# Factors Affecting *In vitro* True Digestibility of Napiergrass

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**ABSTRACT :** Changes of *in vitro* true digestibility (IVTD) of Napiergrass (*Pennisetum purpureum*) were determined by a filter bag system, and their relationships to chemical composition, leaf to stem ratio, plant height, geographic location, climatic factors and harvest interval were studied and used to develop prediction models for the crude protein (CP), acid-detergent fiber (ADF), and neutral-detergent fiber (NDF) contents and IVTD. Partitioning the total variance of IVTD of Napiergrass showed that 80% was attributable to the effect of harvest interval. Days of growth, plant height, leaf/stem ratio, CP, ADF and NDF of Napiergrass had highly significant relationships ($p<0.01$) with IVTD. The highest coefficient of correlation between the ADF, NDF, and IVTD of Napiergrass and growth degree days was obtained when the base temperature was set at 0℃. Growth degree days could predict ADF, NDF, and IVTD of Napiergrass more accurately than plant height, and plant height is not suitable to predict IVTD. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 4 : 507-513)***

**Key Words :** *Pennisetum purpureum*, Napiergrass, Digestibility, Harvest Interval, Plant Morphology, Growth Degree Days

## INTRODUCTION

Napiergrass is a popular forage resource in several subtropical and tropical countries such as Brazil (Aroeira et al., 1999), Kenya (Mbuthia and Gachuiri, 2003) and Thailand (Tudsri et al., 2002). Likewise, Pangolagrass and Napiergrass are two most commonly planted forages in Taiwan. Digestibility of Napiergrass is one of the most common interests of researchers (Aroeira et al., 1999; Tudsri et al., 2002; Mbuthia and Gachuiri, 2003). No doubt, digestibility is one of important components of forage quality (Ball et al., 2001). Forage digestibility and quality can be affected by factors such as environment (Crasta and Cox, 1996), plant morphology and maturity (Twidwell et al., 1988; Buxton and Marten, 1989; Burns et al., 1997). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents of Pangolagrass were shown to be mostly affected by season rather than geographic location or genotype, and its crude protein (CP) content was mostly affected by geographic location and season (Chen et al., 1997). Following study of Chen et al. (1999) indicated that ADF and CP contents of Pangolagrass were more correlated with accumulated temperature than harvest interval. On the other hand, ADF, NDF and CP contents of Napiergrass were more affected by harvest interval than geographic location or season (Wang et al., 2003). Both *in situ* dry matter digestibility and *in vitro* dry matter true digestibility (IVTD) of Pangolagrass and Napiergrass had significant negative correlation coefficients with their ADF and NDF contents (Chen et al., 2003). The purpose of the present study was to expand our evaluation of possible factors affecting the IVTD of Napiergrass and to develop prediction models for chemical composition and IVTD of Napiergrass.

## MATERIAL AND METHODS

### Field trial

Test fields were located at three far apart research branch institutes (Hwalien, Changhua, Hengchun) of Taiwan Livestock Research Institute. These three geographic locations have their own unique climatic characteristics. Hwalien (N23°12', E121°37') locates at the north-east of Taiwan, faces the open ocean and has a high mountain range behind which renders a heavy rain and scare sun shine weather type generally poor for crop production all year round. Hengchun (N22°01', E120°45') locates at the most south end of Taiwan island, and is belong to a tropical weather region with high temperature, rain concentrated in the summer season, and a windy dry season for September through April. Changhua (N24°04', E120°32') locates in the middle region of Taiwan with the climatic characteristics in between the two extremes of Hwalien and Hengchun. If the prediction models could fit all these three locations, it will imply a great possibility to be applicable to all other regions in Taiwan.

Napiergrass cv. TLG2 (*Pennisetum purpureum* cv. TGL2) was harvested with four annual cutting intervals (35-40 days, 50-55 days, 65-70 days, and 80-85 days) from Dec. 1999 till Dec. 2001. Randomized complete block design was used with the three test fields as blocks. Sampling unit was a fixed area of 4 m×3 m. All test fields were initially fertilized with 400 kg/ha of commercial fertilizer ($N:P_2O_5:K_2O$ = 11:9:18). Supplemental fertilization was provided with 200, 300, 400, and 500 kg/ha of commercial fertilizer ($N:P_2O_5:K_2O$ = 20:5:10) right after harvesting for the four

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**Table 1.** The numbers of harvest and ranges of chemical contents and IVTD for calibration set and verification set at three locations

| Sample set | Location | No. of harvest | CP* | ADF* | NDF* | IVTD* | Leaf/stem ratio | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|
| | | | % | | | | | |
| Calibration set | Hwalein | 31 | 4.6-21.4 | 30.5-50.7 | 59.5-78.0 | 58.0-89.4 | 0.5-2.6 | 48.0-327.8 |
| | Changhwa | 34 | 5.8-22.5 | 31.7-55.9 | 56.0-79.9 | 53.8-88.0 | 0.4-3.1 | 80.9-360.4 |
| | Hengchun | 33 | 4.6-18.3 | 33.8-53.9 | 60.5-79.1 | 54.0-85.0 | 0.5-2.1 | 96.0-300.1 |
| Verification set | Hwalein | 11 | 4.6-23.7 | 32.7-50.6 | 62.2-79.3 | 58.1-89.2 | 0.6-3.2 | 69.5-290.0 |
| | Changhwa | 12 | 7.9-20.4 | 33.5-52.6 | 57.5-77.0 | 61.5-86.6 | 0.7-2.6 | 85.8-335.5 |
| | Hengchun | 10 | 6.3-15.3 | 35.8-56.1 | 64.2-78.3 | 55.9-83.6 | 0.6-1.6 | 94.7-283.9 |

*ADF: Acid-detergent fiber; NDF: Neutral-detergent fiber; CP: Crude protein; IVTD: *In vitro* true digestibility.

**Table 2.** Partitioning of total variance for IVTD of Napiergrass by location, season, harvest interval and interaction components

| Source | % of total variance |
|---|---|
| Location | 1.6 |
| Season | 10.3 |
| Harvest interval | 80.3 |
| Location×harvest | 0.6 |
| Harvest×season | 2.7 |
| Location×season | 4.4 |

harvest interval treatments, respectively. At harvesting, plant height and leaf/stem ratio were measured, followed by sample drying and grinding for further chemical composition and IVTD analyses.

### Chemical composition and *in vitro* true digestibility analyses

Samples of Napiergrass were analyzed in duplicate for crude protein (CP) by the Kjeldahl method of AOAC (1984), acid detergent fiber (ADF) and neutral detergent fiber (NDF) by methods of Van Soest (1967). IVTD was determined using ANKOM F57 filter bag and DAISYII-200 apparatus (ANKOM Technology, New York, USA) as described by Holden (1999) and Vogel et al. (1999) with blank bag correction. Goering and van Soest (1970) used the term “true dry matter digestibility” to emphasize the correction made for blank in the calculation of *in vitro* digestibility. Although Holden (1999) and Vogel et al. (1999) still used the term “*in vitro* dry matter digestibility (IVDMD)” in their papers, the term “*in vitro* true digestibility” was used in DAISYII technique procedure of ANKOM and other papers using the same technique (Cusicanqui and Lauer, 1999; Darby and Lauer, 2002; Nouala et al., 2004). Therefore, it should be noted that IVTD and IVDMD were interchangeable for the description of digestibility estimate based on our understanding. Rumen fluid used for IVTD determination was collected two hours after morning feeding from two rumen cannulated Holstein steers routinely fed 2 kg of commercial concentrate daily and Napiergrass silage *ad libitum*.

### Climate data collection and statistical analysis

Climate data were all collected from the agro-meteorological stations located nearest the respective test fields at Hwalien, Changhua, and Hengchun, Taiwan. Climate data included daily average temperature, daily maximum temperature, daily minimum temperature, duration of sunshine, precipitation and day length.

The prediction models were developed from the Napiergrass samples of the first one and half years of field trial. Napiergrass samples of the later half of the second year were used to verify the developed prediction models. Daily average temperature, maximum temperature, and minimum temperature of the ten days prior to harvesting, accumulated sunshine duration and growth degree days (GDD = ∑(daily average temperature-base temperature)) of growth period, and day length of the harvest day were used as independent variables with or without natural log transformation. Plant height, leaf/stem ratio and days of growth were also included as independent variables. ADF, NDF, CP and IVTD were set as dependent variables. Correlation analysis and regression equations with single or multiple independent variables were developed by SAS statistic procedures (SAS Institute, 1988).

To verify goodness of fit of the developed prediction models, regression of predicted values vs. observed values from the later half of the second year was performed to examine the coefficient of regression, intercept of regression, $R^2$ of regression equation and the root mean square error of prediction (RMSE = $(1/n\sum(\text{observation-prediction})^2)^{0.5}$). The harvest numbers and ranges of ADF, NDF, CP and IVTD of calibration sample set and verification sample set were listed in Table 1.

## RESULTS

### Factors affecting IVTD of Napiergrass

Based on the partitioning of total variance for IVTD of Napiergrass by location, season, harvest interval and interaction components, 80% of total variance was shown to be from the effect of harvest interval, and 10% was from seasonal effect (Table 2). There was clear and significant decline of IVTD as the harvest interval increased (Table 3). The 35-40 days harvest interval resulted in the highest IVTD. Comparison among Napiergrass in different seasons showed the highest IVTD in winter season, and the lowest in summer (Table 3). Agreed with the result of total

**Table 3.** Comparison of IVTD of Napiergrass among different harvest intervals, seasons and locations

| Item | | IVTD (% DM) |
|---|---|---|
| Harvest interval | 35-40 days | 81.4$^{a}$ |
| | 50-55 days | 75.0$^{b}$ |
| | 65-70 days | 67.4$^{c}$ |
| | 80-85 days | 62.0$^{d}$ |
| Season | Spring | 75.3$^{b}$ |
| | Summer | 71.0$^{d}$ |
| | Autumn | 72.8$^{c}$ |
| | Winter | 76.5$^{a}$ |
| Location | Hwalein | 75.0$^{a}$ |
| | Changhwa | 73.2$^{b}$ |
| | Hengchun | 72.8$^{b}$ |

$^{a, b, c, d}$ Mean in the same column without same superscript differed significantly ($p<0.05$).

variance partitioning, the difference of IVTD among different seasons was less than that among various harvest intervals. Again, the difference of IVTD among different geographic location was even less, and the cooler and heavy rain region (Hwalein) had the highest IVTD (Table 3).

## Relationship of CP, ADF, NDF and IVTD with plant morphology or climatic factors

Average minimum temperature of ten days prior to harvesting, day length, duration of sunshine, days of growth, plant height and leaf/stem ratio had highly significant relationship ($p<0.01$) to CP with the plant height being the highest correlated (Table 4). Days of growth, plant height, and leaf/stem ratio had highly significant relationship ($p<0.01$) to ADF and NDF with the plant height being the highest correlated (Table 4). Average minimum temperature of ten days prior to harvesting, days of growth was also correlated to ADF ($p<0.05$). Days of growth, plant height, and leaf/stem ratio had highly significant relationship ($p<0.01$) to IVTD with the plant height being the highest correlated (Table 4). CP, ADF and NDF of Napiergrass also showed highly significant relationship ($p<0.01$) to IVTD with correlation coefficients as 0.82, 0.94, and 0.90, respectively. This agrees with Zewdu et al. (2002) who found negative correlation coefficients of CP, ADF and NDF in relation to *in vitro* dry matter digestibility of Napiergrass as 0.92, 0.96 and 0.94, respectively. Our previous study showed similar result in Pangolagrass that IVTD had significant negative correlation coefficients with ADF and NDF contents (Chen et al., 2003). It is worthy of note that CP, ADF, NDF, and IVTD of Napiergrass had no significant relationship to climatic factors including precipitation, day length, and daily average temperature which confirms previous finding that ADF, NDF and CP contents of Napiergrass were more affected by harvest interval than geographic location or season (Wang et al., 2003). This is different than what was observed with Pangolagrass (Chen et al., 1999). Since the days of growth (harvest interval) had highly significant relationship ($p<0.01$) to CP, ADF, NDF and IVTD of Napiergrass, relationship of the growth degree days to CP, ADF, NDF and IVTD of Napiergrass was further investigated as follows.

**Table 5.** The correlation coefficients between growth degree days (GDD) to chemical contents and IVTD (n = 98)

| Chemical content | GDD0$^{1}$ | ln(GDD0)$^{2}$ | GDD12 | ln(GDD12) |
|---|---|---|---|---|
| CP | -0.75 | -0.80 | -0.80 | -0.86 |
| ADF | 0.88 | 0.88 | 0.80 | 0.80 |
| NDF | 0.86 | 0.85 | 0.79 | 0.76 |
| IVTD | -0.92 | -0.91 | -0.87 | -0.84 |

[1] GDD0 and GDD12 are the growth degree days based on base temperature of 0°C and 12°C.

[2] ln = natural logarithm.

## Relationship of CP, ADF, NDF and IVTD with growth degree days

The highest coefficient of correlation between the CP of Napiergrass and growth degree days (GDD) was obtained when the base temperature (lower developmental threshold) was set at 12°C (Table 5). The highest coefficient of correlation between the ADF, NDF and IVTD of Napiergrass and growth degree days was obtained when the base temperature (lower developmental threshold) was set at 0°C (Table 5). The base temperatures of GDD were found to be 15.0°C for CP, and 15.5°C for ADF of Pangolagrass (Chen et al., 1999). There obviously is a difference of ADF and NDF accumulation and IVTD change between Pangolagrass and Napiergrass in responding to the temperature during the growth period. ADF, NDF and IVTD of Napiergrass will change as soon as

**Table 4.** Correlation coefficients of the chemical contents and IVTD to the climatic factors and plant morphology

| | $T_{avg}^{1}$ | $T_{max}^{1}$ | $T_{min}^{1}$ | Precipi-tation | Day length | Duration of sunshine | Days of growth | Plant height | Leaf/stem ratio |
|---|---|---|---|---|---|---|---|---|---|
| CP | -0.15 | -0.02 | -0.51** | 0.03 | -0.25* | -0.42** | -0.57** | -0.73** | 0.65** |
| ADF | -0.03 | -0.06 | 0.21* | -0.05 | 0.15 | 0.04 | 0.77** | 0.88** | -0.57** |
| NDF | -0.04 | -0.05 | 0.16 | 0.06 | 0.06 | 0.08 | 0.78** | 0.81** | -0.47** |
| IVTD | 0.01 | 0.09 | -0.24* | 0.06 | -0.16 | -0.16 | -0.82** | -0.87** | 0.60** |

[1] $T_{avg}$: average temperature of ten days prior to harvesting; $T_{max}$: the highest daily temperature of ten days prior to harvesting. $T_{min}$: the lowest daily temperature of ten days prior to harvesting.

* Significant at 5% level. ** Significant at 1% level.

**Table 6.** Prediction equations of chemical contents and IVTD of Napiergrass based on growth degree days and/or plant height

| Code | Prediction equation* | n | $R^2$ | RMSE (%) |
|---|---|---|---|---|
| （1） | $CP = -8.976 \times \ln(GDD12)+69.2$ | 98 | 0.77 | 2.18 |
| （2） | $CP = -0.04721 \times ht+20.34$ | 98 | 0.53 | 3.09 |
| （3） | $CP = -8.45786 \times \ln(GDD12)-0.00406 \times ht+66.6$ | 98 | 0.77 | 2.18 |
| （4） | $ADF = 0.01115 \times GDD0+27.7$ | 98 | 0.79 | 2.53 |
| （5） | $ADF = 0.07005 \times ht+28.9$ | 98 | 0.78 | 2.60 |
| （6） | $ADF = 0.00628 \times GDD0+0.03516 \times ht+27.34$ | 98 | 0.84 | 2.25 |
| （7） | $NDF = 0.01115 \times GDD0+54.0$ | 98 | 0.77 | 2.72 |
| （8） | $NDF = 0.06569 \times ht+56.0$ | 98 | 0.66 | 3.26 |
| （9） | $NDF = 0.00889 \times GDD0+0.01635 \times ht+53.8$ | 98 | 0.78 | 2.68 |
| （10） | $IVTD = -0.01905 \times GDD0+98.6$ | 98 | 0.87 | 3.19 |
| （11） | $IVTD = -0.11273 \times ht+95.2$ | 98 | 0.76 | 4.37 |
| （12） | $IVTD = -0.01489 \times GDD0-0.03007 \times ht+98.9$ | 98 | 0.89 | 3.04 |

* GDD0 and GDD12 are the growth degree days based on base temperature of 0°C and 12°C.
ln: natural logarithm. ht: plant height.

temperature raising over 0°C. Growth degree days calculated with base temperature set at 12°C (GDD12) had a even higher coefficient of correlation to CP after natural log transformation. This implies a curvilinear relationship between CP and GDD. On the contrast, natural log transformation did not increase the coefficient of correlation between the ADF, NDF, and IVTD of Napiergrass and GDD. Therefore, the response of ADF, NDF, and IVTD of Napier to the GDD was linearly within the range of daily average temperature observed in the present study. The coefficient of correlation between CP, ADF, NDF and IVTD of Napiergrass and GDD was higher than those between these dependent variables and other climatic factors reported in Table 4. This indicates that GDD was far more important determinant of composition and digestibility of Napiergrass in term of climatic factors.

### Prediction models based on GDD and plant height

Based on correlation analysis results, GDD and plant height showed to be the most important factor to affect the composition and digestibility of Napiergrass. To simplify the prediction models, GDD and plant height were used separately or jointly to establish the prediction models for CP, ADF, NDF, and IVTD of Napiergrass.

Prediction models for CP (Table 6) showed the highest $R^2$ as 0.77 and RMSE as 2.18 when ln(GDD12) used as independent variable (Equation 1). Using plant height to replace ln(GDD12) or to be incorporated with ln(GDD12) did not result in a better fit of prediction equation (Equations 2 and 3 vs. 1). Combination of GDD0 and plant height gave a better fit ($R^2 = 0.84$; RMSE = 2.25) prediction equation for ADF than they used separately (Equations 6 vs. 4 and 5). GDD0 used alone or in combination with plant height resulted in a similar fitness for predicting NDF (Equations 7 and 9). Plant height gave a poorer prediction of NDF (Equation 8). With a higher $R^2$ than in case of NDF, GDD0 used alone or in combination with plant height resulted in a similar fitness for predicting IVTD (Equations 10 and 12). Plant height gave a poorer prediction of IVTD (Equation 11).

### Verification of prediction models

Samples of Napiergrass harvested during later half of the second year were used as the verification set of samples (Table 1) to verify the twelve prediction equations listed in Table 6. Outcome of verification was summarized in Table 7.

Regression coefficient (b; Table 7) was significantly different than 1, and the intercept (a; Table 7) was significantly different than 0 for CP when using any one of three prediction equations. This indicates a bias existing for CP prediction.

Equation 6 gave the best prediction of ADF with regression coefficient not significantly different than 1 and intercept not significantly different than 0. Equations 4 and 5 gave similar results, but with a much lower $R^2$ than Equation 6 (0.79 or 0.78 vs. 0.87).

Equations 7 and 9 gave the best prediction of NDF with regression coefficient not significantly different than 1 and intercept not significantly different than 0. Equation 8 was poorer in predicting NDF.

Equations 10 and 12 gave the best prediction of IVTD with regression coefficient not significantly different than 1 and intercept not significantly different than 0. Equation 11 was poorer in predicting IVTD, with regression coefficient significantly different than 1 and intercept significantly different than 0.

## DISCUSSION

Daily average temperature was found to be highly correlated to CP, ADF and NDF of Pangolagrass, and day length was highly correlated to ADF and NDF of

**Table 7.** Parameters of the regressions between predicted and observed values for chemical contents and IVTD of Napiergrass

| Dependent variant | Equation | n | b | P (b = 1) | a | P (a = 0) | $R^2$ | RMSE | Mean of predicated value | Mean of observed value |
|---|---|---|---|---|---|---|---|---|---|---|
| CP | (1) | 33 | 0.68 | ** | 3.15 | ** | 0.70 | 2.68 | 11.0 | 11.6 |
| | (2) | 33 | 0.38 | ** | 7.17 | ** | 0.33 | 3.91 | 11.6 | 11.6 |
| | (3) | 33 | 0.67 | ** | 3.26 | ** | 0.70 | 2.73 | 11.0 | 11.6 |
| ADF | (4) | 33 | 0.85 | | 6.54 | | 0.79 | 2.37 | 42.9 | 42.3 |
| | (5) | 33 | 0.83 | | 6.54 | | 0.78 | 2.40 | 41.8 | 42.3 |
| | (6) | 33 | 0.92 | | 4.19 | | 0.87 | 1.92 | 42.4 | 42.3 |
| NDF | (7) | 33 | 0.87 | | 7.98 | | 0.79 | 2.48 | 69.1 | 69.9 |
| | (8) | 33 | 0.77 | | 14.24 | | 0.73 | 3.16 | 68.1 | 69.9 |
| | (9) | 33 | 0.89 | | 6.69 | | 0.82 | 2.42 | 68.8 | 69.9 |
| IVTD | (10) | 33 | 0.86 | | 8.29 | | 0.87 | 3.76 | 72.7 | 74.7 |
| | (11) | 33 | 0.74 | ** | 19.47 | ** | 0.76 | 4.40 | 74.4 | 74.7 |
| | (12) | 33 | 0.87 | | 7.67 | | 0.90 | 3.53 | 72.6 | 74.7 |

** Significant at the 0.01 probability level; n = number of observation; b = regression coefficient.
P (b = 1) = the probability that the regression coefficient equals to one; a = equation intercept.
P (a = 0) = the probability that the intercept equals to zero.
$R^2$ = coefficient of determination; RMSE = the root mean square error of prediction.

Pangolagrass (Chen et al., 1999). Although Napiergrass was also one of tropical forages, the present study indicated that CP, ADF, NDF and IVTD of Napiergrass had no significant relationship to day length or daily average temperature. Compared to other climatic factors, GDD had a much higher correlation with the composition and digestibility for both Napiergrass and Pangolagrass. The major difference of GDD related parameters between Napiergrass and Pangolagrass is that base temperatures obtained were 15.0°C for CP and 15.5°C for ADF of Pangolagrass (Chen et al., 1999) and 12°C for CP and 0°C for ADF, NDF and IVTD of Napiergrass in the present study. This difference may be related to the different blooming season for Pangolagrass (summer, long day length) and Napiergrass (winter-spring, short day length). Therefore, a small rising of temperature will facilitate the accumulation of less digestible fiber for Napiergrass. This implies that Pangolagrass will easily maintain its quality with minimum effect from days of growth in winter-spring season as long as temperature below 15.0°C. On the contrast, Napiergrass will be more easily affected by days of growth even in winter-spring season since the temperature of winter-spring season in Taiwan mostly was much higher than 0°C. The difference of forage quality items affected by base temperature between Pangolagrass and Napiergrass also reflected on the observation that season and cutting interval have different extend of influence on composition of Pangolagrass (Chen et al., 1997; 1999; 2000) and Napiergrass (Wang et al., 2003). Different base temperatures for the growth of different crops have been reported. Onstad and Fick (1983) employed 5°C as the base temperature to develop the prediction model for alfalfa. Slafer and Savin (1991) concluded a base temperature of 4°C for the growth of wheat before spikelet stage. Lawlor et al. (1990) reported a base temperature range of 8.6 to 11.0℃ for the shoot elongation of sorghum. It seems to be important to keep in mind that base temperature identified by higher correlation coefficient may be different for predicting the same quality item for different tropical forages, or for predicting different quality items of the same forage.

Due to the difference in base temperatures identified from GDD for CP and IVTD of Napiergrass, IVTD of Napiergrass harvested during winter-spring season will be expected to decline along with extended days of growth, but CP may stay unchanged as long as temperature below 12°C. On the other hand, both CP and ADF of Pangolagrass will change in a similar way along with extended days of growth once temperature is over 15.5°C. Digestibility of forage is closely related to ADF such as the change of ADF and IVTD of Napiergrass in relation to GDD. Therefore, we should keep in mind that CP and ADF of Pangolagrass harvested during cool season will be affected by days of growth in a similar trend, but Napiergrass may show a minor change of CP with a greater change of ADF and IVTD when temperature is between 0 to 12°C.

Crude protein of forage is easily affected geographical location, soil type or fertilization, the difficulty of prediction for CP is expected. In the present study, prediction by GDD or plant height all showed bias in the verification set of samples. Acid-detergent fiber is closely related to digestibility, its prediction by GDD or plant height all showed high accuracy based on the coefficient of regression, intercept and $R^2$. *In vitro* true digestibility also can be accurately predicted by GDD alone or in combination with plant height which did agree with what is seen in the prediction of ADF. However, plant height alone gave a poorer prediction of IVTD. Plant height is a common and easily accessible parameter for the forage Napiergrass. Based on the result of the present study, it is not appropriate to use plant height to judge the digestibility of Napiergrass. For prediction of NDF, GDD performed as well as ADF for Napiergrass. In case of Pangolagrass, GDD did not predict NDF as well as ADF (Chen et al., 2000).

Prediction model for forage quality has to be validated before we can be certain about its applicability. The prediction model for alfalfa quality developed by Fick and Onstad (1988) was later found to have bias in prediction (Fick and Janson, 1990; Sandeson, 1992). The prediction model of protein in the present study was proved to have bias by the verification set of samples. It seems that the prediction model has to be modified according to geographical location, soil type or fertilization practice. On the other hand, prediction models for ADF, NDF and IVTD based on GDD were proved to be accurate and acceptable for prediction quality of Napiergrass.

Farmers can utilize the prediction models to monitor or plan the harvest of Napiergrass to be in desired steady quality condition. Even evaluating five different perennial grasses (canarygrass, bromegrass, foxtail, tall fescue, and timothy) across three locations of New Yok state, US, Cherney et al. (1993) found consistent effects of harvest date on ADF and NDF contents and NDF digestibility. Since Taiwan locates across tropical and subtropical regions, forages grow all year round without the uniform growth starting time point in the spring like in temperate region. Harvest date may be conflicted by other factors. Growth degree days should offer more accurate description of growth condition and physiological maturity than harvest date. Therefore, the prediction models for the respective quality of Napiergrass based on GDD should have its reliability to be used by farmers growing Napiergrass. Also, the same information can be useful for cattle and goat farmers and silage makers. Improving the quality of Napiergrass silage has been one of recent research interests (Yunus et al., 2001; Yang et al., 2004). Understanding the difference of nutrient composition among varieties of Napiergrass (Islam et al., 2003) may also be useful. With more and more precise quality information on hand, quality of Napiergrass silage should be much easier to control and predict.

## CONCLUSION

Days of growth, plant height, leaf/stem ratio, CP, ADF and NDF of Napiergrass had highly significant relationship ($p<0.01$) to its IVTD. The highest coefficient of correlation between the ADF, NDF, and IVTD of Napiergrass and growth degree days was obtained when the base temperature was set at 0°C. Growth degree days predicted ADF, NDF and IVTD of Napiergrass more accurately than plant height, and plant height was not suitable to predict IVTD.

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