conditions (Bogdan, 1977). It is widely grown in African countries and ranks second most cultivated crop among the forages in United Arab Emirates after *Trifolium alexandrinum* fodder. Rhodes grass is also grown in other Gulf countries, as it is capable of withstanding under

harsh environmental condition. There are several seed varieties of Rhodes grass, with the 'Fine Cut' variety being known for its high yield and nutritional value, offering a crude protein of content of 9-12% (Arshad, 2015). However, to date, less studies have been conducted on the effect of different sowing season on the biomass yield and nutritive value in the northwest part of Pakistan. The Federally Administered Tribal Areas (FATA) which is now part of KP, is a tribal region in the northwest of Pakistan that comprises seven tribal districts. Historically, subsistence farming has dominated the region, with playing a key role to meet dietary needs, ensuring food security, and cash income on routine basis. Livestock production is essential for poverty alleviation and can significantly improve the socioeconomic conditions of rural populations. However, there are many constrain in the field of livestock in FATA, including a lack of trained personnel, limited access to quality fodder seed, inadequate cultivated land, insufficient irrigation facilities. These challenges negatively impact both animal productivity and economic well-being of farming community of condition of farmers in FATA. Dairy animals of FATA region primarily rely on crop residue such as wheat straw and maize stover, which are not sufficient to meet the nutritional needs of optimal milk production. To improve dairy productivity and provide quality fodder year-round, there is critical need for access to quality, improved fodder crop seeds.

Therefore, considering the issues and challenges mentioned, the International Livestock Research Institute (ILRI) partnered with Farm Dynamic Pakistan FDP under the Agriculture Innovation Programs (AIP) to introduce high yielding grasses in the northwest part of the country, with the help of Livestock and dairy development extension department. AIP-ILRI identified the best agro-climatic zone for the introduction and evaluation of Rhodes grass, focusing particularly on areas mentioned above. The main objective of the three-year research study was to evaluate the effect of different sowing seasons (winter, spring, summer, and fall) and harvest frequencies on the morphological characteristics, biomass yield and nutritive value of Rhodes grass in the newly merged district of the province.

Materials and Methods

Experimental location

The current three-years study was conducted in northwestern part of Pakistan. The area was selected based on an initial conducted survey of fodder and forages resources in the northwestern districts, carried out by ILRI in collaboration with the Livestock and Dairy Development Department Extension (L&DD). The region has a climatic temperature range from 0 to 37 °C with an annual mean temperature 19.6 °C. The lowest mean temperature occurs during month of December and January (8.3 °C), accompanied by snow falls on the mountains and frost in the valley. The highest mean temperature is recorded in June and July (30.7 °C). Spring and winter are the seasons with the most frequent rainfall season with an annual precipitation of 746 mm. The highest rainfall is typically recorded in February, March, July, and August (Pakistan Meteorological Department, 1997).

Plant growth conditions

The morphological characteristics (germination rate (%), number of plants per meter, plant height (cm)) biomass yield, chemical composition, and in-vitro digestibility of Rhodes grass were the main parameters studied during the present investigation. A sum of 80 plots (20 in each season) with a plot size of 5 m × 10 m was sown in four different seasons named Winter (December 15), Spring (March 15), Summer (June 15), and Autumn (September 15). The 'Fine Cut' variety of Rhodes grass seeds were obtained from Farm Dynamic Pakistan and sown using the broadcasting method. The seeds were mixed with sand for sowing after ploughing with tractor, at the recommended seed rate of 8 kg/ha. The experiment was conducted under a randomized complete block design. The germination rates, number of plants per meter, plant height at the time of harvest were carefully measure for each sowing season and harvest. All the fields were uniformly fertilized with manure

at the rate of 8-10 tons ha⁻¹ followed by synthetic fertilizer at sowing, as per the company's recommendation. Irrigation was applied to all field as needed.

Germination rate, number of plant/m and plant height

Germination rate (%)

The seed germination rate (GP) (%) was calculated for each season with a total of 100 seeds sown in each plot in each season to determine the germination rate of Rhodes grass. The following formula was used to calculate germination % (Ashraf and Foolad, 2005).

$$GP = \text{Total germinated seeds} / \text{Total numbers of seed}$$

The mean germination time (MGT) was calculated at the following equation.

$$MGT = \sum Dn / \sum n$$

Whereas, n = the number of seeds germinated on day D, and D = the number of days from the start of germinations.

Number of plants/ meter and tillers/plant

The total number of plants per meter was determine using 1-meter iron frame, which was randomly throw in in each plot three times per season.

Height of the plants

Plant height was determined at the time of harvest using a graduated meter rod in centimeters (cm), with the upper reference point being the last expanded sheet, from several representative plant at each sampling point in each plot, each season.

Sampling

In present investigation, samples were collected on 70th day after sowing (DAS), when the Rhodes grass reached or was near to flowering stage. The samples were taken from each plot during each sowing season, followed by second and third samples on successive cuts 40 days post the first cut, and 40 days post second cut. For each sampling event, a 1 m² area was randomly selected from each plot using a quadrat. The grass was harvested manually at 5 cm above ground level. The fresh weight of the samples from each plot was measured by using a mobile balance in the field. The samples were then transferred into pre-labelled and pre-weighed polythene bags, and immediately transported to the laboratory of Animal Nutrition, The university of Agriculture Peshawar, KP, for further analysis. In laboratory, each sample was chopped, and representative sample of fresh chopped sample was taken in duplicate. These portions were then placed in an oven for drying at 60 °C until constant weight was achieved. The dried weight was recorded for dry matter (DM) content. For further chemical analysis, the dried samples were grounded to a 1 mm particle size by using a Miller grinder. The ground sample was transferred into clean, pre-labelled bottles for storage until analysis of their chemical components. Each bottle was labelled with the sample number, sowing season, harvest number, sample name and plot number from which the sample was collection.

Chemical composition

The chemical composition of contents i.e., DM (method 930.15), ash (method 942.05), crude protein (CP; method 984.13) and acid detergent fibre (ADF; method 973.18) were analyzed using standard methods (AOAC, 1990). The content of neutral detergent fiber (NDF) was determined according to the method (Van Soest *et al.*, 1991). To determine the *in vitro* DM digestibility (DMD), two-stage *in vitro* procedure was adopted as reported (Ashraf and Foolad, 2005).

Statistical analysis

The effect of sowing season and harvest numbers on DM yield, chemical composition and *in vitro* DMD was determined using the PROC MIXED procedure in the Statistical Analysis System (SAS, 2006). Sowing season, harvest numbers and their interactions were taken as fixed effect whereas, replication was considered a random effect. The model used was:

$$Y_{ijk} = \mu + SS_i + HN_j + SS_i \times HN_j + \epsilon_{ijk}$$

Where:

Y_{ijk} is the response of the treatment.

μ is the overall mean.

SS_i is the fixed effect of the sowing season of Rhodes grass.

HN_j is the fixed effect of the harvest number.

$SS_i \times HN_j$ is the interaction effect of sowing season and harvest number.

ϵ_{ijk} is the random error.

Harvest numbers was considered a repeated factor, and replication was considered a random effect. When significant ($P < 0.05$) differences were detected, post-hoc analyses were performed using the Tukey-Kramer test to compute pairwise differences in the means.

Results*Morphological characteristic of Rhodes grass*

A significant variation ($P < 0.05$) was found for the effect of four sowing seasons: Autumn (AU), Winter (WI), Spring (SP), and Summer (SU), as well as the number of harvests on the days to germination (DG), germination percentage (GP), number of plants per meter (NP/m), tillers per plant, and plant height (cm), as summarized in Table 1. The highest DG ($P < 0.01$) was recorded in the WI season (21 days), while the lowest DG was found in the SU season (11.5 days). Moreover, the maximum GP ($P < 0.01$) was observed in the SP season (71.1%), while the lowest GP was found in the WI season (54.6%). The NP/m also varied significantly ($P < 0.001$) across seasons, with the highest value observed in the SP season (101.5). The number of tillers per plant also showed significant variation ($P < 0.05$), with the maximum value recorded in the SP season (6.10 per plant). A high variation ($P < 0.001$) was observed in plant height at harvest across the four seasons and three harvests. In the first harvest, the tallest plants were found in the SP season (105 cm), followed by AU (92 cm), WI (83 cm), and SU (77 cm). A similar trend was observed in the second harvest, with the tallest plants again in SP (110 cm), followed by AU (96 cm), WI (90 cm), and SU (85 cm). In the third harvest, plant height continued to increase overall, with the maximum height observed in SP (117 cm), followed by AU, SU, and WI seasons, as shown in (Table 1).

Table 1. Morphological characteristic of Rhodes grass (*C. gayana*) sown in four seasons in Northwest Pakistan

Sowing season	Germination		No. plants/m	Tillers /plant	Plant height (cm)		
	Days	%			(1st cut)	(2nd cut)	(3rd cut)
AU	18.0 ^b	60.9 ^{bc}	79.4 ^{bc}	5.30 ^b	92 ^b	96 ^b	98 ^b
WI	21.0 ^a	54.6 ^c	73.6 ^c	4.90 ^{bc}	83 ^{bc}	90 ^{bc}	90 ^c
SP	14.5 ^{bc}	73.1 ^a	101.5 ^a	6.10 ^a	105 ^a	110 ^a	117 ^a
SU	11.5 ^c	65.3 ^c	85.8 ^b	4.75 ^c	77 ^c	85 ^c	90 ^c
SEM	0.11	0.330	0.52	0.150	0.230	0.355	0.450
Significant	**	**	***	*	***	***	***

Mean with different superscript (^{abc}) within columns differ at $P < 0.05$. **, $P < 0.01$; *, $P < 0.05$. SEM, standard error of the mean. AU: Autumn, WI: Winter, SP: Spring, SU: Summer season

Biomass yield, nutrient composition, and in vitro dry matter digestibility of Rhodes grass

A significant variation was observed for the effect of four sowing seasons for fresh matter (FM) yield, DM yield, crude protein (CP) and nutrient detergent fibre (NDF) yields (tons ha⁻¹) of Rhodes grass (Table 2). The SP season produced the highest values of FM P<0.01 yield (18.85 vs 11.83 tons ha⁻¹), DM yield (5.20 vs 3.35 tons ha⁻¹) and CP yield (0.41 vs 0.28 tons ha⁻¹), whereas the highest NDF yield (3.77 vs 2.34 tons ha⁻¹) was recorded in SU season among all the sowing seasons of the year Table 2. There was high variation (P < 0.05) recorded for nutrient composition (g/100 g dry matter) and *in vitro* dry matter digestibility (DMD, g/100 g) of Rhodes grass. The highest value of CP (9.11 g/100 g) was observed in AU season followed by SP (8.70), WI (8.50) and SU (7.93), respectively. The maximum value of NDF contents was recorded in SU (44.6), followed by WI (42.8), AU (41.0) and SP (40.0 g/100 g). The *in-vitro* DMD was also variable at different sowing seasons and the maximum value was found for SP (61.0 g/100 g), followed by AU (56.0), WI (54.7) and SU (54.6 g/100 g), respectively (Table 3).

Table 2. Effect of different sowing seasons on DM yields, fresh matter (FM) and CP yield and fibre yield of Rhodes grass (*C. gayana*)

Sowing season	DM (g/100 g FM)	FM yield (tons ha ⁻¹)	DM yield (tons ha ⁻¹)	CP yield (tons ha ⁻¹)	NDF yield (tons ha ⁻¹)
AU	26.9 ^b	14.40 ^b	3.87 ^b	0.35 ^b	2.67 ^b
WI	26.1 ^c	13.16 ^{bc}	3.50 ^{bc}	0.30 ^{bc}	2.34 ^c
SP	27.6 ^{ab}	18.85 ^a	5.20 ^a	0.41 ^a	2.35 ^c
SU	29.3 ^a	11.83 ^c	3.35 ^c	0.28 ^c	3.77 ^a
SEM	0.510	0.450	0.150	0.230	0.355
Significance	*	**	**	*	**

Mean with different superscript (^{abc}) within columns differ at P<0.05. **, P<0.01; *, P<0.05. SEM, standard error of the mean. AU: Autumn, WI: Winter, SP: Spring, SU: Summer season

Table 3. The effect of four different sowing seasons on nutrient composition (g/100 g dry matter) and *in vitro* dry matter digestibility (DMD, g/100 g) of Rhodes grass (*C. gayana*)

Seed rate (kg/ha)	Nutrient composition						<i>In vitro</i> DMD
	DM	Ash	CP	EE	NDF	ADF	
AU	27.0 ^{bc}	7.36 ^a	9.11 ^a	2.07	69.0 ^{bc}	40.0 ^c	56.0 ^{ab}
WI	26.5 ^c	6.81 ^b	8.50 ^{bc}	2.05	70.5 ^b	42.8 ^{ab}	54.7 ^b
SP	27.6 ^{bc}	7.01 ^{ab}	8.70 ^b	2.09	67.0 ^c	41.0 ^{bc}	61.0 ^a
SU	29.0 ^a	6.15 ^c	7.92 ^c	2.04	72.5 ^a	44.6 ^a	54.6 ^b
SEM	0.58	0.320	0.210	0.05	0.610	0.925	0.535
Significance	*	***	*	NS	**	*	**

Mean with different superscript (^{abc}) within columns differ at P<0.05. NS, not significant; ***, P<0.001; **, P<0.01; *, P<0.05. CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; DMD, dry matter digestibility; SEM, standard error of the mean. AU: Autumn, WI: Winter, SP: Spring, SU: Summer season

Effect of harvests on biomass yield, composition, and in vitro dry matter digestibility of Rhodes grass

A significant effect of three consecutive harvests on the FM yield, DM yield, CP and NDF yields (tons ha⁻¹) of Rhodes grass was also observed (Table 3, 4 and 5). The maximum yield of FM (P < 0.001), CP (P<0.001), and NDF (P<0.001) was reported for third harvest followed by second and lowest value were observed for first harvest (Table 4). The highest value of CP (10.2 g/100 g), and *In-vitro* DMD (60.5 g/100 g) was observed at third harvest followed by first and second harvest, respectively. Whereas, the maximum value of NDF contents was recorded at second harvest (72.9), and the minimum NDF value was at third harvest (67.1 g/100 g) (Table 5).

Table 4. Effect of three harvest stages on DM yields, fresh matter (FM) and CP yield and fiber yield (tons ha⁻¹) during maturity of Rhodes grass (*C. gayana*)

Days after sowing	Nutrient composition						<i>In vitro</i> DMD
	DM	Ash	CP	EE	NDF	ADF	
1 st cut	26.0 ^c	6.43 ^b	8.44 ^b	2.20 ^a	70.0 ^b	42.5 ^b	55.1 ^b
2 nd cut	28.6 ^a	5.60 ^c	7.25 ^c	1.86 ^b	72.9 ^a	44.1 ^a	53.2 ^c
3 rd cut	28.1 ^b	8.61 ^a	10.2 ^a	2.10 ^{ab}	67.1 ^c	39.7 ^c	60.5 ^a
SEM	0.610	0.560	0.350	0.600	1.540	0.950	0.630
Significance (cut)	*	**	***	*	***	**	***

Mean with different superscript (^{abc}) within columns differ at P<0.05. ***, P<0.001; **, P<0.01*, P<0.05

Table 5. The effect of harvest numbers (maturity stages) on nutrient composition (g/100 g dry matter) and *in vitro* dry matter digestibility (DMD, g/100 g) of Rhodes grass (*C. gayana*)

Harvest number	DM (g/100 g FM)	FM yield (tons ha ⁻¹)	DM yield (tons ha ⁻¹)	CP yield (tons ha ⁻¹)	NDF Yield (tons ha ⁻¹)
1 st cut	26.0 ^c	11.54 ^c	3.01 ^c	0.25 ^b	2.10 ^c
2 nd cut	28.6 ^a	14.65 ^b	4.15 ^b	0.31 ^b	3.03 ^b
3 rd cut	28.1 ^b	17.56 ^a	4.94 ^a	0.51 ^a	3.32 ^a
SEM	0.510	0.670	0.330	0.305	0.560
Significance	*	***	***	***	***

Mean with different superscript (^{abc}) within columns differ at P<0.05. ***, P<0.001; **, P<0.01*, P<0.05

Interaction effect of sowing season and harvest numbers on DM, nutrients yield, composition, and in vitro dry matter digestibility of Rhodes grass

There was a significant interaction effect between sowing seasons and harvest numbers on the FM yield, DM yield, CP and NDF yields (tons ha⁻¹), of Rhodes grass, as summarised in Table 6.

Table 6. Interaction effect of four Sowing season and three harvest stages on the yields of fresh matter (FM) and dry matter (DM) of Rhodes grass (*C. gayana*)

Harvest number	Days after sowing	Sowing season	DM (g/100 g FM)	FM yield (tons ha ⁻¹)	DM yield (tons ha ⁻¹)
1 st Cut	70	AU	26.7 ^{dc}	11.90 ^f	3.17 ^f
		WI	25.0 ^{fg}	9.60 ^c	2.40 ^g
		SP	25.3 ^f	15.95 ^c	4.03 ^d
		SU	27.0 ^d	8.70 ^g	2.39 ^g
2 nd Cut (40 days post 1 st cut)	110	AU	26.2 ^{ef}	13.75 ^c	3.62 ^c
		WI	27.9 ^{cd}	14.20 ^{de}	3.96 ^{de}
		SP	29.0 ^b	18.70 ^b	5.42 ^b
		SU	30.5 ^a	11.90 ^f	3.62 ^c
3 rd Cut (40 days post 2 nd cut)	150	AU	27.9 ^{cd}	17.75 ^{bc}	4.95 ^{bc}
		WI	26.7 ^{de}	15.70 ^{cd}	4.19 ^{cd}
		SP	28.4 ^{bc}	21.9 ^a	6.21 ^a
		SU	29.5 ^{ab}	14.9 ^d	4.39 ^c
SEM			0.570	0.850	0.190
Significance					
Sowing season			*	**	**
Harvest (maturity stages)			*	***	***
Harvest × sowing season			*	***	***

Mean with different superscript (^{abcdefg}) within columns differ at P<0.05. ***, P<0.001; **, P<0.0; *, P<0.05; SEM, standard error of the mean, AU; autumn, WI; winter, SP; spring, SU; summer, DM: dry matter, FM: Fresh matter

The maximum FM and DM yield were found in the SP season at the third harvest (21.9 tons ha⁻¹ and 6.21 tons ha⁻¹, respectively), while the lowest yields were found in the SU season at first harvest (8.70 tons ha⁻¹ and 2.39 tons ha⁻¹, respectively), as shown in Table 6. A significant interaction effect ($P < 0.05$) was also observed for nutrient composition (g/100 g dry matter) and *in vitro* dry matter digestibility (DMD, g/100 g) of Rhodes grass across the four sowing seasons and harvest numbers as summarised in Table 7. The highest crude protein content (11.7 g/100 g) was observed in AU season at third harvest followed by SP (10.0 g/100 g). The lowest CP content (6.96 g/100 g) was observed at the second harvest in SU season. The *in vitro* DMD was also variable ($P < 0.01$) across different sowing season and harvest number. The maximum DMD value (62.4 g/100 g) was found in both SP and AU seasons at the third harvest, while the lowest DMD value (50.1 g/100 g) was found at the second harvest in SU season, respectively.

Table 7. The Interaction effect of four sowing season and three harvest on nutrient composition (g/100 g dry matter) and *in vitro* dry matter digestibility (DMD g/100 g) of Rhodes grass (*C. gayana*)

Harvest date	Days after sowing	Sowing season	Nutrient composition						<i>In vitro</i> DMD
			DM	Ash	CP	EE	NDF	ADF	
1 st Cut	70	AU	26.7 ^{de}	7.20 ^{cd}	9.49 ^c	2.20 ^a	65.6 ^d	40.3 ^d	52.5 ^{bc}
		WI	25.0 ^{fg}	6.83 ^{cd}	8.40 ^d	2.17 ^a	69.5 ^c	41.4 ^{cd}	52.1 ^{cf}
		SP	25.3 ^f	6.29 ^d	8.40 ^d	2.21 ^a	71.9 ^{bc}	43.5 ^{abc}	56.5 ^{cd}
		SU	27.0 ^d	5.40 ^{de}	7.49 ^{de}	2.13 ^a	73.1 ^{ab}	44.6 ^{ab}	55.3 ^d
2 nd cut	110	AU	26.2 ^{cf}	5.18 ^{de}	7.06 ^c	1.86 ^b	73.3 ^{ab}	45.2 ^{ab}	53.6 ^{de}
		WI	27.9 ^{cd}	5.30 ^{de}	7.47 ^{de}	1.87 ^b	73.0 ^{ab}	43.4 ^{bc}	52.8 ^c
		SP	29.0 ^b	6.35 ^d	7.49 ^{de}	1.88 ^b	71.5 ^{bc}	41.5 ^{cd}	57.1 ^c
		SU	30.5 ^a	5.01 ^e	6.96 ^c	1.83 ^b	74.6 ^a	45.8 ^a	50.1 ^f
3 rd cut	150	AU	27.9 ^{cd}	9.70 ^a	11.7 ^a	2.16 ^a	65.2 ^c	36.5 ^f	62.4 ^a
		WI	26.7 ^{de}	8.30 ^b	9.98 ^b	2.13 ^a	66.7 ^d	40.5 ^d	59.2 ^{ab}
		SP	28.4 ^{bc}	8.40 ^b	10.0 ^b	2.20 ^a	66.3 ^d	38.2 ^c	62.2 ^a
		SU	29.5 ^{ab}	8.05 ^{bc}	9.33 ^c	2.18 ^a	69.7 ^c	43.5 ^{abc}	58.3 ^b
SEM			0.450	0.738	0.339	0.134	2.38	2.50	1.29
Significance									
Sowing season			*	**	*	*	**	**	**
Harvest			*	*	*	*	***	**	*
Sowing × harvest			*	*	*	*	*	*	**

Mean with different superscript (^{abcdefg}) within columns differ at $P < 0.05$

***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$, CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; DMD; dry matter digestibility; AU; autumn, WI; winter, SP; spring, SU; summer; SEM, standard error of the mean

Discussion

Both the germination percentage and days to germination are important factors for the biomass yield of grass. In the current study, a high germination percentage was recorded in the spring sowing season compared to the other seasons, which might be due to the suitable temperature (22-28 °C) for germination of Rhodes grass. Similarly, the days to germination were fewer in the summer season compared to winter and autumn, which could be due to the optimal soil temperature for germination. Similar results were reported in earlier studies conducted on perennial ryegrass and grass (Horst and Dunning, 1989; Iqbal *et al.*, 2006). The sowing season also affected the tiller count per plant, number of plants per meter and plant height, with the maximum value observed in the spring season. This variation might be due the favourable sowing season and temperature that promote germination and increase the growth rate of the plants. In the spring season, plant height (105-

117 cm), tiller per plant (6.10) and maximum number of germinations per meter (73.1) were higher than in the other sowing season. Plant height increased with each harvest, reaching its maximum at third cut. This could be attributed to proper management of the grass, rainfall, and thermal accumulation in different months. The current result agrees with the earlier studies that found variation in tillers per plant (ranging from 4.5 to 6.0), plant height (ranging from 81 to 125 cm), and numbers of plants per meter (ranging from 70 to 95/m) (Khan *et al.*, 2009; Yossif and Ibrahim, 2013; Kumari *et al.*, 2017). According to earlier studies, the frequency of defoliation and the duration of the deferral period are related to the quality of the forage (Bilbao and Hago, 2000).

The result of the current study shows that there was high variation in biomass yield, nutrient yield, and composition depending on the sowing season. The FM (18.85 tons/ha/cut) and DM (5.20 tons/ha/cut) were highest in the spring season compared to the other season in the year. This might be due to suitable temperature, rainfall and humidity which promote higher and earlier germination rate, plant height and maximum number of tillers and leaves per plant. Similar findings were reported in the earlier studies, with FM yield ranging from 16.4 to 21.1 ton/ha/cut for Rhodes grass (Borhan and Hagi, 2000; Gherbin *et al.*, 2007; Arshad *et al.*, 2016). Similarly, the DM yield was consistent with values reported in different studies, ranging from 3.5 to 5.5 tons/ha/cut. These studies also observed the variation in Rhodes grass cultivars for the dry fodder yield (Arshad *et al.*, 2016; Brima, 2007). The content of CP and NDF was also in accordance with previous studies, which reported CP ranging from 6.5 to 9.9% and NDF from 49 to 75%. The *in vitro* DMD was highest in the spring season (61.0%) which might be due to lower NDF, higher leaf-to-stem ratio, and increased leaves and CP content compared to fodder other season fodders.

The yield of FM, DM, CP yield and contents, *in-vitro* DMD increased with a decreased in the NDF contents with each harvest, with the highest FM (17.56 tons/ha/cut) and DM (4.94 tons/ha/cut) yields obtained at the third harvest. This increase in yield might be attributed to the suitable environmental temperature during the growth period and proper rainfall compared to the first two harvests. The current study aligns with previous results, which also showed an increase in FM and DM yields, with the highest yield recorded at third harvest (Brima, 2007). The reduction in NDF contents with each harvest, from the first to the third, may be due to the application of high doses of fertilizers (Koul, 1997; Abbas, 2003; Brima, 2007). The increase in CP (10.2 g/100 g) content and *in-vitro* DMD (60.5 g/100 g) may be attributed to high application of fertilizers, irrigation, a higher leaf-to-stem ratio, and lower NDF content, in early harvest as compared to the first harvest. This increase with each successive harvest might also be due to the spreading of the grass roots and overall bulging of the plant, filling the gaps that were initially present due to germination. Similar results were observed by De Luca *et al.* (2001), Gasim (2001), and Adam (2004), who reported that this increase may be due to the high seed rate and germination of seed. This increase in DM and nutrient yield may also be due to the high application of nitrogen fertilizers (Buerkert *et al.*, 2001; Soliman, 2005).

Conclusion

The study concluded that Rhodes grass should be sown in the spring season in the northwest region of Pakistan to achieve the highest fresh yield (18.85 tons ha⁻¹) and dry matter yield (5.20 tons ha⁻¹), along with superior nutritive value and *in vitro* dry matter digestibility (DMD) of 61.0 g/100 g, compared to the other seasons. This is likely due to the favourable environmental conditions, including optimal temperatures (20-28 °C) and adequate rainfall, which support maximum germination and growth of the grass. Additionally, the dry matter yield and *in vitro* DMD of Rhodes grass consistently increased ($P < 0.05$) with the number of harvests, from the first to the third harvest.

Authors' Contributions

Conceptualization: NK, RK; Formal analysis: NK, NAK; Investigation: NK, RK; Methodology: RK; Project administration: NK; Resources: NAK; Software: NK, RK; Supervision: NAK; Funding acquisition: KAA, YMH, AAM and TAS; Writing - original draft: NK, RK and NAKhan; Writing - review & editing, revision: RI, TAS, KAA, YMH, AAM.

All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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