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Effect of Plant Height at Cutting and Previous Frequency of Defoliations on Dm Yield and Nutritive Value of Hay Made from Final Regrowth of *Hyparrhenia rufa (Nees)* Grass

Getachew Assefa

Department of Animal Production and Extension,
Faculty of Veterinary Medicine, University of Gondar, P.O. Box, 196, Gondar, Ethiopia

Abstrac: Low income from hay, due to low leaf percentage and it's tough stem at maturity, is a problem of livestock and hay producers in areas where *Hyparrhenia rufa (Nees)* is a dominant grass species. Hay making before it matures usually affected by seasonal rain. This research was conducted to determine appropriate plant height at intermediate cutting and frequency of defoliation which result maximum leaf and total digestible DM yield of hay made from the final regrowth of *hyparrhenia rufa(Nees)* grass. Three defoliation frequencies (single, double and triple) and four plant height at cuttings (30, 70, 110 and 150cm) were tested in factorial arrangement in Randomized Complete Block Design with three replications. The data were analyzed using JMP (10.0.2) software. The research has found that cutting twice when *Hyparrhenia rufa (Nees)* attain 30cm height increased leaf DM and total digestible DM yield of hay made from final regrowth, respectively, from 3.33 and 3.28t/ha to 4.66 and 6.13t/ha. Therefore it is concluded that *Hyparrehini rufa (Nees)* hay quality can be improved by controlling its growth by cutting.

Key words: *Hyparrhenia rufa* · Defoliations frequency · Cutting frequency · Defoliation stage · Cutting stage · Hay quality

INTRODUCTION

Livestock feed scarcity and low quality are the major problems in the long dry season (9 months) of Ethiopia. Quality problem is more serious in areas where *hyparrhenia rufa* is the dominant grass species. *Hyparrhenia rufa (Nees) Stapf* is a fast growing, perennial, tall (60-240 cm) and erect grass [1-2]. It is thought to be native of Africa and is now widely naturalized in most tropical regions (Africa, Asia, North and South Americas, Pacific). It is cultivated in Africa, in the United States, in the Caribbean Islands and in China [3]. Hay made from fully matured *hyparrhenia rufa* grass is low in its leaf percentage and the stem is woody and unpalatable.

Harvesting *hyparrhenia rufa* for hay before flowering at a height of 60-70 cm has been recommended by FAO [1]. However, because of seasonal rain, this time is not favorable for hay making, in tropical and subtropical countries [4] including Ethiopia. When favorable time for hay making comes (end of main rainy season) *Hyarrhenia rufa* is totally mature and lignified. This research was conducted on the objective of determining appropriate plant height at intermediate cutting and frequency of defoliation which result maximum leaf and total digestible DM yield of hay made from the final re-growth of *hyparrhenia rufa* (Nees) grass.

MATERIAL AND METHODS

Experimental Site: The experiment was conducted between June 2011 and October 2012 in Ethiopia at University of Gondar forage demonstration site, 12°36' N, 37°28' E, [5], 2133 meter above sea level. The annual rainfall of the area is 1000 to 1500 mm. The rainy season is from June to end of September. The annual average air temperature is 25 to 30°C [6]. The soil was clay and the nutrient contents were 0.06%, 17pp and 3.35 cmol/kg for total nitrogen, available phosphorus and exchangeable potassium, respectively.

Corresponding Author: Getachew Assefa, Department of Animal Production and Extension, Faculty of Veterinary Medicine, University of Gondar, P.O. Box, 196, Gondar, Ethiopia.

Experimental Design and Treatments: Three defoliation frequencies (single, double and triple defoliations) and four plant height at cutting (30, 70, 110 and 150cm) were arranged in factorial experiment in Randomized Complete Block Design (RCBD) as described by Gomez and Gomez [7] with tree replication. The net plot size for each replication was 2.5m^2 (2.5 x 1m). The spacing between plots and replications was 2 and 1 m, respectively. The spacing between individual plants within rows and between rows was as recommended by FAO [8] i.e. 25 and 40 cm respectively.

Planting and Management Practices: Three years old *Hyparrhenia rufa* (ILRI accession No.13771) which have been used in University of Gondar for demonstration was used on well prepared seed bed. Uniform root splits were propagated under rain-fed conditions in June 2011 when the soil was moist. Phosphate and N fertilizers were added as recommended by Tarawali *et al*. [9] for grass establishment, in the form of di-ammonium phosphate and urea, respectively at the rate of 100kg/ha phosphate fertilizer at time of establishment and 200kg/ha urea close to the root split after *hyparrhenia rufa* has established well. The first standardization cut had been made almost after a year in may 2012 when the plant was dormant. Subsequent defoliation continued from July to October 2012 whenever the plant attained the specified height of defoliation for each treatment. Manual cutting method, was applied using sickle. While cutting the stable height for all treatment was constant (5cm from the ground).

Data Collection and Analytical Procedures: Leaf percentage was calculated from mean weight of leaves and stems recorded from the five fresh and dry plants selected randomly from each treatment. For plant height measurement 25 randomly taken grass were used as described by Cornelissen *et al*. [10]. Lottery method was used after all plants that touched diagonally stretched thread are numbered. For chemical analysis and *in vitro* DM digestibility determination, fresh weight from each treatment was taken immediately after harvest and independently dried under the shade until constant weight is reached and dry weight was taken. Two hundred gram hay sample was taken from each treatment plot harvest and sent to ILRI-Ethiopia nutrition laboratory for chemical analysis. Chemical composition and *in vitro* Dry Mater Digestibility (IVDMD) were analyzed using near-infrared spectroscopy (NIRS) techniques. All data collected were statistically analyzed using the procedure outlined by Gomez and Gomez [7] for factorial experiment in a Randomized Complete Block Design using JMP (10.0.2). The least significance difference (LSD) were used for mean separation for DM yield, chemical analyses and IVDMD. To meet the assumption of normality, the data were transformed prior to carrying out the ANOVAs

RESULTS

Leaf Percentage and Leaf Yield: Frequency of defoliation had significant ($P < 0.001$) effect on leaf DM yield and leaf percentage of final regrowth of *hyparrhenia rufa(Nees)* grass. As frequency of defoliation increased, leaf percentage of final regrowth increased and leaf yield decreased (T1). Significantly ($P<0.001$) highest leaf yield (4.04t/ha) and leaf percentage(81.91%) were recorded from final regrowth of *hyparrhenia rufa (Nees)* which had defoliated once and three times, respectively, when it attained 30cm height.

Dry-Matter Yield: Frequency of defoliation showed significant ($P < 0.001$) effect on final regrowth DM yield of *hyparrhenia rufa* (T1). The DM yield decreased as the frequency of defoliation increased from single to triple defoliation. Defoliation stage had variable effect on final regrowth total DM yield of *hyparrhenia rufa*. Up to stage of 70cm plant height, defoliation stage has no significant effect ($P >0.05$) on total (leaf and stem) DM yield final regrowth of *hyparrenia rufa*. Once after *hyparrhenia rufa* has attained 70cm height, as stage of plant at defoliation increased, the final regrowth total yield also decreased (T1).

Final Regrowth Plant Height: There was significant ($P<0.001$) difference among treatments in their final regrowth plant height. As plant height at defoliation deceased from 150 to 70cm, the final regrowth height of *hyparrhenia rufa* increased from 58.75 to 102.69cm. At 95.6cm and 102.69cm regrowth height, leaf DM yield were height (4.15t/ha). The time required to attain this height was 33days.

Chemical Composition and *in vitro* Dry-Matter Digestibility: All chemical components, except DM percentage, were significantly ($P < 0.001$) affected by frequency of defoliations (T2). Significantly ($P<0.001$) higher CP (7.48) and IVDMD (52.76%) percentage were

Table 1: Effect of defoliation frequency (DF) and defoliation stage (DS) on dry matter yield, leaf percentage and final regrowth plant height.

	Total (leaf and stem) yield			Final regrowth			
Defoliation frequency (DF)	IC	FRC	Total	Height(cm)	GP (day)	LP(%)	LDMY (t/ha)
Single (S)	2.58c	8.69a	11.27b	140.92a	53.60a	46.52c	4.04a
Double (D)	4.80b	7.96b	12.76a	122.90b	40.00b	47.84b	3.81b
Triple (T)	7.36a	3.23c	10.59c	73.10c	28.80c	57.17a	1.85c
Defoliation stage							
30 cm (A)	1.97d	7.34b	9.31d	95.00c	33.33b	56.52a	4.15a
70cm (B)	5.17c	7.38b	12.55b	102.69b	32.00b	52.36c	3.86a
110 cm (C)	7.33b	5.07c	12.40b	90.01d	28.67c	53.47c	2.71c
150-cm (D)	10.09a	3.80d	13.89a	58.73e	19.33d	55.16b	2.10d
Control (UDP)	0.00	9.53a	9.53c	218.45a	91.00a	34.04d	3.24b
DF X PHAT							
AS	1.49j	10.60a	12.09ef	162.58b	60.00b	42.99f	4.56bc
AD	2.00ij	10.44a	12.43de	95.60g	31.00d	44.67f	4.66a
AT	2.50hi	0.99h	3.49h	26.81L	9.00g	81.91a	0.81h
BS	2.82h	10.42a	13.24ct	127.46c	45.00c	49.63e	5.17abc
BD	5.19f	9.01b	14.20bc	114.49e	30.00d	51.37de	4.63bc
BT	7.51d	2.70g	10.21g	66.13j	21.00e	56.10b	1.51fg
CS	3.90g	7.40c	11.30f	120.56d	42.00c	51.58de	3.82cd
CD	6.80e	6.35d	13.15d	110.46f	29.00d	52.60d	3.34cde
CT	11.29b	1.47h	12.76de	39.00k	15.00f	56.24b	0.83g
DS	4.79f	5.48e	10.27g	85.56h	30.00d	53.37cd	2.92de
DD	10.00c	4.47f	14.47b	75.52i	20.00e	55.53bc	2.48ef
DT	15.52a	1.46h	16.98a	15.12M	8.00g	56.58b	0.83g
UDP(control)	0.00	9.53a	9.53g	218.45a	91.00a	35.04g	3.33cde
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
RMSE	0.66	0.44	0.62	2.17	2.7	1.39	0.74

Numbers with the same superscript within a column and within a factor are not different (P < 0.05) ; IC, intermediate cut; FRC, final regrowth cut; LP, leaf percentage; LY, leaf yield; UDP, undefoliated plant; RMSE, Mean- Square Error.

Table 2: Effect of defoliation frequency (DF) and defoliation stage (DS) on chemical composition and digestibility of hay made from final regrowth of *hyparrhenia rufa* (Nees) grass

	Chemical composition and IVDMD (% DM basis)						
Defoliation frequency (DF)	DM	Ash	CP	NDF	ADF	ADL	IVDMD
Single (S)	91.62a	9.14b	6.88b	74.48a	49.03a	7.17a	51.07c
Double (D)	91.64a	8.94c	7.48a	73.72b	48.09ab	7.07a	52.06b
Triple (T)	91.73a	9.61a	6.28c	72.74c	47.52c	6.93a	52.76a
Defoliation stage (DS)							
30 cm (A)	91.28a	9.31c	4.63c	72.84b	47.23b	6.54b	55.67c
70 cm (B)	91.90a	10.17b	5.60b	72.33b	45.94c	6.56b	55.89b
110 cm(C)	91.90a	9.12d	10.50a	73.37b	48.35b	6.79b	55.91b
150cm(D)	91.33a	10.40a	10.79a	70.10c	44.66d	6.58b	57.93a
Control (UDP)	91.90a	7.15e	2.88d	79.60a	54.87a	8.82a	34.42d
DF X PHAD							
AS	91.17d	8.51j	7.40c	77.70a	54.21a	6.57cde	56.07f
AD	91.37cd	9.49h	5.48e	72.20bc	46.52cde	7.76b	58.67c
AT	91.30cd	9.92e	1.00h	68.60d	40.97g	5.30f	52.26i
BS	91.90a	10.80b	1.46h	73.00bc	47.51cd	6.33de	54.87h
BD	91.45cd	9.95d	9.01b	72.10bc	45.47def	6.69cde	57.92d
BT	91.97a	7.76f	6.34d	71.90cd	44.85df	6.68cde	54.87h
CS	91.90a	9.03i	10.43a	72.20bc	44.99ef	6.79cd	60.15b
CD	91.90a	8.42k	10.60a	73.90b	48.17c	6.21de	52.26i
CT	91.90a	9.92e	10.47a	74.00b	51.90b	7.37bc	55.33g
DS	91.23cd	10.20c	10.63a	69.90cd	43.57f	7.37bc	49.82j
DD	91.57b	9.69g	10.87a	70.80bcd	45.42def	5.87ef	57.05e
DT	91.20d	11.30a	10.88a	69.60cd	45.00ef	6.50cde	66.92a
UDP(control)	91.90a	7.15L	2.88f	79.60a	54.87a	8.82a	34.42k
P	<0.001	<0.001	<0.001	<0.004	<0.001	<0.005	<0.001
RMSE	0.63	0.003	0.45	2.09	1.28	0.05	0.25

Numbers with the same superscript within a column and within a factor are not different (P < 0.05). IC, intermediate cut; FRC, final regrowth cut; UDP, undefoliated plant.

Table 3: Effect of defoliation frequency (DF) and defoliation stage (DS) on total nutrient yield (t/ha) of hay made from final regrowth of *Hyparrhenia rufa* grass

Defoliation frequency (DF)	Final cut DM yield (t/ha)	CP%	CP (t/ha)	IVDMD%	Digestible DM t/ha
Single	8.69a	6.88b	0.60a	51.07c	4.44a
Double	7.96b	7.48a	0.60a	52.06b	4.14b
Triple	3.23c	6.28c	0.20b	52.76a	1.70c
P	<0.001	<0.001	<0.001	<0.001	<0.001
RMSE	0.44	0.45	0.03	0.25	0.020
Defoliation stage (DS)					
30 cm (A)	7.34b	4.63c	0.34c	55.67d	4.09a
70cm (B)	7.38b	5.60b	0.41c	55.89c	4.12a
110cm(C)	5.07c	10.50a	0.53a	55.91c	2.83c
150cm(D)	3.80d	10.79a	0.41b	57.93a	2.20d
Control (UDP)	9.53a	2.88d	0.27d	34.42e	3.28b
P	<0.001	<0.001	<0.001	<0.001	<0.001
RMSE	0.44	0.45	0.03	0.25	0.020
DF X PHAT					
AS	10.60a	7.40c	0.78a	56.07f	5.94ab
AD	10.44a	5.48e	0.57c	58.67c	6.13a
AT	0.99h	1.00h	0.01g	52.26i	0.52i
BS	10.42a	1.46h	0.15f	54.87h	5.72b
BD	9.01b	9.01b	0.81a	57.92d	5.22c
BT	2.70g	6.34d	0.17ef	54.87h	1.48g
CS	7.40c	10.43a	0.77a	60.15b	4.45d
CD	6.35d	10.60a	0.67b	52.26i	3.32e
CT	1.47h	10.47a	0.15f	55.33g	0.81hi
DS	5.48e	10.63a	0.58c	49.82j	2.73f
DD	4.47f	10.87a	0.49d	57.05e	2.55f
DT	1.46h	10.88a	0.16f	66.92a	0.98h
UDP(control)	9.53a	2.88f	0.46d	34.42k	3.28e
P	<0.001	<0.001	<0.001	<0.001	<0.001
RMSE	0.44	0.45	0.03	0.25	0.020

Numbers with the same superscript within a column and within a factor are not different (P < 0.05). CP, Crude protein ; IVDMD, *in vitro* dry matter digestibility**.** UDP, undefoliated plant ; RMSE, Mean- Square Error.

recorded from hay made from final regrowth of *hyparrhenia rufa* defoliated twice and three times, respectively, in its growth period. Similarly, plant height at cutting affected the nutritive content of final regrowth of *hyparrhenia rufa*. Significantly (P<0.001) higher CP (10.79%) and IVDMD (57.93%) were recorded in regowth of a *hyparrhena rufa* which had been defoliated at its 150cm height growth stage. Significant (P<0.002) deference in CP content and IVDMD also observed on hay made from final regrowth of *hyparrhenia rufa* due to the interaction effect of frequency and stage of defoliation. As compared to other treatment combinations; single, double and triple defoliation when *hyparrhenia rufa* attains 70 -150cm resulted significantly (P<0.001) higher CP%. Triple defoliation at the age of 150cm plant height had also resulted significantly (P<0.001) higher (66.92) percent IVDMD. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were significantly (P<001) higher in hay made from regrowth of *hyparrhenia rufa* which had been defoliated once at 30cm plant height at cutting.

Digestible Nutrient Yield: Frequency of defoliation significantly (P<0.001) affected the total digestible CP and DM yield. The highest digestible DM was recorded from hay made from final regrowth of *hyparrhenia rufa* which had been defoliated once in its growth period. Single and double defoliation resulted similar (P>0.05) digestible CP yield. Stage of defoliation also significantly (P<0.001) affected digestible nutrient yield. Significantly (P<0.001) higher digestible CP and DM recorded from hay made from *hyparrenia rufa* which had been defoliated at 110 to 150 cm and 30 -70cm height stage, respectively**.** Significant (P<0.002) deference was also observed on digestible CP and DM yield of *hyparrhenia rufa* hay made from final regrowth due to the interaction effect of frequency and stage of defoliation. As compared to other treatment combinations and control, single defoliation at 30 and150cm height stage and double defoliation at 70 cm height stage resulted significantly (P<0.001) higher (0.87t/ha) digestible CP yield. Digestible DM was significantly (P<0.001) higher (6.13t/ha) from hay made from final regrowth of *hyparrhenia rufa* defoliated twice when it attained 70cm height stage(T3).

DISCUSSION

Final Regrowth Plant Height and Time Interval Required to Attain the Specified Treatment Plant Height at Cutting: The observed decrease in the heights of *hyparrhenia rufa* with increased in cutting frequency agrees with the report by Adams *et al.* and Onyeonagu C. C. and Asiegbu J. E., [11-12] that frequent defoliation of Himalayan grasslands by large number of cattle reduced the ability of the grasses to replenish leaf area, set seeds and store food reserves in their roots, thereby reducing plant growth. Similar finding had also been reported by Fu-Hsing Hsu *et al*. [13] at plant height and dry matter percentage of both Nile and Pangola grasses increased with cutting stage delayed.

Dry-matter Yield: In the present study, the DM yield of final regrowth decreased as the frequency of defoliation increased. Tesema [14] also reported similar effect of frequency of defoliation on Napier grass. The DM yield of Napier grass had increased as the frequency of defoliation decreased. In this study, the increased intermediate cut cumulative DM yield observed as plant height at cutting increased was due to the time interval differences between subsequent cutting in different treatment. As plant height at cutting increased, the time interval between two subsequent intermediate cuttings was increased. For intermediate cuttings, the treatment with taller height at cutting had longer time interval between subsequent cuttings. However, the longer time interval or plant height at cutting, in intermediate cuttings, resulted shorter time interval between the last intermediate cut and final regrowth cut. Related finding had been reported by Rengsirikul *et al*., [15] that as inter-cutting interval increased from 1 to 3 months, the total DM yield for Bana and Common Napier grass had increased. The total (intermediate plus final cut yield) DM yield of *hyparrhenia rufa* recorded in this study (9 - 13t/ha) also agreed with the report of FAO [8], 4.5 - 18.7t/ha for the specie under different management.

Leaf Percentage and Leaf Yield: In the present study, increased frequency of defoliation increased leaf percentage and decreased leaf yield of hay made from final regrowth of *hyperrhenia rufa*. The increased leaf percentage as defoliation increased was due to reduction of plant height and shorter time for maturation or lignifications. This result agreed with the finding of Fu-Hsing Hsu *et al*. [13] that plant height and dry matter percentage of both Nile and Pangola grasses increased with cutting stage delayed, while leaf:stem ratios decreased with growth stage advanced.

Chemical Component and *in vitro* Dry-Matter Digestibility: In present study, the higher CP% was recorded from 110 and 150cm plant height at cutting which had been previously defoliated single, double and triple. *in vitro* dry mater digestibility percentage was higher in hay made from final regrowth of *hyparrhenia rufa* which had been defoliated three times when it attained 150cm. These were due to their lower stage of maturation of the regrowth (8 to 42 days only) as compared to single defoliation (60 days) (T1). Due to similar reason significantly higher Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were recorded in hay made from regrowth of *hyparrhenia rufa* which had been defoliated once at 30cm plant height at cutting stage. Similar finding has reported by Enoh *et al*. [16].and Fu-Hsing Hsu *et al*. [13]. As pastures mature they are characterized by high content of fiber with a higher grade of lignifications and low protein content [16]. As the harvesting interval delayed from 8 to 12 weeks, the CP declined by 23%, while the fiber fractions (CF, NDF, ADF) and ADL increased by 20 and 4%, respectively, for native and Brachiaria grasses in the Adamawa Plateau of Cameroon [16].The CP contents of both Nile and Pongola grasses decreased with the delayed cutting stages, while those of neutral detergent fiber (NDF) and acid detergent fiber (ADF) increased with later cutting stages [13].

CONCLUSIONS

Hyparrehini rufa (Nees) grass hay quality can be improved by controlling its growth by defoliation. Any decision on which cutting stage and frequency to apply would need to make decision on whether quantity or quality of fodder is more important. From present study one can conclude that hay with optimum leaf percentage and maximum total dry mater digestibility can be harvested from final regrowth of *hyparrhenia rufa* if it is harvested twice in its growth period where it attain 30cm height.

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