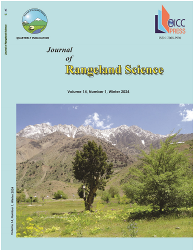

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Effects of Seed Rate and Harvesting Stage on Agronomic Performance and Quality Traits of Rhodes Grass (*Chloris gayana* K.) in Northwestern Ethiopia

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Abstract:

The experiment was conducted in 2018 cropping season with the objective of evaluating the effects of harvesting stage and seed rate on agronomic performance and quality traits of Rhodes grass (*Chloris gayana* K.) grown in northwestern Ethiopia under rain fed conditions. A factorial experiment was conducted using two factors of main factor harvesting stages in three levels (60, 90 and 120 day) and the sub factor of seed rate in three levels (5, 10 and 15 kg/ha) using a Randomized Complete Block Design (RCBD) with three replications. Data were collected for morphological traits such as plant height, tillers number, leaf length, leaf number per plant and quality traits such as Crude Protein (CP%), total ash, Acid Detergent Fiber (ADF%), Neutral Detergent Fiber (NDF%) and Acid Detergent Lignin (ADL%). The data were subjected to ANOVA using SAS software. Results showed significant effects of seed rate by harvesting stage interaction on all plant morphological traits, DM yield and quality traits ($P < 0.05$). As the seed rate and harvesting stage increased, there was an increase in tiller number, leaf length, plant height, NDF and ADL and ADF%. There were significant ($P < 0.05$) increments in DM yield as the result of descending seed rate and advanced maturity. Also, CP and total ash were markedly decreased as the harvesting stages were increased. It could be concluded that both seed rate and harvesting stage are important agronomic practices in Rhodes grass production; hence, 90 days harvesting stage and lower level of seed rate (5 kg/ha) are recommended for better yield and quality traits of Rhodes grass.

Keywords: Agronomic practices; Morphological traits; Nutritional quality; Seed rate

1. Introduction

The major feed resources for livestock in Ethiopia are natural pasture and crop residues. However, these feed resources are characterized as low in supply of feed due to overgrazing and poor botanical composition, low biomass yield and low nutritive value (Abdulatife and Ebro, 2015). The main limited factor to boost livestock productivity in the country is shortage of feed, both in quantity and quality. Sufficient feed for livestock is not available throughout the year country (CSA, 2021). On the other hand, the contribution of improved forage as livestock feed in Ethiopia is very limited; less than one percent despite more than four decades of research and development efforts in the country (CSA, 2021). Among the potential forage species, Rhodes grass is one good example of improved forage grass that could be easily adopted by the smallholder farmers in Ethiopia. Rhodes grass is the promising perennial grass adaptive to broader range of agro-climatic conditions. Tebeje et al. (2014) reported that Rhodes grass with proper agronomic practice such as hoeing, manuring and mulching reflected in better restoration of degraded rangeland of Borana, Ethiopia. Like Napier grass, Rhodes grass was also widely produced in Shashogo Woreda, Hadiya zone, Southern Ethiopia (Assefa et al., 2015). Rhodes grass has valuable features for tropical countries as it provides a relatively better yield and good quality fodder.

Although the grass has such important features, it is not well studied under Ethiopian context. It is presumed that factors such as seed rate, harvesting stage, type of forage cultivar and agro ecology could affect the biomass yield and quality traits of the forage plants (Collar and Aksland, 2001). Seed rate varies depending on seed quality (germination and purity), sowing method, environmental conditions and land preparations. Appropriate seed rate enables the farmer to keep appropriate plant population, avoid over and under population in a given plot of land which has negative effect on yield and quality (EARO, 2004). The importance of different factors in Rhodes grass is not well studied under the conditions of the current study area before wider scale of the grass.

The objective of this experiment therefore was to determine the effects of seed rate and harvesting stage on agronomic performance and quality traits of Rhodes grass grown under rain fed conditions in Ethiopia.

2. Material and methods

2.1 Study area

The experiment was conducted at North Mecha District (Fig. 1), Tagelwodefitkebele, situated at 50 km far from Bahir Dar to the northwest of the Addis Ababa Road. The area lies at an altitude of 1774 m.a.s.l and global position of Latitude and Longitude 11°25.55′ N & 37°04.00′ E, respectively. Topography of the site was gentle slope and well drained in which the farmer used the area to frequently cultivate crop alternatively in a year round. The district experiences one main rainy season (uni-modal) with a long rainy season extending from half March to the mid October.

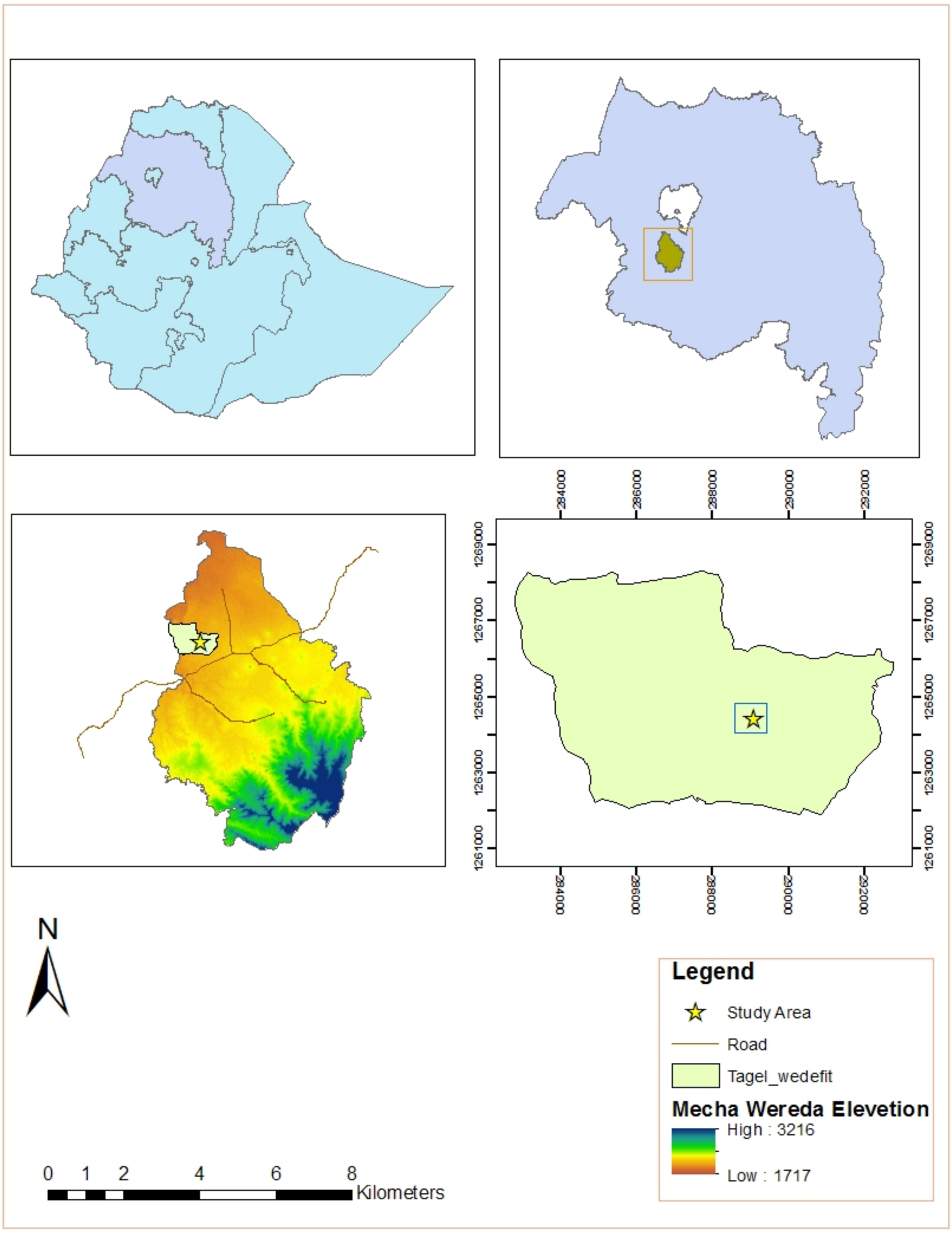

Figure 1. Map of the study area, North Mecha District

But the effective rainfall is from May to half October. The mean annual rainfall was 820 – 1,250 mm with a peak in June, July and August having an average of 105 rainy days (1,070 mm rainfall) during the study period and the soil type is loam with pH of 6.4. The mean maximum and minimum temperature was 25 and 20 °C, respectively (BOARD, 2006).

2.2 Land preparation, seed sowing and management

The experimental land was plowed four times in March and April and sowed in June, 2018 in the cropping year. The plot sizes were 12 × 34 m, 9 × 9 m and 3 × 3 m for the whole experimental plot, block and sub plot sizes, respectively. The seed was purified; select the weed, and other impurities to increase the germination percentage. Following that the seed was weighed and sow according to their respective seed proportion treatment combination and broadcasted on a well prepared seedbed on the experimental site. Three seeding rates 5, 10 and 15 kg/ha were used in the current experiment within the recommended range. The Rhodes grass seed was planted in mid-June, 2018 in a rainy season according to the recommendation of Cameron and Lemcke (2008), broadcasted at the depth of 2 cm on the ground on a well-prepared seedbed. Fertilizers NPS (containing nitrogen, phosphorous and sulfur) and Urea fertilizer were applied at the rate of 100 and 50 kg/ha during sowing and after germination, respectively. Weeds were controlled by hand to avoid interference by interspecific competition. The first weeding practice was done just before urea application and then, two times per month until the final harvesting accomplished to eliminate the re-growth of undesirable plants (weeds) and removal of the dry root in order to promote fodder re-growth by increasing soil aeration and to minimize nutrient competition.

2.3 Experimental design

A factorial experiment was conducted using two factors of seed rate in three levels (5, 10 and 15 kg/ha) and harvesting stages in three levels (60, 90 and 120 days) based on a randomized complete block design (RCBD) with three replications. There were three blocks, each containing nine plots resulting to 27 plots in total. The spacing between block and plots were 1 and 0.5 m, respectively.

2.4 Data collection

Data on the morphological parameters were recorded at each harvesting stage throughout the experimental period. Sample of Rhodes grass was randomly selected in a quadrant (within 1 × 1 m, the remaining area for border effects) to record the number of tillers per plant, total number of leaves per plant, and leaf length per plant. Sample tillers from each randomly-taken grass was used to determine the number of leaves per plant (Butt et al., 1993; Zewdu et al., 2003). The grass was mowed about five cm above the ground from all the treatments, excluding border effects, then freshly harvested plant samples were weighed and recorded and open/air dried till around 14 % moisture content in three consecutive days and weight were taken. A sample taken from each harvesting stage was thoroughly dried and 200 g sample each was sent for yield determination by drying till constant weight recorded. After drying, samples were ground by grass grinder to pass a 1 mm Wiley mill screen and stored in airtight containers for different chemical analyses. Samples of each treatment were subjected to chemical analysis for determination of crude protein following the methods of (AOAC, 2004). Forage quality measurements such as determination of nitrogen using Kjeldhal method (crude protein = N × 6.25), acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined (Van Soest et al., 1991). Ash was determined by igniting forage sample at 550 °C overnight, and total DM by drying at 105 °C (Chemlab, 1984).

2.5 Statistical analysis

The collected data were managed and organized with MS-Excel (2010). All data collected were statistically analyzed using the procedure of General Linear Model (GLM) procedure of SAS software for least square analysis of variance. Means comparisons were done using Duncan's Multiple Range Test (DMRT) for variables whose F-values declared a significant difference.

3. Results

3.1 Effect of seed rate and harvesting stage on:

3.1.1 Plant height

The leaf length, plant height, leaf number and tiller number increased with maturity of the grass (Tables 1, 2, 3). The tallest plant height (1.17, 1.20 and 1.36 m) was recorded from all seed rates (5, 10 and 15 kg/ha), respectively, from the later stage of harvesting stage (120 days) while the shortest plant heights (0.46, 0.49 and 0.52 m) were obtained from all seed rates (5, 10 and 15 kg/ha) and from the early harvesting stage (60 days). The intermediate harvesting stage (90 days) had an intermediate plant height (1.13, 1.15 and 1.19 m) at all seed rates (5, 10 and 15 kg/ha).

3.1.2 Tillers number

The maximum number of tillers (22) was obtained from the highest seed rate (15 kg) both at the mid (90 days) and late harvesting stage (120 days) and then, followed by 10 and 5 kg seed rate sown at 120 and 90 d of harvesting, which produce 21 and 18 tiller numbers, respectively (Table 3). Harvesting Rhodes grass from the lower seed rate (5 kg/ha) at the early harvesting stage (60 days) showed significant differences ($P < 0.05$) tiller number with higher seed rate (10 kg/ha) at late harvesting (120 days). The minimum tiller number (18 tillers) was observed from the lowest seed rate (5 kg/ha) and from the mid harvesting (90days), it was statistically different ($P < 0.05$) with 10 and 15 kg/ha seeding rates at 60 days of harvesting. Therefore, the total number of tillers per plant increases with proportional increasing seed rate and increasing harvesting stages.

3.1.3 Leaf length

Regarding the harvesting dates, the longest day of harvesting (120 days) showed 48 cm leaf length followed by 90 days (33 cm leaf length) with the lowest at 60 days (29 cm leaf length) of harvest (Table 3). Rhodes grass harvested with seed rates of 5, 10 and 15 kg/ha had 32, 34 and 39 cm

Table 1. The effect of harvesting stage (main factor) on morphological traits of Rhodes grass

Harvesting date	Plant height (m)	Tillers number per plant	Leaf length per plant (cm)	Leaves number per plant	Dry matter yield (t/ha)
60 days	0.49 b	15.47 b	29.20 c	82.97 c	8.41 b
90 days	1.16 a	20.23 a	33.07 b	103.73 b	8.35 b
120 days	1.24 a	21.00 a	43.87 a	169.53 a	9.25 a
Mean	2.06	18.97	35.38	118.74	8.67
SEM	0.41	3.00	7.60	45.19	0.50
Sig. level	**	**	**	**	**

SEM = standard error of means, ** = significant at 0.01, Means with the same letter are not significantly different

leaf length where the longest was observed at 15 kg/ha seed rate.

3.1.4 Leaves number per plant

Rhodes grass harvested from lower seed rate (5 kg/ha) and intermediate (10 kg/ha) seed rate at late harvesting stage (120 days) scores the highest leaf count per plant (168 and 220.3 leaves, respectively) (Table 3). The leaves number increased with advancement of harvesting date and the highest number (170 leaves) was observed at 120 days of harvesting. This was followed by 90 days of harvest (104 leaves) and the lowest number of leaves per plant (83 leaves) were observed at 60 days of harvest.

3.1.5 DM yield

The total DM yield of the longest harvesting period (120 days) was significantly higher than 90 and 60 days of harvest and the earlier harvests were not significantly different (Tables 1–3). The highest seed rate at late stage of the harvest might be proper maturity of the grass to set full seeding potential.

3.2 Effect of seed rate and harvesting date on quality traits

3.2.1 Total ash

The highest total ash was observed at 90 days (11.19 %) while there was no significant difference between 60 and 120 days of harvesting. From all seed rates, the intermediate seed rate (10 kg/ha) showed significantly the highest ash content while there was no significant difference among 5 and 15 kg/ha seed rates.

3.2.2 Neutral detergent fiber (NDF)

The NDF content of highest harvesting date was significantly higher than 90 and 60 days of harvesting. The earlier stages of harvest did not have significant difference in terms of NDF content. In terms of seed rate, the lower seed rates (5 and 10 kg/ha) have similar and higher NDF than 15 kg/ha seed rate.

3.2.3 Acid detergent fiber (ADF)

The ADF content is increased as maturity of the plant increased, which significantly higher ADF contents were observed at 90 and 120 days of harvest. The lowest ADF was recorded at 60 days of harvest of Rhodes grass. Regarding the seed rates, 5 and 10 kg seed rates showed significantly higher ADF but the 15 kg seed rate showed significantly

Table 2. The effect of seed rate (sub factor) morphological traits of Rhodes grass

Seed rate	Plant height (m)	Tillers number per plant	Leaf length per plant (cm)	Leaves number per plant	Dry matter yield (t/ha)
5 kg/ha	0.92 b	17.23 b	32.97 b	91.30 c	8.58 a
10 kg/ha	0.95 b	18.90 ab	34.87 b	117.20 b	8.74 a
15 kg/ha	1.02 a	20.57 a	38.30 a	147.73 a	8.68 a
Mean	0.96	18.09	35.38	118.74	8.67
SEM	0.051	1.670	2.701	28.247	0.081
Sig. level	**	**	**	**	ns

SEM = standard error of means ** = significant at 0.01, ns = non-significant, Means with the same letter are not significantly different

Table 3. The effects of harvesting stage and seed rate interactions on morphological traits of Rhodes grass

Harvesting date	Seed rate	Plant height (m)	Tillers number per plant	Leaf length per plant (cm)	Leaves number per plant	Dry matter yield (t/ha)
60	5	0.46 c	13.70 c	27.00 c	63.30 e	8.15 c
	10	0.49 c	15.00 c	29.00 bc	80.00 d	8.62 b
	15	0.52 c	17.70 b	31.60 b	105.60 cd	8.45 b
90	5	1.13 b	18.00 b	31.60 b	90.30 d	8.35 bc
	10	1.15 b	20.70 a	32.30 b	103.60 cd	8.35 bc
	15	1.19 b	22.00 a	35.30 b	117.30 c	8.35 bc
120	5	1.17 b	20.00 a	40.30 a	120.30 c	9.25 a
	10	1.20 b	21.00 a	43.30 a	168.00 b	9.25 a
	15	1.36 a	22.00 a	48.00 a	220.30 a	9.25 a
Mean		0.96	18.90	35.38	118.74	8.67
SEM		0.06	1.00	1.2	18.57	0.05
Sig. level		**	**	**	**	**

SEM = standard error of means, ** = significant at 0.01, Means with the same letter are not significantly different

lower ADF content (Tables 4–6).

3.2.4 Acid detergent lignin (ADL)

The highest ADL content was observed at 120 days of harvest while the earlier harvests (60 and 90 days) were the lowest. The lowest seed rate (5 kg) showed significantly higher ADL content, but the higher seed rates showed significantly lower ADL values in the current study (Tables 4–6).

3.2.5 Crude protein (CP)

Rhodes grass harvested at 60 days showed significantly the highest CP value, followed by 90 and 120 days of harvest. The 10 kg seed rate showed significantly higher CP% whereas the 5, and 15 kg showed lower values of CP in the current study (Tables 4–6). Therefore, the result indicated that the CP content was significantly reduced with advanced in harvesting stage. The decline in CP content with advancing stage of maturity is due to the accretion of a higher proportion of NDF corresponding to plant growth. The CP content was higher in the early stage as compared with the intermediate stage and late stage.

4. Discussion

As it could be expected the plant height increased progressively with increasing plant maturity at all seed rates indicating that an increment in plant height at later harvest stages could be due to massive root development and efficient nutrient uptake, allowing the plant to continue to increase in height of the grass. The expected increment in plant height at maturity is in agreement with the findings of Allah and Bello (2019) who reported increment in plant height as the forage matures in an experiment conducted in Nigeria. Moreover, the plant height obtained in the present study was higher (0.49 cm) than the results of Rambau et al. (2016) who reported that plant height for Napier grass was 58.5 cm after 12 weeks. The differences in plant height could be attributed to the nature of the grass, soil and climatic conditions. It might be due to a different management system, agro-ecology. Additionally, the lowest plant height was recorded from the lowest seed rate (5 kg/ha) while the highest plant height was recorded from the highest seed rate (15 kg) of Rhodes grass. Yasin et al. (2003) using Mott Napier grass recorded more plant height in lower seed rate which might partly be attributed to more plants to develop tendency to increase intermodal distance. But in the result, all seed rates didn't show significant differences due to the tillering habit of the grass spreading freely in different directions. The present result is in line with Tilahun et al. (2017) who showed that harvesting stage had a significant effect on plant height ($P < 0.01$) with height increasing progressively from 48 cm at 60 days of harvesting stage to 115 cm at 90 days and 126 cm at 120 days although authors reported that plant spacing had no significant effect on plant height with a mean height overall of 0.96 cm. Also, other similar findings by Ansah et al. (2010) reported an increase plant height with increase in harvest days. Similarly, cutting interval had significant effects on plant height with height increasing progressively as cutting interval increased (Wangchuk et al., 2015). There was no significant difference of plant height at harvesting among all planting spaces of Desho grass (Worku et al., 2017).

The increment of tillers per plant might be due to the fact that plants require lower seed rates to grow and develop under the reduced competition for environmental resources, especially light, space, moisture and nutrients (Zewdu, 2008). In turn, by increasing the seed rate, the plants showed a stronger apical dominance in search of solar radiation, thus

Table 4. The effect of harvesting date (main factor) on forage chemical composition of Rhodes grass

Harvesting date	Ash (%)	NDF (%)	ADF (%)	ADL (%)	CP (%)
60 days	10.87 ab	52.20 c	38.72 b	11.23 ab	13.85 a
90 days	11.19 a	63.15 b	51.50 a	10.58 b	12.36 b
120 days	9.33 b	73.50 a	56.37 a	13.58 a	10.30 c
Mean	10.13	62.95	48.86	11.80	12.17
SEM	0.99	10.65	9.12	1.58	1.78
Sig. level	**	**	**	**	**

SEM = standard error of means, ** = significant at 0.01, Means with the same letter are not significantly different

presenting less tiller number. The number of tillers per plant increased with grass maturity as the number of tillers developed. When the plants approached maturity, numerous fine branches appeared, growing out from the leaf axils of the main stems (Ansah et al., 2010).

Similar findings showed that there was a significant difference on the number of tillers ($P < 0.05$) in all seed rates, i.e.as seed rate increases, the number of tillers per plant also increases (Worku et al., 2017). The number of tillers increases from 54.6 to 79.9 tillers per plant in Desho grass as reported by Worku et al. (2017); it was significantly greater than that from the current study (20.7 to 22). This difference might be due to plant type, different plant spacing and maturity stage, weather, soil type and fertility. Also, Rambau et al. (2016) for Napier grass showed that the number of tillers increased with the increased maturity of the Napier grass, but the average number of tillers was much less (9.4 – 12.9 tillers) than that from the current result (12 to 22 tillers). It could be due to plant type, climate, and season. The maximum tillers (22.5) in the Mott Napier grass were recorded in the space of 120 × 120 cm and the minimum tillers (11.5) were counted in a seed rating of 15 kg (Yasin et al., 2003) which is in between for the species of grass from this result (20 tiller in 120 days). Also, different findings showed similar results with the current finding. According to Mustaring et al. (2014), tiller number increased as maturity increased so that Brachairia cultivars such as *B. mulato* had the highest ($P < 0.05$) tiller number than *B. brizanta* and *B. mutica* at similar harvesting dates. Tiller number per plant increased linearly with increasing plant spacing (Sanderson and Reed, 2000). Khan and Manghatt (1965) on pearl millet (*Pennisetum typhoides*) reported that the number of tillers increased consistent with an increase in plant spacing.

The length of the leaf was increased progressively with decreasing seed rate and raising the stage of harvesting. This is due to the fact that the leaf length in grasses is greatly influenced by the developmental stage of the plant reproductive or vegetative. Regarding leaf length, Lemaire and Gastal (1997) stated that this variable is of fundamental importance for the efficiency of pasture productivity since the changes that occur in the forage plant morphology as well as in pasture structure due to the number of green leaves per tiller and the leaf final length expresses the maximum number of green leaf tissue per tiller. According to Marcelino et al. (2006), leaf blade had final length of 19.22 cm of Marandu grass under field condition evaluation, which was less than the average leaf length of *Chloris gayana* (35.4 cm). This variation comes from differences in their species, soil fertility, maturity stage, and weather. Another finding by (Tilahun et al., 2017) reported for Desho grass shows that the mean length of leaves was significantly ($P < 0.05$) greater at higher seed rate (15 kg/ha) than in the intermediate (10 kg/ha) and lower seed rate (5 kg/ha) (19.0 vs. 18.2 and 17.7 cm, respectively) but it was less than the current finding. Additionally, the longest leaf length per

Table 5. The effect of seed rate (sub factor) on forage chemical composition of Rhodes grass

Seed rate	Ash (%)	NDF (%)	ADF (%)	ADL (%)	CP (%)
5 kg/ha	9.76 b	62.51 a	52.03 a	13.47 a	11.65 b
10 kg/ha	10.19 a	68.72 a	51.42 a	11.60 b	13.16 a
15 kg/ha	10.07 b	57.62 b	43.13 b	10.32 b	11.70 b
Mean	10.13	62.51	52.03	13.47	11.65
SEM	0.983	5.563	4.060	1.584	0.858
Sig. level	**	**	**	**	**

SEM = standard error of means, ** = significant at 0.01, Means with the same letter are not significantly different

Table 6. The effects of harvesting stage, seed rate and their interactions on chemical composition of Rhodes grass

Harvesting date	Seed rate	Ash (%)	NDF (%)	ADF (%)	ADL (%)	CP (%)
60 days	5 kg/h	10.87 a	55.73 c	44.40 c	16.60 a	13.84 a
	10 kg/h	10.87 a	52.16 c	36.96 d	8.40 e	14.12 a
	15 kg/h	10.87 a	48.72 c	34.80 d	8.70 e	13.60 a
90 days	5 kg/h	8.70 c	58.60 c	55.80 b	9.50 de	12.00 b
	10 kg/h	11.13 a	75.41 a	55.70 b	12.10 b	12.87 b
	15 kg/h	10.75 a	55.43 c	43.00 c	10.13 cd	12.20 b
120 days	5 kg/h	9.70 b	73.20 a	55.90 b	14.31 a	9.10 c
	10 kg/h	9.70 b	78.60 a	61.60 a	14.31 a	12.50 b
	15 kg/h	8.60 c	68.70 b	51.60 b	12.13 b	9.30
Mean		10.13	62.95	48.49 c	11.80	12.17
SEM		2.26	7.25	3.8	3.63	0.39
Sig. level		**	**	**	**	**

SEM = standard error of means, ** = significant at 0.01, Means with the same letter are not significantly different

plant increased with maturity of the Napier grass (Rambau et al., 2016). It increases from 63.3 to 78.5 cm in Napier grass (Rambau et al., 2016) that was significantly greater than the current finding (50 to 26 cm). This difference might be due to the genetic makeup of the grass, additional supply of nitrogen kg/ha, soil type and its fertility. Similar findings were observed from different studies. Leaves' expansions from narrow spacing were smaller in length as compared to those from wider spacing (Begna et al., 2000).

Regarding the seed rate, the highest number of leaves per plant (148 leaves) at 15 kg/ha seed rate, followed by 10 kg/ha seed rate (117 leaves) with the lowest value (91 leaves) was counted at the smallest seed rate (5 kg/ha) (Table 3), However, in this study, it was observed that with the increase in the stage of maturity, the greater the numbers of leaves which are important for the photosynthetic and transpiration surface were produced from the newly emerging tillers. Also, more leaves per plant were produced at the highest seed rate. This could be due to less competition between plants which resulted in taller plants and better growth.

The increment of leaves in total observed in the current study might be due to the fact that nitrogen increased plant growth and plant height and this resulted in more nodes and internodes and consequently, more leaves. This result is in agreement with finding by Tilahun et al. (2017) who indicated that leaf number, which in part, determines the photosynthetic capacity of the plants, was significantly ($P < 0.01$) affected by harvesting stage while the seed rate had no effect on this parameter. As the number of leaves per plant increased from 249 leaves at 75 days to 410 leaves at 135 days in Desho grass, but higher than that from the current finding given as 220.3 leaves/plant at 120days. The difference might be due to genetic variation, long plant height of Rhodes grass containing much number of leaves per plant and soil fertility also at similar grass. Asmare et al. (2017) reported that the number of leaves per plant was significantly affected by harvesting date. The highest number of leaves per plant (220.3 leaves) was observed at late stage of harvesting (120 days) while the lowest number (63.3) was observed at early stage (60 days) of harvesting for Desho grass. Similarly, the result of Wangchuk et al. (2015) showed that cutting interval had a significant ($P < 0.05$) effect on leaves/plant (40 and 60 > 80 days). The number of leaves per plant increased with maturity of the Napier grass (Rambau et al., 2016). The reports of different authors (Butt et al., 1993; Zewdu et al., 2002) for various forage species indicated the highest number of leaves per plant in later stages of harvesting.

Regarding seeding rate, there was not a statistical difference among the different seed rates. DM yield observed in the current result is in agreement with the report of Asmare et al. (2017) who observed that the total DM yield of the longest harvesting period (150 days) was the highest (20.75 t/ha) whereas the lowest DM yield (12.71 t/ha) was produced from the shortest harvesting period (90 days). The DM yield of Rhodes grass (9.25 t/ha) at 120 days of harvesting is lower than Desho grass (20.75 t/ha) at 150 days harvesting as reported by Asmare et al. (2017). The difference might be due to plant type, rainfall, soil fertility and management practices during cultivation. The highest total DM yield of 9.75 t/ha was obtained from 15 kg/ha seed rate configuration and this was significantly higher than that of 5 kg/ha seed rate (Sumran et al., 2009).

The result of Sumran et al. (2009) was in line with the current finding but their report is higher than the current funding at a relatively similar seed rate. The difference might be due to their intensive management of nitrogen fertilizer and irrigation and may be the genetic makeup of the grass. The result of Punpipat et al. (1995) for Napier grass is disagreed with this result that higher spacing of 75 × 75 cm gave the higher DM yield of 4,209 kg/ha than at spacing

50 × 75, 50 × 50 and 50 × 25 cm which were 3,383, 3,043 and 3,065 kg/ha, respectively but as a result, higher DM yield was observed from higher seed rate the contradiction coming from different spacing used and the nature of the Napier grass. Also, the current result is in agreement with Tilahun et al. (2017), total DM harvested increased progressively from 7.1 t/ha at 75 days of age to 25.5 t/ha at 135 days of age but not by seeding rate. Saeed (1996) on Mott Napier grass reported that close spacing produced higher productivity than wider plant spacing after establishment. Higher total DM yield of Napier grass was observed for high and medium plant density compared to lower plant density per hectare (Zewdu, 2008). The closest spacing had a higher DM yield than the widest spacing (Jimba and Adedeji, 2003). Similarly, DM yield per cut of king Napier grass increased with increasing intervals between the harvests from 1,779 kg DM/ha/cut at 30 day interval to 4,683 kg DM/ha/cut at 60 day interval (Lounglawan et al., 2014).

The ash content indicates the crude mineral available from the plant. As grasses mature, the mineral content declines due to a natural dilution process and translocation of minerals to the roots (Minson, 1990). Other studies also indicated that the concentration of minerals in forage varies due to factors like plant developmental stage, morphological fractions, climatic conditions, soil traits and fertilization regime (McDowell and Valle, 2000). Generally, the current result is in agreement with Bayble et al. (2007) who suggested that the mineral contents of herbaceous forages declines as the stage of maturity advances. This result is similar to the finding indicating that the ash content showed a decrease as the cutting interval of King Napier grass increased (Lounglawan et al., 2014). In addition, ash concentration declined significantly ($P < 0.01$) as harvesting age increased with values at 75 d exceeding those at 105 and 135 d. Progressive increases in plant spacing resulted in significant increases in ash concentration (Tilahun et al., 2017) for Desho grass in northwestern Ethiopia. But, the result recorded by Rambau et al. (2016) was contrary to the current finding, who indicated that plant maturity had no effect on ash content of Napier grass. The total ash content of the natural pasture declined with advancing stage of harvesting (Kitaba and Tamir, 2007).

Generally, the current result indicated that the content of NDF was increased as the grass becomes matured. This is due to the fact that as the plant becomes mature, the cellulose, hemicelluloses, lignin and silica which are found the insoluble portion of the forage become increased. Also, more seeds are produced at the time of plant maturity, there is a translocation of protein from leaf and stem to seed; therefore, high fiber is remaining on the plant. Aganga et al. (2005) has also reported clearly that when the maturity of the grass is increased, the quality and digestibility decreased because they are inversely related. The large amount of NDF containing largely lignin was increased with the increase of cutting age.

The NDF obtained in the present study was higher (78.63 %) than the results of (Ansah et al., 2010), who reported that NDF for Napier grass was (76.5 %) at 120 days of harvesting. The differences in NDF could be attributed to the nature of the grass, soil and climatic conditions. The NDF content of grass was the highest (77.68 %) from the late harvesting (150 days) while it was comparatively lower for earlier harvesting periods (72.78 % at 90 days and 73.96 % at 120 days) (Asmare et al., 2017); relatively lower NDF is observed in the current study (68.71 % at 90 d). The difference might be due to season of harvesting, variety, soil and climatic conditions. Mustaring et al. (2014) noted the NDF content of Brachaiaria varieties such as *B. brizantha*, *B. mulato* and *B. mutica* as 65.66 to 71.96 % at 8 weeks after planting, which is in line with the current result (73.21 % in 60 days). This is because they grow those grasses in the mixture with legume which have an advantage of providing higher protein value at any given time than accumulating high NDF content. It agrees with other results (Zewdu et al., 2002), NDF increased with increase in harvesting days ($60 < 90 < 120$ d). The authors in Ethiopia and another country (Bayble et al., 2007; Ansah et al., 2010) recorded the increases in NDF when Napier grass was harvested at 60, 90 and 120 d and should be expected with increasing grass maturity. Bernes et al. (2007) reported an increase in NDF with an increase in maturity date in Timothy grass (*Phleum pratense*). Similarly, the NDF content increased as forage maturity increased (Aganga et al., 2005; Salamone et al., 2012). In other studies, plant spacing had no significant effect on the NDF content (Semman et al., 2014). In contrast to our result, Rambau et al. (2016) demonstrated that plant maturity had no effect on the NDF content of Napier grass.

Structural cell wall components increase as the plant gets matured because photosynthesis components are converted to structural components at the expense of soluble carbohydrates (Ammar et al., 2010). ADF is the percentage of highly indigestible and slowly digestible material in a feed or forage. Higher forage ADF results in reduced digestible dry matter as a consequence of increased lignifications of cellulose in the latter stage of the plants (DePeters, 1993). Therefore, an increase in ADF content with the advance in harvesting days of grass was reinforced; the results of Asmare et al. (2017) indicated that Desho grass harvested at 150 d after planting had a higher ADF (45.06 %) than for samples harvested at 90 d and 120 d after planting (40.27 and 42.15, respectively) which is less than the result of the current finding (61.32 % at 120 d). Similarly, as Ansah et al. (2010) reported, Napier grass scored the lowest (51.1 %) ADF content at 120 d of harvesting than the current finding (61.32 % at 120 days). Hence, the highest weather condition in contrary to the current finding Rambau et al. (2016) showed plant maturity had no effect on the ADF content of Napier grass, but the average ADF content (37.83 %) was relatively lower than the current finding (35.51 %). Therefore, this indicates that Rhodes grass performs better during feed digestion in the rumen than Napier and Desho grasses and it can easily be converted into milk, meat and other animal products. As reported by Zewdu and Baars (2006), the *Panicum coloratum* and *Chloris gayana* (Rhodes grass) produced relatively different ADF (34.4 % and 33.8 %) content as compared to the current result. This might be due to the differences in soil type, agro ecology and grass type, etc.

Mustaring et al. (2014) who reported that the ADF contents of Brachaiaria cultivars such as *Brachiaria brizantha*, *B. mulato* and *B. mutica* were 38.21, 38.79 and 46.09 %, which is almost lower than the current result. Bernes et al. (2007) reported an increase in ADF with an increasing maturity date in Timothy grass (*Phleum pratense*). Also, similar findings show ADF concentration increased significantly ($P < 0.01$) with an increase in harvesting stage, but it was unaffected by plant spacing in Desho grass (Tilahun et al., 2017). Bayble et al. (2007) recorded an increase in ADF when Napier grass was harvested at 60, 90 and 120 d, which was due to an increase in grass maturity. Plant seed rate had no significant effect on the ADF of napier grass (Semman et al., 2014). The ADF contents increased as forage maturity increased as they are proportional with each other or vice versa with forage digestibility (Aganga et al., 2005; Salamone et al., 2012).

The ADL content result indicated that with the age increase, the level of lignin in grass also increased which showed a rapid lignification to occur in late development stages and the presence of insoluble fiber, particularly lignin lowers the overall digestibility of the feed by limiting nutrient availability (Van Soest, 1994). It was in conformity with other reports (Aganga et al., 2005) observing that ADL increased with the progressive stages of maturity for different forages. The late stage had the highest lignin content, implying that though Napier grass had high DM, the high lignin content would bind the cellulose and hemicellulose and prevent them from being digested and utilized efficiently by the rumen microbes. Therefore, forages with lower ADL concentrations are more desirable (Ansah et al., 2010).

Reports (Zewdu et al., 2002; McDonald et al., 2010) showed that ADL content increased with the advance in harvesting days of forage crops. ADL was reported in Indonesia on *B. brizantha*, *B. mulato* and *B. muticagive* higher (8.48, 8.18 and 11.15 %) (Mustaring et al., 2014) when compared to the current result; this might be due to lower CP record in the current study or the nature of the grass. Also, a similar report by Zewdu and Baars (2006) indicated that the ADL content of *Panicum coloratum* (5.25 %) and Rhodes grass (5.96 %) grass were higher than this study (3.96 %). This might be due to the varied harvesting stage, soil fertility, plant nature. Bayble et al. (2007) recorded increases in ADL when Napier grass was harvested at 60, 90 and 120 days, which was expected with increasing grass maturity. Bernes et al. (2007) reported an increase in ADL with an increase in maturity date in Timothy grass (*Phleum pratense*). Seed rate had no significant effect on the ADL (Semman et al., 2014). Plant maturity had no effect on the ADL content of Naper grass (Rambau et al., 2016).

The CP content was observed in the early stage as compared with the intermediate stage and late stage. This could be attributed mainly to dilution of the CP contents of the forage crops by the rapid accumulation of cell wall carbohydrates at the later stages of growth (Van Soest, 1994). Decreasing CP contents of grasses with increasing plant harvesting might be because of reduced leaf to stem ratio at a later stage of harvesting (Chaparro and Sollenberger, 1997). In the present study, late harvesting contained low levels of CP (9.11 %). Despite the decline in CP content with increasing stage of maturity, the intermediate harvesting concentration exceeded the minimum CP level (7.5 %) required for rumen function (Jusoh et al., 2014). This indicated the possibility of improving the feeding of animals in tropical regions by early harvesting of Rhodes grass before maturity, thus enhancing the quality of nutrients supplied to animals. A general decline in CP concentration with increasing harvesting interval corresponds with the results of other studies showing declines in CP with advancing phenological stages. In the present study, the CP content at early harvesting is double of natural pasture as indicated by Kitaba and Tamir (2007) advancing the harvesting stage significantly ($P < 0.05$) which decreased the CP content of the forages from the natural pasture; the mean CP in control ranged from 6.8 % at 30 d to 4.8 % at 120 days of harvesting. Therefore, by growing Rhodes grass in different strategies (depending on their accesses of land), especially in the form of specific plot from their crop, land farmers can improve the natural pasture productivity. As indicated by Haryani et al. (2018), six Napier grass cultivars produce greater average CP content (14.44 %), which is almost similar to the present study.

The results obtained CP in the current result was the highest in the early stage compared with the intermediate stage and late stage (Manyawu et al., 2003; Khaled et al., 2006; Peiretti et al., 2015). Kranberger and Klemenčič (2003) and Peiretti (2009) showed that the CP decreased with an increase in harvest day. Lounglawan et al. (2014) observed that the CP levels decreased by 27 % from the 60 day harvest to the 120 d. Similarly, harvesting period on the CP content of Desho grass which significantly decreased with increasing age of the plants (Asmare et al., 2017). The CP content was constantly reduced with the advance in cutting days, and higher CP content was observed in plant samples cut at 60 d than either at 90 or 120 d (Bayble et al., 2007). CP concentration of leaves declined dramatically with increase in cutting interval from 28.2 % at 40 days to 8.8 % at 80 d ($P < 0.05$). Similarly, CP concentration in whole plants declined from 40 to 80 d ($P < 0.05$) (Wangchuk et al., 2015). The CP content of Napier grass also decreased with maturity, and the CP level decreased by 16 % from early to late stage. The CP content serves as an important indicator of fodder quality (Sultan et al., 2007; Jusoh et al., 2014).

5. Conclusion

In the current study, it was shown that both the effects of harvesting stage and seed rate had a noteworthy effect on all plant morphological traits, forage DM yield and quality traits of Rhodes grass. From forage quality perspective, the Rhodes grass should be harvested before maturity at 60 days retains its high nutrient content (CP) though the amount of DM yield which was greater for late harvesting (120 days). Hence, 90 days harvesting stage and lower level of seed rate were found significant for better yield and quality traits of Rhodes grass. Generally, there was a significant ($P < 0.05$) interaction between the seed rate and harvesting stage for morphological characteristics of Rhodes grass which were independent or fixed factors and all other morphological parameters were dependent variables in this field experiment. It could be concluded that both seed rated and harvesting stage are important agronomic practices in Rhodes grass production. To make the current finding value, the result has to be supported with feeding live animal evaluation trials.

Ethical approval:
This manuscript does not report on or involve the use of any animal or human data or tissue. So the ethical approval does not applicable.

Authors Contributions:
All authors contributed equally to performing experiments, analyzing data, and writing the paper.

Availability of data and materials:
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interests:
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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