The Relationship between Climatic Factors and Acid-Detergent Fiber, Neutral-Detergent Fiber and Crude Protein Contents in Digitgrass[1]

Chia-Sheng Chen[2], Ya-Shin Hwa[3],
Su-Min, Wang[2] and Yu-Kuei Chang[2]

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Abstract

Samples of Survenola (*Digitaria X umifolia*), a variety of Digitgrass, were planted in the field and treated according to a set of programmed harvest cycles to study the impact of climatic factors on the quality of the grass for marketability. Such quality was to be assessed by the contents of acid-detergent fiber (ADF), neutral-detergent fiber (NDF) and crude protein (CP) contained in the grass sample. It was found that seasonal changes had greater effect on the quality of the grass than did the length of the harvest cycle. The ADF, NDF, and CP contents in Digitgrass, as shown in this study, were related to mean temperature and day length, but were not statistically related to accumulated sunlight duration, precipitation or the length of the harvest cycle. The base temperatures for the accumulation of ADF, NDF and CP in Digitgrass were also inferred in this study. The contents of ADF and CP had higher correlation with accumulated temperature ("Tacm") than mean temperature. The highest correlation coefficient (0.81) between the ADF content and Tacm was attained when the base temperature was set to 15.5 C, while the highest correlation coefficient (0.88) between CP and Tacm is attained at a base temperature of 15.0 C. In addition to measuring the effects of individual climatic factors on Digitgrass, stepwise regression was used to measure the combined effects of these factors to the protein and fiber contents in Digitgrass. Through the stepwise regression, we found that the determination coefficient of regression

(1) Contribution No. 938 from Taiwan Livestock Research Institute, Council of Agriculture.
(2) Hengchun branch Institute, TLRI, COA, Hengchun, Pingtung, Taiwan, R.O.C.
(3) Hwalien County Government, Taiwan, R.O.C.

(R^2) for ADF was reached at 0.81 when accumulated temperature and day length were introduced as factors. For NDF, however, R^2 was lower (0.71) when the same factors were introduced. For CP, we found that R^2 could reach up to 0.78 when the accumulated temperature alone was introduced as a factor. Adding other factors such as mean temperature and length of harvest cycle only increased the R^2 slightly for the CP.

Key words : Forage quality, Environment, Accumulated temperature.

Introduction

The acid-detergent fiber (ADF), neutral-detergent fiber (NDF) and crude protein (CP) are widely used as indicators to evaluate the nutritive value and quality of forage (van Soest, 1967; Marten *et al.,* 1975; Lippke, 1980, Waldo and Jorgensen, 1980; Rohweder *et al.,* 1978, Windham *et al.,* 1983). Among all of the factors that influence forage quality, herbage age or maturity is the most important. The digestibility and protein content of forage consistently decrease with herbage age (Alexander *et al.,* 1961; Burton *et al.,* 1963; van Soest *et al.,* 1978; Shaver *et al.,* 1988; Llamas-Lamas and Combs, 1990; Li *et al.,* 1991). van Soest *et al.* (1978) indicate that for forage growing in temperate climate regions, the grass digestibility of the first-cut can be predicted by looking at the time of the harvest takes place. However, this is hardly the case in tropical regions. In addition to herbage age, forage quality is also affected to a certain extent by environmental factors, such as temperature, moisture, sunlight, and the supply of fertilizer (Deinum *et al.,* 1968; Alkin *et al.,* 1987; Halim *et al.,* 1989; Kephart and Buxton, 1993).

Due to differences in climate and conditions of local markets, the number of harvests per year and harvest time vary at each location in Taiwan. In northern Taiwan, Digitgrass can be harvested only two or three times a year from late spring to autumn, while in southern Taiwan Digitgrass can grow in the winter and can thus be harvested up to six times a year in an irrigated sward. In the Heng-Chun Peninsula of southern Taiwan, Digitgrass is mainly harvested from autumn to spring to avoid over production and the frequent summer rain. Given such different production conditions in Taiwan, we cannot infer the caliber of forage quality simply by looking at herbage age or cutting interval. In a previous study, we assessed the quality of six lines of Digitgrass in different environments and showed that the seasons have much greater effect than genotype and location on the ADF and NDF contents in Digitgrass. We also found that seasonal factors and location have nearly the same effect on the CP content in Digitgrass, while the effect of the length of harvest cycle is less obvious (Chen *et al.,* 1997). Moving forward from what we have learned in our last study, we are now further exploring the seasonal effect of weather by examining the relationships between the ADF, NDF, and CP components in Digitgrass and changes in climatic factors. The quantification indices comprising several factors to indicate changes in grass quality are also discussed.

Material and Methods

Ⅰ. Material and Treatment：

The material used in this study, Survenola (*Digitaria X umifolia*), is a variety of Digitgrass released from University of Florida. A Survenola sward had been established at the Hwa-Lien branch station of the Taiwan Livestock Research Institute in September 1994. The sward consists of four 20 m^2 (4 m × 5 m) block, each divided into four plots for a total of sixteen blocks that were arranged by randomized complete block design. The blocks were harvested at four different cycles (Treaments A, B, C and D) beginning in March 1995 to April 1996. From March to October 1995, the harvest cycles are 25 days for treatment A, 35 days for treatment B, 45 days for treatment C, and 55 days for treatment D. From November 1995 to February 1996, the harvest cycles are 35 days for treatment A, 45 days for treatment B, 55 days for treatment C, and 65 days for treatment D. From March 1995 to April 1996, there were fifteen cuts in treatment A, eleven cuts in treatment B, eight cuts in treatment C, and seven cuts in treatment D. At the beginning of the experiment and after each harvest cycle, 250, 350, 450, and 550 kg/ha of composed fertilizer (N : P_2O_5 : K_2O =11 : 9 : 18) were applied to the plots A, B, C and D. After each cut, agronomic characters and yield were surveyed, and one kilogram of fresh plants was taken as sample from each plot and air-dried in an oven at 80℃ for 48 hours then ground for chemical analysis.

Ⅱ. Forage Components Measurement：

The amount of CP was measured by the AOAC method (1984), while ADF and NDF were measured by the van Soest method (1967).

Ⅲ. Climate Data Collection：

Climate data were collected from an agrometerological station located at Hwa-Lien District Agriculture Improvement Station, about one kilometer away from the field where the experiment took place. The mean temperature (maximum, minimum, and average temperature) used in this analysis is the mean temperature of the ten day period prior to each harvest time. Day length is the number of daytime hours on the day of harvest. Duration of sunlight is the total number of hours of sunlight in the entire growth period. Effective accumulated temperature is the sum of the daily differences between the mean temperature of the day and a proposed base temperature for the entire growth period. The relationship of climatic data and the result of the chemical analysis was analyzed by the SAS method (1985).

Result

Ⅰ. Variations of ADF, NDF and CP contents in different harvest cycles

In the span of one year, the ADF, NDF and CP contents of the four treatments were substantially different (Fig. 1) . The ADF content is higher in longer harvest cycles. The highest ADF content (46.6%) was found in treatment D harvested in August (55-day period), and the lowest (29.3%) was found in treatment A harvested in February (35-day period), their difference being 17.3%. In summer and early autumn, the ADF content in treatments B, C and D were about 45% and decreased to about 30% in winter and early spring. However, the ADF content of the longest harvest cycle (treatment D) in winter and early spring (65-day period) were lower than those of the shortest harvest cycle (treatment A) in summer and early autumn (25-day period).

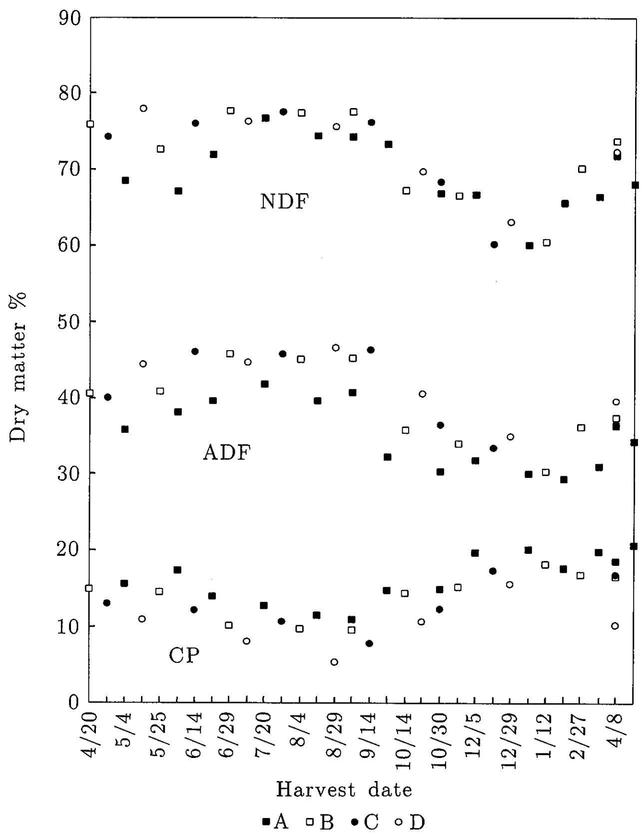

Fig. 1. The contents of NDF, ADF, and CP harvested in continuous cycles. The four treatment cycles were: from March to October -- 25 days (treatment A), 35 days (treatment B), 45 days (treatment C), and 55 days (treatment D); from November to February of the following year -- 35 days (treatment A), 45 days (treatment B), 55 days (treatment C), and 65 days (treatment D).

The NDF content is also higher in longer harvest cycles but with a smaller difference between longer and shorter cycles than that of the ADF content (Table 1) . The highest NDF content (77.9%) was found in treatment D harvested in May (55-day period) and the lowest (60.1%) was found in treatment A harvested in January (35-day period), their difference being 17.8%. As with the ADF content, the NDF content in the longest harvest cycle (treatment D) in winter and early spring (65-day period) were also lower than those in the shortest harvest cycle (treatment A) in summer and early autumn (25-day period).

Table 1. Average contents of the ADF, NDF and CP in different treatments and seasons

Treatments+	ADF	NDF	CP	Seasons	ADF	NDF	CP
		%				%	
A	41.6[d#]	72.1[d]	16.7[a]	Spring	37.6[b]	71.8[d]	16.0[b]
B	40.0[c]	71.6[c]	14.6[b]	Summer	43.8[a]	75.6[a]	10.5[d]
C	38.3[b]	71.5[b]	13.3[c]	Autumn	37.6[b]	70.6[b]	12.5[c]
D	34.9[a]	69.4[a]	10.5[d]	Winter	32.4[c]	63.9[c]	17.8[a]

+ : Treatments of length of the harvest cycle as indicated in Figure 1.

: Means with different superscripts within the same column are different ($P<0.05$).

The CP content is lower in longer harvest cycles. A higher content of CP is found in winter and a lower content of CP is found in summer in all of the samples.

The ADF, NDF and CP contents in the four treatments in different seasons are summarized in Table 1. For the ADF content, the percentage difference of the four treatment cycles total 6.7%, and 11.4% among the seasons. For the NDF content, the range was 2.7% among treatments and 11.7% among seasons. These results indicate that the effect of seasons was greater than the effect of harvest cycle length on the ADF and NDF contents. As for the CP content, the difference among treatments was 6.2% and 7.3% among seasons. The effect of season was also greater than the effect of harvest cycle length on CP, but the difference between the two factors was smaller than that for ADF and NDF.

Ⅱ. Correlation Between Chemical Components and Climatic Factors

The ADF and NDF contents are highly correlated with the mean maximum temperature, mean minimum temperature and average temperature of the ten day period before harvest time, but have no correlation with the difference between maximum and minimum temperatures. The ADF and the NDF contents have also significant correlation with day length but have no correlation with sunlight duration and precipitation in the growth period (Table 2).

Table 2. Correlation coefficient between the ADF, NDF, and CP contents and the factors of climate

	T_{max}	T_{min}	T_{avg}	Differ. of temp	Precipi-tation	Duration of sunshine	Day length	Days of growth
ADF	0.69**	0.74**	0.73**	0.09	0.08	0.12	0.67**	0.19
NDF	0.71**	0.77**	0.75**	0.06	0.09	0.07	0.76**	0.04
CP	−0.65**	−0.67**	−0.67**	−0.18	0.05	−0.15	−0.39*	−0.26

* : Significant at 5% level.

** : Significant at 1% level.

The CP content is negatively correlated with the mean maximum temperature, mean minimum temperature and average temperature of the ten day period before harvest time. It is also negatively correlated with the day length on the day of harvest at a level of 5%. The CP content has no correlation with sunlight duration and precipitation. The three components, ADF, NDF, and CP, have no correlation with harvest cycle length.

Table 3. The stepwise regression of climatic factors on the ADF, NDF, and CP contents

	ADF		NDF			CP	
Step	Variable entered	Model R^2	Variable entered	Variable removed	Model R^2	Variable entered	Model R^2
1	Accu. temp.	0.65	Min. temp		0.59	Accu. temp.	0.78
2	Day length	0.81	Day length		0.65	Max. temp.	0.80
3	Length of the harvest cycle	0.82	Accu. temp.		0.71	Length of the harvest cycle	0.82
4				Min. temp.	0.71	Day length	0.83

model:
ADF=0.02×Accu. temp.+0.046×Day length+0.032×Length of the harvest cycle-2.8
NDF=0.013×Accu. temp.+0.06×Day length+23.4
CP=−0.013×Accu. temp.−0.051Length of the harvest cycle−0.192×Max. temp.+0.013×Day length+23.7

In addition to the mean temperature, we calculated the accumulated temperature from a proposed base temperature, and then estimated their coefficients of correlation with the contents of the three components in Digitgrass. The highest coefficients of correlation between the accumulated temperature and the ADF and the CP were 0.81 and 0.88 when the base temperatures were 15.5℃ and 15.0℃, respectively (Fig. 2). But the highest correlation coefficient between accumulated temperature (when the base temperature was set at 17.0℃) and the NDF content was only 0.63, lower than its correlation coefficient with the mean temperature around harvest time. The variation in the contents of ADF and CP, have higher correlation with temperature changes during the period of growth as indicated by accumulated temperature than with the mean temperature around harvest time. Yet for variation in the NDF content, this is not the case, mean temperature around harvest time seems to be a more important factor than accumulated temperature.

Ⅲ. Combined Effects of Climatic Factors

The ADF, NDF and CP components are substantially influenced by various climatic factors, which act in combination rather than independently, to change the chemical component of grass. Therefore, stepwise regression was used to measure the combined effects of these factors on the contents of ADF, NDF and CP. For the regression of ADF, when accumulated temperature is introduced as the only climatic factor, the coefficient of determination (R^2) of the model was 0.65. After adding day length as an additional factor, the R^2 of the model became 0.81. For the regression of NDF, accumulated temperature and day length were introduced, the result was a coefficient of determination (R^2) of 0.71. It was observed that NDF had a low correlation with accumulated temperature alone (when 17.0℃ is set as the base temperature), but when day length was introduced as a combined factor, the R^2 is significantly higher, reaching up to 0.71. For the regression of CP, accumulated temperature alone produced an R^2 of 0.78. With the introduction of the mean average temperature and length of the harvest cycle as additional factors, the R^2 increased only slightly. Maximum, minimum and average temperatures are highly co-linear, therefore, they produced very similar results when introduced into the model.

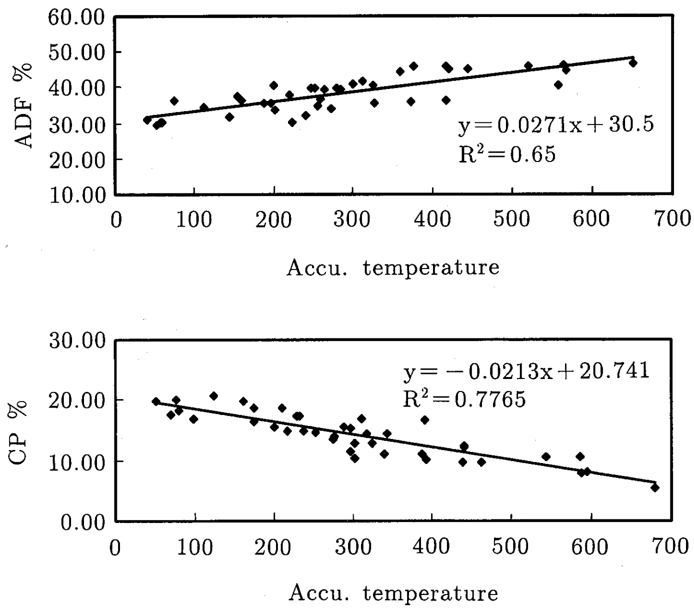

Fig. 2. Regressions of the accumulated temperature on ADF and CP contents.

Discussion

Forage can be harvested all year-round in Taiwan, but the forage quality is far from uniform as shown here and in our previous researches (Chen *et al.,* 1997). In digestability, only the effect of factors in herbage age and fertilizer on forage quality have been examined, and information from those studies is insufficient to explain the fluctuations in quality at different locations and during different seasons. As animal husbandry continues to improve through genetic gain, the need for high quality forage will also continue to increase. It is particularly important for us to understand the key factors that influence forage production so that we can effectively control or raise its quality. Therefore, establishing an evaluation system based on quality grade is a goal for Taiwan's forage market in the near future.

As summarized in several researches, herbage age or maturity is considered to have a greater influence on forage quality than environmental factors. The problem with this finding is that environmental factors do influence the growth and developmental rate of forage, thereby altering its quality. Forage quality is variable even when herbage is harvested in similar morphological stages. Our data also showed that fiber contents of the shortest harvest cycle in summer are higher than those of the longest harvest cycle in autumn.

It was shown that rising temperature is the main cause of ligninfication (Van Soest *et al.,* 1978) and temperature does accelerate the transformation of photosynthetic products into constitutive materials (Fales, 1986; Akin *et al.,* 1987). Our results also showed that temperature has much greater influence on the ADF, NDF and CP components than other environmental factors do. This might be due to the fact that temperature simultaneously affects the developmental rate of plant tissues and its chemical components. The base temperatures for accumulating ADF, NDF and CP were proposed in this study. For ADF and CP, the coefficient of correlation rose as effective accumulated temperature rather than mean temperature around the time of harvest was used as a factor. But this was not the case for NDF. The NDF concentration was more closely related to mean temperature around the time of harvest rather than effective accumulated temperature. This phenomenon is in accord with the time series of the accumulating activity of hemicellulose, cellulose, and lignin in cell wall development. It can also explain why the NDF content shows greater statistical errors (Chen *et al.,* 1997) and lower heritability (Soh *et al.,* 1984).

Photoperiod is a major factor that influence plant differentiation and development (Gardner *et al.,* 1985). Long day length promotes reproductive growth of Digitgrass and hence decreases the leaf/stem ratio. Therefore, it is not surprising to find that the day length have significant correlation with the ADF and the NDF contents, while its correlation with the CP content was only moderate. However, the influence of air temperature or day length alone is insufficient to explain the fluctuations in forage quality (Fick *et al.,* 1994).

Although seldom explored in the past, observing the combined influence of different climatic factors on forage helps to elucidate causes for variations in forage quality. For example, accumulated temperatures of the herbage harvested in May and October are about the same but the contents of ADF, NDF and CP in the harvested herbage are quite different. These differences can be partially explained by the differences in the day length on the day of harvest. The day length in May is much longer than it is in October and may compensate for the difference between the observed and the expected values of herbage components that were predicted from accumulated temperature alone.

The contents of ADF, NDF and CP do not correlate with precipitation and sunlight duration, both of which are quite irregular in field conditions. Changes in fiber contents under the condition of water deficit have been reported, but inconsistent results were obtained (Wilson, 1983, Halim *et al.,* 1989). In different soil moisture under non-stressed conditions, forage quality is fairly consistent. Our results are also in accord with the suggestion that shading has only minor effect on forage quality (Kephart and Buxton, 1993).

We conclude that the air temperature and the day length are critical factors affecting the quality of Digitgrass. They can account for up to 80% of the variations in the ADF and the CP contents in Digitgrass and 70% for its NDF content. Since the results here were obtained from a single location, whether they are sufficient to predict the change of quality for a genotype in a broad area will need further study.

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盤固草酸洗纖維、中洗纖維及粗蛋白與氣象因子的關係[1]

陳嘉昇[2] 黃耀興[3] 王紓愍[2] 成游貴[2]

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摘 要

本研究以 Survenola（*Digitaria X umifolia*）為材料，於四種割期處理下連續試驗一年，分析其酸洗纖維（ADF）、中洗纖維（NDF）及粗蛋白（CP）變化，以探討牧草化學成份與氣象因子間的關係。試驗結果顯示，酸洗纖維、中洗纖維與粗蛋白含量的季節間差異大於割期處理間差異，其含量變化與收穫前的平均氣溫及日長有顯著相關，但與累積日照時數及降雨量無關；酸洗纖維、中洗纖維與粗蛋白含量在不同割期間有顯著差異，但與割期長短之相關並不顯著。本研究並估算累積酸洗纖維、中洗纖維及粗蛋白含量之基礎溫度。酸洗纖維、粗蛋白含量與累積溫度間之相關係數大於其與平均氣溫之間，但中洗纖維則無此現象。酸洗纖維與粗蛋白的基礎溫度分別為 15.5℃及 15℃，其與積溫之相關係數分別為 0.81 及 0.88。除了個別因子的探討外，本研究以逐步迴歸選擇重要的影響因子，並估算因子間的聯合效應。對酸洗纖維而言，聯合積溫及日長兩因子，其迴歸式之決定係數可達 0.81。中洗纖維迴歸式之決定係數較低，顯示除氣象因子外，尚有其他重要影響因子。對粗蛋白而言，積溫單一因子之決定係數即達 0.78，加上均溫及割期長短後僅微幅的提高決定係數，而日長之影響力則更低。

關鍵詞：牧草品質、環境、積溫。

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(2) 行政院農業委員會畜產試驗所恆春分所。
(3) 花蓮縣政府畜產課。