Journal of the Korean Society of Grassland and Forage Science 37(3) : 201~207 2017
https://doi.org/10.5333/KGFS.2017.37.3.201
ISSN 2287-5824 (Print)
ISSN 2287-5832 (Online)

Research Article

Effect of Cutting Height on the Feed Value and Drying Rate of Rye (*Secale cereale* L.) Hay

Yu Wei Li[1], Jong Geun Kim[1,2,*]
[1]Graduated School of International Agricultural Technology, SNU
[2]Research Institute of Eco-friendly Livestock Science, GBST, SNU

ABSTRACT

Hay-making is one of the most common forage preservation practices in livestock operations. The objective of hay-making is to minimize nutrient loss by shortening field drying time. Measuring the impacts of cutting height of forage crop is necessary to optimize hay production balancing yield and quality, in order to obtain substantial biomass increase through harvest of regrowth. This experiment was conducted to investigate the impact of cutting height of rye (*Secale cereale* L.) on drying rate and hay quality. Heading stage rye was harvested at 8cm or 15cm stubble heights. Hay was daily tedded at 09:00 and sampled at 09:00, 13:00 and 17:00 to determine moisture content (MC). After two month of preservation, CP (crude protein), ADF (acid detergent fiber), NDF (neutral detergent fiber), IVDMD (*in vitro* dry matter disappearance), TDN (total digestible nutrient), RFV (relative feed value), DM (dry matter) loss, visual scores and total fungi count were determined for estimation of hay quality. Cutting height at 15cm could enhance the drying rate and CP content ($p<0.05$), but also increases DM loss ($p<0.05$) compared to cutting at 8cm. Cutting heights did not affect ADF, NDF, IVDMD, TDN and RFV value ($p>0.05$). Visual scores of rye hays cutting at 8cm and 15cm, ranged from 83 to 85. Cutting at 8cm tended to maintain higher core bale temperature and fungal count than cutting at 15cm during preservation, but there was no significant difference.

(**Key words** : Hay, Rye, Quality, Drying rate, Preservation)

Ⅰ. INTRODUCTION

Due to frequent and heavy rainfall in the eastern mountain area of South Korea, silage has been a more common forage preservation practice. However, silage can’t be consumed and the quality can’t be checked before silage stable state. Therefore, instead of silage, the hay is used which is imported from other countries. This experiment aimed to help increase domestic hay production in South Korea. Haymaking is accomplished through rapid removal of moisture in forage to reach DM concentration above 800 g kg^{-1} which is DM level for long-term hay storage without further nutrient loss. Throughout the forage harvest, drying, and preservation process, forage loses DM and nutrients through chemical, physical, and biological reactions. Optimized hay production management is important to achieve consistent production of high quality hay.

Cutting height has been known for affecting regrowth of forage and also for affecting total biomass productivity. Dry matter and nutrition productions of forage were greater when harvested at a lower cutting height (Smith and Nelson ,1967; Kust and Smith, 1961). Lower cutting heights increased the forage yield, but also increased soil contamination in forage. Inclusion of pasture soil may result in poor quality or high ash containing hay. Quality of alfalfa (*Medicago sativa* L.) decreased when harvest was made at a lower cutting height. Relative Feed Value of alfalfa improved from 0.9 to 7 units per every increased inch of cutting height (Daniel *et al.,* 2007). Leaves are higher in relative feed value (RFV) while stems typically contain higher levels of non-digestible nutrients. So, the nutritive value of stems is lower than leaves (Santis *et al.,* 2004). It is proved by them that the nutritive value, IVDMD and CP declined with the reduction in leaf stem ratio (LSR) .Low cutting height also causes stand damage (Smith. 1972). The similar result was reported by Daniel et al. (2007).

This study aimed to investigate the effect of cutting height on the drying rate and hay quality of rye (*Secale cereale* L.) hay.

* Corresponding author : Jong Geun Kim, Graduate School of International Agricultural Technology, Seoul National University, Pyeongchang 232-916, Korea. Tel : +82-33-339-5728, Fax : +82-33-339-5727, E-mail: forage@snu.ac.kr

Ⅱ. MATERIAL AND METHODS

1. Hay preparation

These experiments were conducted in Pyeongchang Campus of Seoul National University in the Republic of Korea. During the experiment (5 May~9 May 2016), average temperature was 11 ℃, average amount of precipitation was 4.8mm, average wind speed was 4.7m/s, and the average humidity was 66.1%. Other details of meteorological data during the experimental period are shown in Table 2.

Two 10 m^2 (5m x 2 m) plots were planted with rye at 150 kg/ha seeding rate on 25th of September in 2015 and harvested at heading stage on 5^{th} of May in 2016 using a harvester (NOVACAT 301 & Alois poettinger) equipped with a hay conditioner (Table 1). Plots received 80 kg /ha N, 150 kg/ha P_2O_5, and 150 kg/ha K_2O when planted. Over the winter all plots received the same dressing of N fertilizer, 70 kg/ha. Rye was harvested at 8cm or 15cm stubble height. Rye biomass was tedded at 09:00 and approximately 300g of grab sample was randomly collected three times (09:00, 13:00 and 17:00) a day to determine moisture content (MC) in the samples.

2. Hay Storage

All treated hay samples were stored in Nylon bags tightly and preserved in a dark-dried room in ambient temperature for two months (11 May~11 July, 2016). Temperature was recorded during the preservation progress for two months (11 May~11 July, 2016). Dial probe thermometers with 50mm size dial and 300mm size stainless were put into each Nylon bag of samples to check the variation of temperature, with the results recorded at 13:00 every day for two months. After two months' preservation, the hay samples were evaluated in visual score (leafiness, odor, color, softness and mold) and dry matter loss. Visual score was estimated by the criterion written by Burns and Gary (1991). Dry matter loss was measured as difference of hay bale weight between baling and after preservation for two months.

3. Viable count of fungi

The spread-plate method was used for counting of fungi (Michael *et al*., 2012). Dilution was prepared by mixing 1g of hay sample with 9ml 0.85% NaCl. Then samples were pipetted onto the surface of a potato dextrose agar (PDA) plate and spread evenly over surface of agar using one-off plastic spreader. After 3 days of incubation at 29°C, the plates were checked for fungal growth.

4. Chemical analysis

Each sample of about 300g was collected and dried in a forced air drying oven at 65°C for 72 hours. Dried sample was

Table 1. Agronomic characteristics of 'Gogwoo' rye (*Secale cereale* L.) harvested at heading maturity stage.

Growth stage	DM (%)	Plant height (cm)	Yield	
			Fresh matter (kg/ha)	Dry matter (kg/ha)
Heading stage	18.8	111	27,833	5,233

Table 2. Meteorological data during the experimental period in Pyeongchang, 2016

Date	Average temperature (℃)	Highest temperature (℃)	Lowest temperature (℃)	Precipitation (mm)	Evaporation capacity (mm)	Average wind speed (m/s)	Average humidity (%)	Insolation duration (hr)
2016.5.5	14.3	21.8	8.0	0	4.9	4.2	35.5	11.5
2016.5.6	13.8	18.0	9.9	1.1	5.0	5.7	78.6	3.4
2016.5.7	11.6	19.5	4.9	0	5.2	4.2	60.8	12.7
2016.5.8	13.1	21.0	1.7	0	5.3	2.1	55.4	10.8
2016.5.9	14.6	21.7	7.1	0	5.5	1.8	56.8	8.9
Mean	13.5	20.4	6.3	0.2	5.2	3.6	57.4	9.5

ground using a Wiley mill to 1 mm particle size and stored in a plastic sample cup having an air-tight lid.

Crude protein (CP) was determined by the Dumas method (Nielson, 2010) using a nitrogen analyzer (EUROEA3000 elemental analyser ®, Eurovector). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using ANKOM 2000 Automated Fiber Analyzer (Goering and Van Soest, 1970). The two-stage technique (Tilley and Terry, 1963) was used to measure *in vitro* dry matter disappearance (IVDMD). Relative feed value (RFV) was calculated by Holland *et al* (.1990). Total digestible nutrient (TDN) was calculated by known ADF (Holland *et al*., 1990): TDN = 88.9 - 0.79 x ADF %.

5. Statistical analyses

The effects of two different cutting height on CP, ADF, NDF, IVDMD, TDN, RFV and viable count of fungi were analyzed by PROC *t*-test (SAS, 2002). The level of probability for statistical difference was established at $p<0.05$.

Ⅲ. RESULT AND DISCUSSION

Cutting rye at 15cm stubble height lost moisture faster than cutting at 8cm (Fig. 1). It is presumed because of less dense biomass and better air circulation at 15 cm stubble height. On the fourth day of field drying, both treatments achieved a moisture concentration below 200 g kg^{-1}. Cutting height was related in the yield of forages. Curran and Posch (2000) reported about 12% decline in DM yield between cut heights that left 10.2 vs. 50 cm.

In a case of silage corn, increasing the cutting height improved nutritive value through reducing the concentration of NDF, ADF and ADL (Neylon and Kung, 2003). The result in this experiment showed that cutting in the rest part is 8cm and 15cm did not show significant difference in contents of ADF, NDF, IVDMD, TDN, and RFV ($p>0.05$). The hay tedder generally improves the drying conditions by spreading the hay swath over large area. In this study, the reason for no significant difference in achieving a moisture content below 20% was tedding practice once per day. Cutting at 15cm showed higher in CP content than cutting at 8cm ($p<0.05$) (Table 3). Studies reported CP loss during hay storage ranged from moderate (Davies and Warboy, 1978) to no change (Nelson, 1972). Rotz and Abrams (1988) reported insignificant or even a small increase of CP while greater degree of carbohydrate loss in high-moisture hay. The CP concentration in rye hay increased at15 cm cutting height when compared with that in fresh rye.

Cutting at 15cm stubble height loss more DM than cutting at 8cm (Fig. 2). This may also be due to more mature and greater fiber content in lower stem compared with the less mature top portion (Bolormaa. 2008). The two treatments did not show significant difference in contents of ADF, NDF,

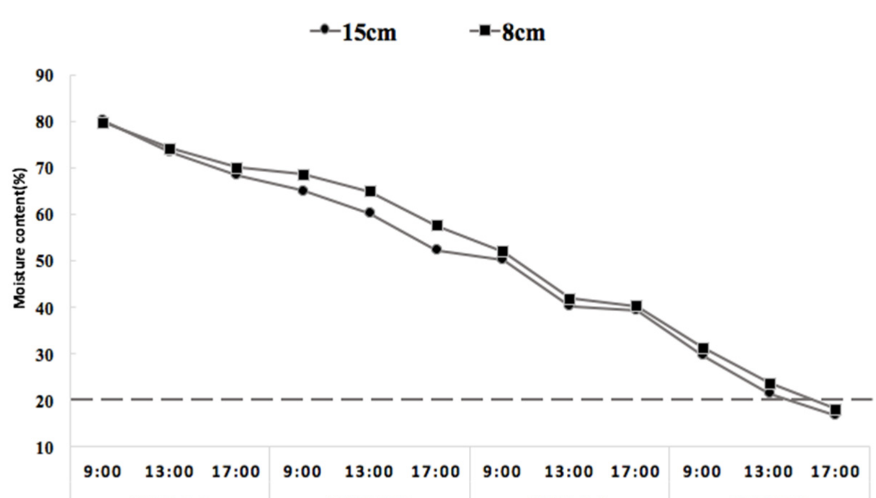

Fig. 1. Comparison of cutting height effect on moisture content in heading stage harvested rye biomass during field drying.

IVDMD, TDN, and RFV ($p>0.05$) (Table 3), even showed ineffective in the amount of total fungi during preservation. ($p>0.05$) (Table 5). Daniel et al. (2007) reported improved alfalfa quality from taller stubble height. The lowest sections of the alfalfa plant also contain higher concentration of fiber and fewer leaf proportion. A Nebraska study (Ogden and Kehr, 1968) where the top half of a full bloom alfalfa canopy was separated from the bottom half indicated that a larger percentage of the digestible nutrients and less fiber was found in the top half versus the bottom half of the plant.

Lima (2015) state that hay baled at over 20% moisture has a high probability of mold growth, which will decrease the quality of hay through degradation of protein and nonstructural carbohydrates, which can result in less palatable hay or a toxicity to livestock.

The digestibility of DM and nutrients usually decreases during storage (Davies and Warboy, 1978), but the digestibility of fiber changes is less effected (Nelson, 1968). This study indicated lower IVDMD and higher fiber content in post storage rye hay than pre-storage when harvested at 8 cm stubble height.

Visual scores of rye hays cut at 8 cm or at 15 cm indicated acceptable to good storage condition (83 and 85) (Table 4). Rye hays cut at 15 cm stubble height demonstrated better

Table 3. Effect of cutting height on the quality of rye hay

Cutting height	CP	ADF	NDF	IVDMD	TDN	RFV
cm	--------------------------------%--------------------------------					
Fresh	7.9	34.9	57.9	74.5	61.4	99
8	7.6	35.8	59.7	70.0	60.7	96
15	10.7	35.7	59.3	74.1	60.4	95
Mean	9.2	35.8	59.3	72.1	60.6	96
LSD(0.05)	2.46	NS	NS	NS	NS	NS

*CP: crude protein, ADF: acid detergent fiber, NDF: neutral detergent fiber, IVDMD: *in vitro* dry matter disappearance, TDN: total digestible nutrient, RFV: relative feed value

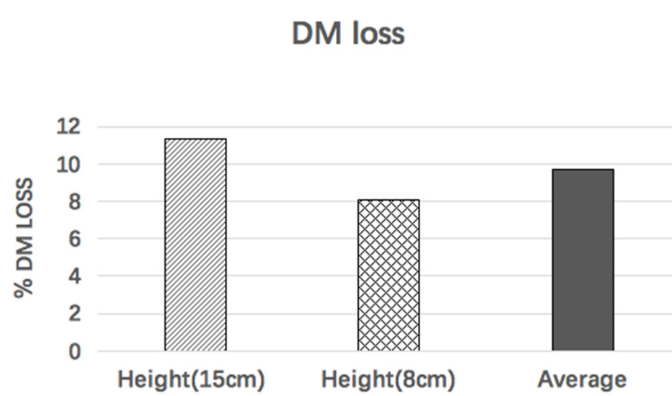

Fig. 2. Effect of cutting height on the DM loss of rye hay harvested at heading stage.

Table 4. Effect of cutting heights on the visual evaluation of rye hay bales after preservation

Cutting Height, cm	Visual score *						
	Stage of harvest	Leafiness	Color	Odor	Softness	Mold/ Dust	Total
8	30	23	12	13	8	-3	83
15	30	26	11	13	7	-2	85
Mean	30	25	10	12	8	-5	79

*: > 90 : Excellent, 80-90 : Good, 65-79 : Fair, < 65 : Poor.

visual scores than those at 8 cm. It was proved that visual score also depends on harvest time. Visual score of the grass harvested at late boot was good (86), while at heading was good (80), and it was poor (63) when harvested at bloom stage (Seo *et al*., 2000).

All the temperature of treatments dropped down slightly at the first week of storage. The temperature then continually increased, maintaining a stable temperature around 24 °C after one-month preservation. Across the results, temperature of bales was affected by air temperature. When ambient temperature dropped on 3 June, all the temperature of treatments dropped down as well. And cutting in 8cm showed higher temperature than tedding in 15cm during preservation. The bale core temperature of cutting at 15cm remained below ambient temperature throughout the whole storage period while the temperature of cutting at 8cm was higher than ambient temperature from around at the 3rd week (23 May) of the storage period (Fig. 3). The reason is same as the result from Han and Kim. (1996) in that the amount of microorganisms increased with the increase of moisture content, causing more heat in hay bales during storage process. Rotz and Muck (1994) also demonstrated that in hay containing high moisture, microbial respiration causes heat accumulation in the core of hay bales during the first 3 to 5 weeks of storage. They also stated that heating during the first month of storage helps dry the hay. After the first month, hay would be relatively stable during the remaining storage period.

Baling hay with too much moisture can lead to spontaneous heating, mold development, DM loss, and nutrient loss (Barnes et al.,2007). The fungi counted at the two cutting heights did not differ (p>0.05). Moisture and temperature are major factors affecting populations of microbes in stored forage (Han and Kim. 1996.). Significant fungal growth in wet hay requires relative humidity to be at least 70% and temperature to be at or above 20℃ (Rees, 1982). The reason why the fungus was not high in this experiment is presumably because the temperature was above 20℃ but the moisture content of hay was low.

Table 5. Effect of cutting height on fungi counting in rye hay after 2 months of preservation

Cutting height (cm)	Viable total fungi CFU/g
15	2.4×10^7
8	6.3×10^7
Mean	4.4×10^7
LSD(0.05)	NS

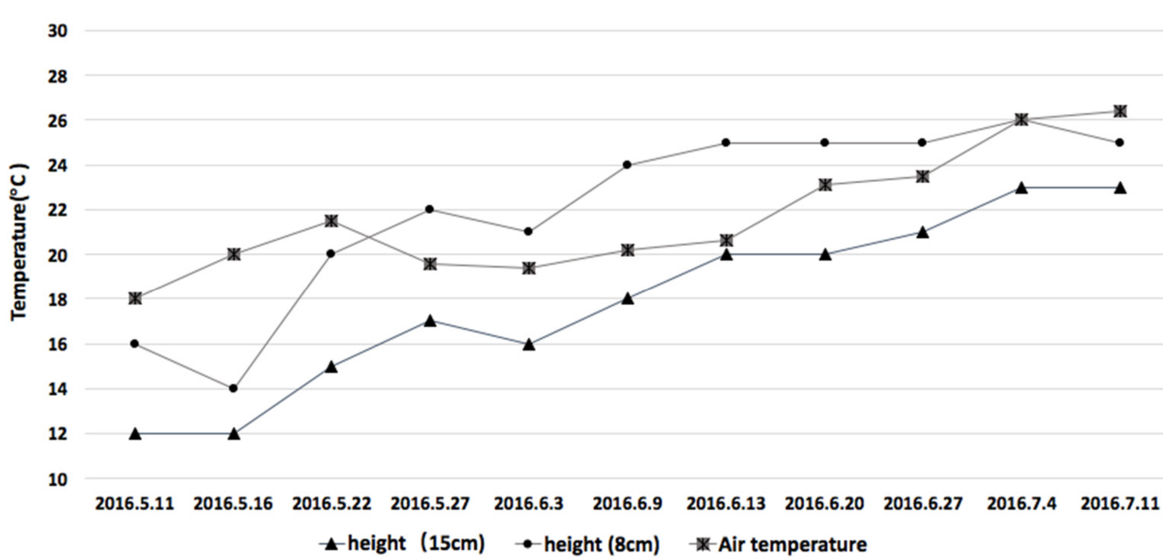

Fig. 3. Core temperature of rye hay bales measured during preservation periods.

Ⅳ. CONCLUSION

Cutting in longer height (15cm) was faster on drying process due to better ventilation. Cutting in 15cm showed higher in CP content ($p<0.05$), but got more dry matter loss compared with cutting in 8cm ($p<0.05$). On another hand, cutting in 15cm and 8cm didn't show significant difference in ADF, NDF, IVDMD, TDN and RFV, even showed ineffective in the amount of total fungi during preservation ($p>0.05$). Comprehensively considering yield, quality and drying rate, this research recommends cutting rye in a shorter height around 8cm.

Ⅴ. ACKNOWLEDGEMENT

This research was supported by Ministry of Agriculture, Food and Rural Affairs research fund (Project No. 514003-3), 2016

Ⅵ. REFERENCES

Barn, R. F., Nelson, C. J., Collins, M. and Moore, K.J. 2003. Forages. 6th eds. Vol. I. Blackwell Publishing Professional. Ames, Iowa, USA

Burns, J.D. and Gary, B. 1991. High quality hay production. The Univer sity of Tennessee Agricultural extension service. https://www.shelby countytn.gov/DocumentCenter/View/1183

Bolormaa Baatar. 2008. Effect of cutting height and frequency on yield in a Mongolian rangeland report on land restoration training program.

Barnes Robert F, C. Jerry Nelson, Kenneth J. Moore, Michael Collins. 2007. Forages, The Science of Grassland Agriculture. pp. 609-612.

Curran, B and J. Posch, 2000. Agronomic management of silage for field and quality-silage cutting height. Crop Insight 19:1-4.

Daniel W., Mike, B., Ron, W. and Nick, S. 2007. The long and short of alfalfa cutting height. University of Wisconsin Board of Regents. Focus on Forage. 1:1-13.

Wiersma, D., M. Bertam, R. Wiederholt, and N. Schneider. 2007. The Long and short of alfalfa cutting height. Focus on Forage. 1:1-13

Davies, M.H., and I.B. Warboy. 1978. The effect of propionic acid on the storage losses of hay. Journal of British Grassland Society. 33:75-82.

Goering HK, and PJ. Van Soest. 1970. Forage fiber analysis. Agric. Handbook 379, U. S. Gov. Print. Office, Washington, D. C.

Han, K. J. and D. A. Kim. 1996. Effect of Cultivar, Drying Agent and Preservative on Quality Changes of Full Harvested Oat Hay. Journal of the Korean Society of Grassland and Forage Science. 16:315-326.

Holland, C., Kezar, W., Kautz, W.P., Lazowski, E.J., Mahanna, W.C. and Reinhart, R. 1990. The Pioneer Forage Manual-A Nutritional Guide. Pioneer Hi-Bred International, Inc., Des Moines, Iowa, USA.

Kust, C.A., and D. Smith. 1961. Influence of Harvest Management on Levels of Carbohydrate Reserves, Longevity of Stands and Yield so Hay and Protein from Vernal alfalfa. Crop Sci. 1:267-269.

Lima, D. 2015. Hay moisture level. Ohio State University Extension. https://u.osu.edu/beef/2015/07/01/hay-moisture-levels/

Meuriot Frédéric, Marie-Laure Decau, Annette Morvan-Bertrand, Marie-Pascal Prud'Homme, François Gastal, Jean-Claude Simon, Jeffrey J. Volenec and Jean-Christophe Avice. 2005. Contribution of initial C and N reserves in *Medicago sativa* recovering from defoliation: impact of cutting height and residual leaf area. Functional Plant Biology. 32:4

Michael Madigan, John Martinko, David Stahl and David Clark. 2012. Brock biology of Microorganisms (Thirteenth Edition). pp. 157-159

Nelson, L.F. 1968. Spontaneous heating, gross energy retention and nutrient retention of high-density alfalfa hay bales. Trans. ASAE 11:595-600.

Nelson, L.F. 1972. Storage characteristics and nutritive value of high-density native hay bales. Trans. ASAE 15:201-205.

Neylon, J.M. and Kung, L.Jr. 2003. Effects of cutting height and maturity on the nutritive value of corn silage for lactating cow. Journal of Dairy Science. 86:2163-2169.

Nielsen, S. S. 2010. Food analysis. 4th ed. Purdue University. Springer. New York.

Ogden, R.L. and W.R. Kehr. 1968. Field management for dehydration and hay production. P. 23-27. In Proceeding of 10th Tech. Alfalfa Conf., USDA-ARS.

Ottman, M. J. and M. T. Rogers. 2000. Alfalfa Yield Response to Cutting Height and Cutting at Dawn and Dusk. The University of Arizona College of Agriculture and Life Sciences 2000 Forage and Grain Report. Series P-124.

Rees, D.V.H. 1982. A discussion of sources of dry matter loss during the process of haymaking. Journal of Agriculture Engineering Research. 27:469-479

Rotz, C. A., and R. E. Muck. 1994. Changes in forage quality during harvest and storage. Pages 828-868 in Forage Quality, Evaluation, and Utilization. 13-15 April 1994, Nat. Conf. on Forage Quality, Evaluation, and Utilization, G. C. Fahey, M. Collins, D. R. Mertens, and L. E. Moser, eds. Univ. Nebraska, Lincoln. ASA-CSSASSSA, Madison, WI.

Rotz, C.A. and S. M. Abrams. 1988. Losses and quality changes during alfalfa hay harvest and storage. Trans. ASAE 31:350-355.

Santis, G. De, D. Dantone, and E. Chiaravalle. 2004. Changes During Growth in the Nutritive Value of Components of Berseem Clover (*Trifolium alexandrinum* L.) under Different Cutting Treatments in a Mediterranean Region. Grass and Forage Sci. pp. 59:4.

SAS Institute Inc. SAS/STAT user guide. Cary, NC:SAS Institute Inc. 2002.

Seo, S, E. S. Chung, and J.G. Kim. 2000. Mechanical and Chemical Conditioning Effect on Field Drying Rate and Quality of Grass Hay. Asian-Australasian Journal of Animal Science. 13:1109-1112.

Smith D. 1972. Cutting Schedules and Maintaining Pure Stands. Alfalfa Science and Technology. Agron. Monograph. No.15 pp. 481-496.

Smith, D. and C.J. Nelson. 1967. Growth of Birdsfoot Trefoil and Alfalfa. I. Responses to Height and Frequency of Cutting. Crop Science. 7:130-133.

Tilley, J.M.A. and R.A. Terry. 1963. A two-stage for the *in vitro* digestion of forage crop. Journal of British Grassland Society. 18:104-111.

(Received : July 22, 2017 | Revised : September 18, 2017 | Accepted : September 18, 2017)