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To the Graduate Council:

I am submitting herewith a thesis written by Threepone Jawjit entitled "Effect of Stage of Maturity of Orchardgrass Hay on Yield, Chemical Composition, and Animal Performance." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

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EFFECT OF STAGE OF MATURITY OF ORCHARDGRASS HAY ON YIELD, CHEMICAL COMPOSITION, AND ANIMAL PERFORMANCE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Threepone Jawjit

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ABSTRACT

Three stages of maturity of orchardgrass hay which were harvested at the boot stage, 14 days after the boot stage, and 26 days after the boot stage were studied in order to determine the effect of stage of maturity on its productive and nutritive values. Due to mold contamination in the boot-stage hay of the first cutting, the boot-stage hay of the second cutting was used in the feeding and digestion trials.

Total dry matter yield which was estimated at each stage of maturity by weighing the forage from a known area and determining the percent dry matter increased with advancing stage of maturity.

A decrease in percent crude protein and an increase in percent of acid-detergent fiber, acid-insoluble lignin, and cell-wall constituents were found with an increase in stage of maturity.

Nutritive value was determined by a feeding trial with dairy heifers and effectively demonstrated that a decrease in body weight gain and voluntary feed intake occurred with increasing maturity of hay. A digestion trial conducted with sheep showed that the hay cut at the late stage of maturity had lower digestibility coefficients for every nutrient than those of hays cut at an early and the medium stage of maturity.

With advancing stage of maturity, digestible dry matter (DDM) obtained by in vivo digestion trial and dry matter disappearance (DMD) obtained by in vitro fermentation technique and nylon bag technique

decreased. It also appeared that dry matter disappearance (DMD) values by *in vitro* technique and nylon bag technique could produce reasonable estimates of the nutritive value of these forages.

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CHAPTER I

INTRODUCTION

During the past few years, there has been an increase in the improvement of several high-yielding cool season perennial grass cultivars in order to increase their productive and nutritive values as well as using them as a sole diet for livestock.

Among these cultivars, orchardgrass (Dactylis Glomerata) is a desirable forage grass because of its persistence, leafiness, productivity, ability to grow well on soil of low fertility, early spring growth, and abundant leafy aftermath production.

Even though there are numerous factors influencing to the productive and nutritive value of orchardgrass, the stage of maturity is considered to be the primary factor.

The general objective of this investigation was to study the nutritive and productive value of orchardgrass hay harvested at three stages of maturity using chemical constituents, digestion and feeding trials, and animal performance.

CHAPTER II

REVIEW OF LITERATURE

I. EFFECT OF PLANT MATURITY ON THE YIELD OF ORCHARDGRASS HAY

The productivity of the forage is considered by the dairy farmers to be of economic importance. To obtain maximum production from forage, many factors should be investigated, one of which is stage of maturity.

Workers generally agree that yields of forage increase with advancing maturity. Results of studies conducted in two consecutive years of experiments by Minson et al. (15) demonstrated that dry matter production of S37 cocksfoot (Dactylis glomerata) increased with an eight-day delay in the cutting date. Effects of harvest dates on dry matter yield of orchardgrass were also reported by Minson et al. (16). They showed that with a thirty-six-day delay in cutting date, the dry matter production increased from 1,440 pounds per acre to 4,900 pounds per acre. Austenson (3) indicated that first harvest yields of orchardgrass increased at nearly uniform rates up to full bloom stage and rose relatively little after that time. He also showed that maximum yields of orchardgrass were obtained at the full bloom stage. Austenson's (3) study also pointed out that when the first harvest date was delayed from April 21 to May 31, aftermath yields declined. Further postponement of the first harvest had no additional effect on aftermath yields.

Evans et al. (12) demonstrated that as the stage of maturity advanced, the dry matter yield increased. The dry matter yield of orchardgrass cut on May 5 was 1,662 lbs./acre, while that cut on June 6 was 4,703 pounds per acre. Washko (31), comparing the dry matter yield of three orchardgrass varieties harvested each spring at different stages of maturity over a three-year (1960-1962) period at West Virginia, showed that the total dry matter yield harvested increased as harvesting time varied from the pre-joint stage to the past bloom stage. The maximum dry matter production of every variety seemed to be at the early bloom stage. However, they indicated that the most beneficial time of first harvest for the production of large aftermath yields was at the early stage of maturity. Delay of first harvest until past bloom caused a reduction in aftermath yields.

II. EFFECT OF PLANT MATURITY ON CHEMICAL COMPOSITION

Chemical composition of orchardgrass depends on many known and unknown factors such as soil, climate, species, variety, and diseases. However, chemical composition depends primarily on the physiological and morphological development of the plants.

Percent crude protein in orchardgrass hay was found to decrease with advancing maturity by Sullivan and Routley (26), Minson et al. (16), Austenson (3), and Montgomery (17, 18). Austenson (3) reported that the percentage of protein in orchardgrass decreased from 16.3 to 4.7 as the plants changed from the vegetative to the hard dough stage.

Similar results were obtained in recent experiments of Montgomery (18). These experiments showed that the percentage of crude protein

in orchardgrass at the boot stage was 23.0 compared to 14.6 two weeks after the boot stage.

Armstrong et al. (2) and Ely et al. (11) noted a slight decrease in the percentage of ether-extract as the plant matured. Ely et al. (11) also showed that an increase in nitrogen-free extract occurred in orchardgrass as it developed from the early to the late stage of maturity. However, data on the chemical composition of orchardgrass at different stages of maturity obtained by Armstrong et al. (2) did not show any difference in the percentage of nitrogen-free extract.

Cell-wall constituents (CWC) increase as orchardgrass matures. Montgomery (17), using orchardgrass hay at two stages of maturity, demonstrated an increase in the percent of CWC (61.8 to 63.8) when harvesting changed from the boot stage to two weeks after the boot stage. These results correspond with the results of experiments recently conducted by the same worker (18).

In general, the percentage of crude fiber increases as forages mature. Bernie (6) and Ely et al. (11) reported a marked increase in percent crude fiber as orchardgrass matured. Montgomery (17, 18) also confirmed that percent acid-detergent fiber (ADF) of orchardgrass increased in the advanced stage of maturity.

The effect of advancing maturity in orchardgrass is also seen in the case of lignin and cellulose fractions, both of which have increased to a marked degree (2, 3, 17, 18).

Armstrong (2), studying the lignin and cellulose content of grassland species at different stages of maturity, reported that both true lignin and cellulose increased significantly as orchardgrass

changed from the pre-flowering stage to the seeding stage. Austenson (3) found that as orchardgrass developed from the vegetative stage to the hard dough stage, the percent lignin increased from 4.2 to 10.4. Similar results were noted by Montgomery (17, 18).

Mineral analysis of the orchardgrass at different stages of maturity indicated that with advancing stage of maturity the percentage of minerals in plants also declined (15, 16).

III. EFFECT OF PLANT MATURITY ON VOLUNTARY FEED INTAKE

One of the most important biological criteria considering overall nutritive value of forage is the level of animal intake. There are many factors which have an effect on the voluntary intake of forage. The stage of maturity at which forages are harvested is one of these factors. It has been shown to affect nutritive value of forage and thus it has an effect on voluntary intake of the animal.

Spahr et al. (25) used orchardgrass hay in three stages of maturity (the flowering stage, the headed and mature pollen stage, and the seed at milk stage) to evaluate its nutritive value by a digestion and feeding trial with Holstein cows. They reported that a 15-day delay in the cutting date caused a significant reduction in hay intake. Average daily hay intake per 100 lbs. of body weight was 2.29 lbs. for cows consuming hay harvested in the flowering stage and 1.19 lbs. for cows eating hay harvested in the headed and mature pollen stage.

Haenlein et al. (13), using three varieties of orchardgrass cut at different stages of maturity, concluded that date-of-cut was significantly related to voluntary consumption by sheep. In this

experiment, the daily decline in average voluntary intake with advancing maturity of hay was estimated to be 0.7 gm. dry matter per $W_{kg.}^{.73}$.

Studies by Minson et al. (16) indicated that sheep which were fed orchardgrass in the late stage of maturity had a lower daily dry matter intake than those fed orchardgrass harvested earlier. From this experiment, they noted that delaying the cutting date 46 days caused dry matter intake to decrease from 90.2 to 39.4 g./kg. $L.W.^{0.73}$. Similar results were obtained by the same group of workers in the second year of the experiment. However, two-year experiments by Montgomery (17, 18) at the Tennessee Dairy Experiment Station indicated that lactating cows did not show any significant difference in feed intake of orchardgrass hay harvested at the boot stage and 14 days after the boot stage.

IV. EFFECT OF PLANT MATURITY ON DIGESTIBILITY

It is well recognized that digestibility of forages decreases as plants mature (15, 20, 23, 25) and evidence (15) indicates that the rate of this decrease depends on the type of herbage and stage of morphological development.

In Vivo Digestibility Studies of Orchardgrass

There is ample evidence to document the decrease in dry matter digestibility associated with maturation of orchardgrass. Ely et al. (11) have shown that apparent digestibility coefficients of three cellulose fractions, and of pentosans, total carbohydrates, and organic

acid fractions decreased with the advancing maturity of orchardgrass. However, the digestion coefficients for the starch and sugar fractions were high at all growth stages.

Minson et al. (15, 16) reported that dry matter digestibility and organic matter digestibility of S37 and Germinal orchardgrass fell slowly up to the time of head emergence and then fell more rapidly with further advances in maturity. In digestion trials with heifers, Murdock et al. (20) noted that average dry matter digestibility of orchardgrass decreased from 75.6 percent to 54.8 percent when orchardgrass changed from the vegetative stage to the full bloom stage.

In Vitro Digestibility Studies of Orchardgrass

Dehority et al. (9) used in vitro techniques to study the digestibility of orchardgrass hemicellulose and pectin at the early bloom stage and the early seed stage. They found an appreciable decrease in hemicellulose and pectin digestibility as the plant matured and they suggested that this decrease resulted from lignin forming a physical barrier between hemicellulose or pectin and the rumen bacteria.

Pritchard et al. (22) found that the percentage of in vitro dry matter digestibility of orchardgrass decreased from 60.8 to 42.7 as the plants changed from the vegetative stage to the post-flowering stage. Similar results were obtained by Terry and Tilley (27). They indicated that the decline in digestibility was associated with a reduction in the content of water soluble and protein constituents in the plant, and with a reduction in the digestibility of fiber.

Mowat et al. (19) found the in vitro dry matter digestibility of orchardgrass stems to be greater than leaves at immature growth stages. At head emergence the digestibility of the orchardgrass leaves were similar to that of the stems; and at later growth stages, leaves were more digestible than stems. Evidence of a strong inverse linear relationship between in vitro digestibility and lignification in orchardgrass was reported by Johnson and Waite (14).

In Vitro and In Vivo Digestibility Relationship

One objective of the in vitro technique is to estimate the in vivo digestibility of forages. Clark and Mott (8), using 11 forages of known in vivo digestibility found that in vitro digestibility was significantly correlated ($r = 0.77$) with in vivo data. Tilley and Terry (28) established a two-stage technique for the in vitro digestion of forages. By using this technique, they concluded that in vitro digestibility was highly correlated with in vivo digestible dry matter (DDM). Similar results were obtained with a correlation coefficient of 0.88 between in vivo DDM and in vitro DDM of the forage by using the Tilley and Terry technique (21).

Smith et al. (24) and Barth and Mohammed (4) confirmed that in vivo DDM could be predicted from in vitro DDM. Barth et al. (5) found that in vitro DDM of eight forage samples by the two-stage artificial rumen technique proposed by Tilley and Terry (28) yielded reliable estimates of the total collection in vivo DDM.

V. EFFECT OF PLANT MATURITY ON THE ANIMAL PERFORMANCE

Animal performance is influenced by many factors. The quality of forage is one of these factors. It has long been known that the stage of maturity of plants has a strong effect on plant quality and thus the cutting date of plants also affects animal performance.

Unfortunately, there is limited data on the performance of animals fed on orchardgrass hay harvested at different stages of maturity as a sole diet. However, Spahr et al. (25), working with orchardgrass hay in order to determine its quality, reported that a 15-day delay in the cutting date caused a reduction in milk production and lowered body weight gains. This resulted from lower digestibility and lower hay intake.

Similar results were noted by Montgomery (17). He reported that dairy cows fed orchardgrass hay harvested at the boot stage produced 39.9 pounds fat corrected milk per day while the cows fed with hay harvested two weeks after the boot stage produced 36.9 pounds per day. However, results of another recent experiment (18) did not demonstrate any significant difference in either milk production and body weight gains of the cows fed hay harvested at the boot stage and of those fed with hays harvested 14 days after the boot stage.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. EFFECT OF PLANT MATURITY ON TOTAL DRY MATTER YIELD

Orchardgrass (Dactylis glomerta) was grown at the Middle Tennessee Experiment Station. Ammonium nitrate fertilizer was applied to plants prior to the first cutting at the rate of 200 pounds per acre. In order to get the range in maturity, first cutting orchardgrass was harvested in the boot stage (April 30)[1], 14 days after the boot stage (May 14)[2], and 26 days after the boot stage (May 26)[3]. Because of excessive moisture at time of baling the boot stage hay (April 30) was contaminated by mold. In order to replace the molded hay, a second cutting was made at the boot stage (June 8) in the same area that was cut April 30. An additional 100 pounds of ammonium nitrate was applied after the first cutting.

Dry matter yield was estimated at each stage by weighing the forage from a known area and determining the percent dry matter.

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[1]Refers to the early stage of maturity (boot stage).

[2]Refers to the medium stage of maturity (two days before bloom).

[3]Refers to the late stage of maturity (full bloom).

II. FEEDING TRIAL

Rate of Body Weight Gain and Voluntary Feed Intake

Eighteen non-pregnant Holstein heifers were used as experimental animals. Individual body weights were taken after a 16-hour shrink (no feed and water) at the beginning and end of the experiment.

A randomized complete block design was used. Three heifers were assigned to each group on the basis of weight and condition. Two groups were then assigned to each of the three treatments. The three treatments were: The boot stage, 14 days after the boot stage, and 26 days after the boot stage of orchardgrass hay. All animals were individually fed *ad libitum* to insure 5-15 percent refusal.

An 84-day feeding period was conducted for hays harvested at 14 days and 26 days after the boot stage. Due to limited amounts of boot stage hay the heifers in that treatment group were fed for 56 days.

The heifers were fed twice daily, in the morning and in the afternoon. Weigh-backs were taken daily in the evening. Rate of gain of body weight was expressed as kilograms per day. Voluntary feed intake was determined during the entire feeding period. The voluntary feed intake was expressed as grams dry matter per unit of metabolic body weight.

III. *IN VIVO* DIGESTIBILITY STUDIES

Experimental Sheep and General Procedure

Eighteen sheep were utilized for *in vivo* digestibility studies. Because of inadequate metabolism stalls, the digestion trial was divided

into two phases. Each phase contained nine sheep from The University of Tennessee's Blount Farm. For the first phase, the sheep were weighed and randomly assigned to each of the three orchardgrass hays before being placed in the metabolism stalls described by Briggs and Gallup (7).

In the second phase, the same nine sheep were rearranged into new experimental groups. One sheep from each treatment group in phase one was chosen to make up the experimental groups in phase two. Thus any possible carry-over effect from the previously fed ration was eliminated.

In each phase, a fourteen-day preliminary period was used in order to allow sheep to become accustomed to the experimental ration and the metabolism stalls. During the first twelve days of the preliminary period, these sheep were given a full-feed of hay with a refusal of about 5 - 10 percent. On the thirteenth day, feed intake was reduced to 90 percent of full-feed and continued at this level for the remainder of the trial. The preliminary period was followed by a seven-day collection period. Feces which were collected on the fifteenth through the twenty-first days were attributed to forage consumed during the thirteenth to the nineteenth days. Feces collected from each individual sheep were weighed daily, mixed thoroughly with a spatula, and put into a labeled jar to which a few crystals of thymol were added. All feces jars were stored in a refrigerator at 40° F. until the end of the collection period.

Throughout the trials, the sheep were fed their daily hay ration in two equal portions: one-half in the morning and one-half in the

evening. The sheep had access to water twice daily, in the morning before feeding and from noon to 4:30 p.m. in the evening.

Samples of the three orchardgrass hays fed and refusals were collected daily.

Chemical Analyses

Feed, refusal, and fecal samples. At the end of the collection period, the seven-day fecal samples were mixed thoroughly and the total wet weight was recorded. Three-200 gram subsamples of the feces of each sheep were placed in an oven at 105° C. for dry matter determination. The remainder of the fecal samples were dried at 50° C. for three days and allowed to air equilibrate for five days. These were used for subsequent chemical analyses.

Samples of the three orchardgrass hays, the fecal material and refusals were ground to pass through a 1 m.m. screen of a Wiley Mill.

Residual dry matter and nitrogen were determined in accordance with the A. O. A. C. procedures (1). Acid-detergent fiber and acid-insoluble lignin were determined using Van Soest's (29) procedure. Determination of cell-wall constituents of all samples followed the procedure proposed by Van Soest (30). Gross energy was determined in a Parr Oxygen Bomb Calorimeter.

IV. IN VITRO FERMENTATION STUDIES

Preparation of Samples

Samples of the different stages of maturity of orchardgrass hays were collected from both phases during the in vivo digestibility

studies. The air-dry samples were ground through a 40 mesh screen of a Wiley Mill to insure uniformity of particle size and were placed in air-tight bottles.

Experimental Treatments and Technique Used

The *in vitro* digestion experiment was conducted in two trials. Each trial consisted of three samples of hay which were obtained from each phase of the *in vivo* digestibility studies. Each sample was replicated three times. A 2 x 2 x 3 factorial experiment was then designed for this study in order to determine the effects of the treatments and interaction between treatment combinations.

A two-stage *in vitro* fermentation technique described by Tilley and Terry (28) was used to determine dry matter disappearance of orchardgrass hay at different stages of maturity.

V. NYLON BAG *IN VIVO* DIGESTION TRIAL

Preparation of Samples

The samples used in this investigation were obtained from the same source as the samples used *in vitro* fermentation studies.

Experimental Treatment and Procedure

Three samples of different stages of hay (obtained from each phase during *in vivo* digestion trial) with three replications were used to determine the dry matter disappearance. Two rumen fistulated cows were employed in this study. The dry matter disappearance was determined for two trials in order to check the experimental technique. Therefore a 2 x 2 x 2 x 3 factorial experiment was designed for this investigation.

Nylon bags measuring 2 x 4 inches were prepared from nylon parachute material. Approximate three grams of the ground sample hays were placed in each bag. The bags containing samples were then anchored to polyethylene bottles. They were then placed in the ventral portion of the rumen of the two rumen-fistulated dairy cows. After 48 hours in the rumen, the bags were gently removed and washed, and then frozen in order to stop microbial activity. Finally, they were dried at 105° C. for 12 hours or overnight.

Percent dry matter disappearance (DMD) was calculated from the amount of dry matter present in the bags before and after they were placed in the rumen.

VI. STATISTICAL ANALYSIS

Data collected from the feeding trial, digestion trial *in vitro* fermentation technique, and nylon bag *in vivo* digestion trial were tested by means of analysis of variance and Duncan's (10) new multiple-range test to determine a statistically significant difference between means.

CHAPTER IV

RESULTS AND DISCUSSION

I. TOTAL DRY MATTER YIELDS

The results of total dry matter yields of orchardgrass hay harvested at different stages of maturity are presented in Table I. It can be seen that the average dry matter yield per acre increased with advancing maturity. These results agreed well with the results of Minson et al. (15, 16), Evans et al. (12), and Washko et al. (31). Increasing total dry matter yield with advancing maturity may be explained as the result of an increasing fraction of nitrogen-free extracts, cellulose and crude fiber.

II. CHEMICAL COMPOSITION

Chemical composition of orchardgrass hay harvested at different stages of maturity is shown in Table II. Hay harvested at the early stage of maturity was higher in crude protein content than those harvested at the late stage of maturity. Results of this investigation agreed well with the results obtained by recent experiments (17, 18) in that with advancing stage of maturity, the crude protein content of hay declined. This decline results from a decrease in leaf-stem ratio which has a high correlation ($r = +0.96$) with protein content (3).

The percent of acid-detergent fiber (ADF) and acid-insoluble lignin increased with advancing stage of maturity of the orchardgrass

TABLE I

EFFECT OF STAGE OF MATURITY OF ORCHARDGRASS HAY ON DRY MATTER YIELDS

Area	State of Maturity			
	Early* (April 30)	Medium (May 14)	Late (May 26)	Early** (June 8)
1	1,220	3,670	4,640	844
2	1,565	3,740	3,090	1,499
3	2,030	2,450	6,020	1,656
4	1,615	4,180	4,580	756
5	2,220	3,470		1,744
6	2,415			1,376
Av. dry matter, percent	18.6	23.6	30.6	-
Mean dry matter yield (pound/acre)	1,844	3,502	4,583	1,313

*Orchardgrass harvested on April 30 was contaminated by mold during storage.

**Orchardgrass harvested on June 8 replaced molded hay in feeding and digestion trial.

TABLE II

EFFECT OF STAGE OF MATURITY OF ORCHARDGRASS HAY ON CHEMICAL COMPOSITION (ON DRY MATTER BASIS)

	Stage of Maturity		
	Early	Medium	Late
Dry matter, percent	89.1	91.0	91.9
Acid-detergent fiber, percent	35.1	38.7	44.7
Acid-insoluble lignin, percent	3.7	3.8	5.3
Cell-wall constituents, percent	62.2	66.0	73.8
Crude protein, percent	18.2	12.4	9.0
Gross energy, kcal./gm.	4.73	4.52	4.52

hay. However, there appeared to be little difference in the percentage of acid-insoluble lignin of hays harvested at the early and the medium stage of maturity. Percentage of acid-detergent fiber (ADF) and acid-insoluble lignin were higher when orchardgrass hay reached the late stage of maturity. This increase indicated that as plants matured, the cellulose or crude fiber content and the amount of lignified area would also increase.

The cell-wall constituents (CWC) of the hay showed a tendency to increase as the hay matured. These results support the data of Montgomery (17, 18). Increase in amounts of the cell-wall constituents with advancing stage of maturity was due to increase in the amount of cellulose and hemicellulose.

III. FEEDING TRIAL

Body Weight Gain

Body weight gains are presented in Table III. Average daily weight gains of heifers fed with either hay cut at the early stage and at the medium stage of maturity was significantly ($P < .01$) higher than that of heifers fed hay cut at the late stage of maturity.

Comparison average body weight gains between heifers fed hay cut at the early stage and heifers fed hay cut at the medium stage of maturity, it was noted that the average body weight gains of the former was significantly ($P < .05$) higher than that of the later. There was no significant difference in daily gains between the replicate lots of heifers fed the same hay.

TABLE III

EFFECT OF STAGE OF MATURITY OF ORCHARDGRASS HAY
ON PERFORMANCE OF DAIRY HEIFERS

	Stage of Maturity		
	Early	Medium	Late
No. of heifers per treatment	6*	6**	6**
Av. wt. and gain per head, kg.			
Initial wt.	283.8	283.3	286.7
Final wt.	333.6	336.7	302.2
Total gain	49.8	53.4	15.5
Daily gain	0.89[a]	0.64[a]	0.18[b]
Av. dry matter intake, gm.			
Per $W_{kg}^{.75}$ per day	114.4[a]	100.1[b]	88.7[b]

[a,b]Means with different superscript letters are significantly at the 1 percent level of probability and with same superscript letters are significantly different at the 5 percent level of probability.

*56-day feeding period.

**84-day feeding period.

It can be observed that as the hay advanced in maturity the average body weight gains decline. The decline in average body weight gains of heifers resulted from lower digestibility and lower hay intake.

Voluntary Hay Intake

Average hay intake of dairy heifers fed the three different stages of orchardgrass maturity is presented in Table III. There were large differences in the hay intake of the three groups of heifers. The heifers fed hay harvested at the early stage of maturity consumed significantly ($P<.01$) more than those consuming hays cut at the medium and the late stage of maturity. It can also be seen that the heifers fed hay cut at the medium stage of maturity consumed significantly ($P<.05$) more than those fed hay harvested at the late stage of maturity. A reason thought to be a factor is that the hay cut at the early stage of maturity is of a good quality. It is more palatable and easier to digest than those hays cut at the late stage of maturity. Therefore, there is a faster rate of passage of a higher quality hay through the digestive tract, especially through the rumen. Consequently, the heifers fed hay cut at the early stage of maturity more frequently become hungry and eat more.

IV. DIGESTIBILITY STUDIES

In Vivo Digestion Trial

Mean digestion coefficients from the sheep trial can be found in Table IV. It was noted that there were no significant differences

TABLE IV

MEAN DIGESTIBILITY COEFFICIENTS OF ORCHARDGRASS HAY HARVESTED AT DIFFERENT STAGES OF MATURITY

	Stage of Maturity		
	Early	Medium	Late
Dry matter, percent	$62.8^{a} \pm .20$	$63.8^{a} \pm 1.07$	$54.3^{b} \pm .53$
Acid-detergent fiber, percent	$60.9^{a} \pm .78$	$62.7^{a} \pm .71$	$53.2^{b} \pm 1.11$
Cell-wall constituents, percent	$67.2^{a} \pm .51$	$65.9^{a} \pm 1.14$	$55.5^{b} \pm .68$
Crude protein, percent	$69.9^{a} \pm .46$	$64.9^{b} \pm .66$	$56.4^{c} \pm .28$
Energy, percent	$61.6^{a} \pm .20$	$61.0^{a} \pm .89$	$50.3^{b} \pm .60$

^{a,b,c}Means with different superscript letters are significantly different at the 1 percent level of probability.

in the apparent digestibility of dry matter, acid-detergent fiber, cell-wall constituents, and energy between hays cut at an early stage of maturity and that cut at the medium stage of maturity. However, the digestion coefficients of crude protein of hay harvested at the early stage were significantly ($P < .01$) higher than hay cut at the medium stage of maturity. As noted in Table IV, the late stage of maturity of orchardgrass hay had significantly ($P < .01$) lower digestion coefficients for every component than did the hays cut in an early or medium stage of maturity.

The decline in the digestion coefficients of hay harvested at the late stage resulted from an increase in the proportions of crude fiber, which is generally accompanied by greater lignification of the cell walls. The consequent decline in crude fiber digestibility inevitably causes the reduction in digestibility of other constituents, because unbroken cell walls prevent admittance of the digestive enzymes to the cell contents.

In Vitro Fermentation Studies

Table V shows the percent dry matter disappearance (DMD) of the orchardgrass hay by rumen microbes *in vitro*. The DMD of hay harvested at the late stage of maturity was significantly ($P < .01$) lower than those of hays cut at an early and the medium stage of maturity. There was slightly higher *in vitro* DMD of hay at an early stage of maturity as compared to that of hay at the medium stage of maturity. However, the difference was not significant ($P > .05$).

TABLE V

MEAN DIGESTIBLE DRY MATTER OF ORCHARDGRASS HAY AT DIFFERENT STAGES OF MATURITY BY MEANS OF *IN VIVO* DIGESTION TRIAL, *IN VITRO* FERMENTATION TECHNIQUE, AND NYLON BAG DIGESTION TRIAL

	Stage of Maturity		
	Early	Medium	Late
In vivo digestible dry matter, percent	62.8[a]	63.8[a]	54.3[b]
In vitro dry matter disappearance, percent	66.9[a]	65.9[a]	54.2[b]
Nylon bag dry matter disappearance, percent	75.4[a]	71.5[b]	57.2[c]

[a,b,c]Means with different superscript letters are significantly different at the 1 percent level of probability.

The decline in the *in vitro* DMD with advancing stage of maturity is the result of a decrease in leafiness and an increase in stem portion. Generally, the stems of common grasses have a much higher lignin content than leaves even at the early maturity stage. Lignin exerts a direct controlling effect on the digestibility, since it is the indigestible part of plants and will prevent access of rumen microbes to the other constituents of the plants. Consequently, the level of digestibility of plants decrease.

Nylon Bag in Vivo Digestion Trial

The results of the dry matter disappearance (DMD) determination by nylon bag *in vivo* digestion trials are shown in Table V. As shown in Table V, statistical analysis indicates that the DMD of hays harvested at an early and the medium stage of maturity was significantly ($P<.01$) higher than that of hay harvested at the late stage of maturity. There was also significantly ($P<.01$) difference in DMD obtained from hays cut at an early and the medium stage of maturity. These results indicated that with advancing maturity the digestibility of hay decreased.

A Comparison of Methods that Estimate Digestible Dry Matter

Digestible dry matter (DDM) obtained by *in vivo* digestion trial and dry matter disappearance (DMD) obtained by *in vitro* fermentation technique and by the nylon bag *in vivo* technique were compared in order to determine how well or close they express the nutritive value of orchardgrass at three different stages of maturity. A summary of DMD and DDM is shown in Table V. The nylon bag DMD values appeared to be

higher than *in vitro* DMD and *in vivo* DDM, particularly DMD of the early-stage and of the medium-stage hay. This might be the result of the hay substrate was so fine that it could pass through the bag. It can be seen that among these three methods, nylon bag technique shows an over-evaluation of forage digestibility. These results agree well with Barth *et al*. (5).

A comparison of *in vitro* DMD and *in vivo* DDM of hays harvested at an early and the medium stage of maturity indicated that the *in vitro* DMD values were a little higher than *in vivo* DDM. This probably results from disappearing of the tested substrate or a large quantity of rumen microbes being produced during the period of fermentation. However, *in vitro* DMD of hay harvested at the late stage of maturity agreed well with the *in vivo* DDM.

The correlation among these methods was not determined because of the limited number of observations of *in vitro* DMD and nylon bag DMD.

CHAPTER V

SUMMARY

This study was designed to determine the dry matter yield and the nutritive value of orchardgrass (Dactylis Glomerata) hay harvested at the boot stage, 14 days after the boot stage, and 26 days after the boot stage. The nutritive value was determined by proximate chemical analysis, metabolism trials by sheep, in vitro fermentation technique as well as in vivo nylon bag technique, and performance of dairy heifers. The important results were as follows:

1. The total dry matter yield of orchardgrass hay harvested at late stage of maturity was higher than those harvested at an early stage of maturity. Increasing total dry matter yield with advancing stage of maturity is due to an increase in the total carbohydrates of the plant as they reach the late stage of maturity.
2. On a dry matter basis, the chemical analysis of the hay revealed a marked decrease in crude protein content with advancing maturity. An increase was shown for acid-detergent fiber (ADF), cell-wall constituents (CWC), and acid-insoluble lignin. The gross energy of orchardgrass hay harvested at the boot stage was slightly higher than those of harvested at 14 days and 26 days after the boot stage.
3. The average hay intake of heifers fed with hays harvested at an early stage and the medium stage of maturity was higher

than those fed with hay at the late stage of maturity.

4. With advancing stage of maturity in the hay, the body weight gain decreased. Since the dairy heifers fed with hays harvested at an early and the medium stage of maturity supported average daily gains of 0.89 and 0.64 kilograms per head per day, respectively, while the heifers fed with hay at the late stage of maturity supported average daily gains of 0.18 kilograms per head per day.
5. There were no significant ($P > .05$) differences in the digestion coefficients of dry matter, acid-detergent fiber, cell-wall constituents, and energy of orchardgrass hays harvested at an early and the medium stage of maturity. However, the digestion coefficients of crude protein of hay at an early stage was significantly ($P < .01$) higher than that of hay at the medium stage of maturity. The poor hay (hay cut at the late stage of maturity) had significantly lower digestibility coefficients in every nutrient than those hays at the early stage and the medium stage of maturity.
6. With advancing maturity, digestible dry matter (DDM) obtained by the in vivo digestion trials, dry matter disappearance (DMD) obtained by the in vitro fermentation technique and the nylon bag in vivo decreased significantly.
7. It appeared that all three methods could estimate the nutritive value of the forage.

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APPENDIX

TABLE VI

EFFECT OF STAGE OF MATURITY ON THE BODY WEIGHT INCREASE OF INDIVIDUAL DAIRY HEIFERS (KILOGRAM PER DAY)

Stage of Maturity								
Early			Medium			Late		
Animal No.	Lot No.		Animal No.	Lot No.		Animal No.	Lot No.	
1	1*	0.68	7	3**	0.82	13	5**	0.03
2		1.09	8		0.53	14		0.06
3		1.14	9		0.73	15		0.21
4	2*	0.92	10	4**	0.67	16	6**	0.31
5		0.63	11		0.59	17		0.25
6		0.88	12		0.46	18		0.22

*56-day feeding period.

**84-day feeding period.

TABLE VII

EFFECT OF STAGE OF MATURITY ON VOLUNTARY FEED INTAKE OF ORCHARDGRASS HAY BY INDIVIDUAL DAIRY HEIFERS (GRAM DRY MATTER PER $W_{Kg.}^{3/4}$ PER DAY)

Stage of maturity								
Early			Medium			Late		
Animal No.	Lot No.		Animal No.	Lot No.		Animal No.	Lot No.	
1	1*	111.0	7	3**	102.3	13	5**	79.2
2		114.9	8		94.4	14		94.0
3		112.3	9		101.7	15		85.2
4	2*	124.7	10	4**	102.9	16	6**	87.3
5		107.8	11		98.8	17		100.6
6		108.6	12		99.7	18		86.0

*56-day feeding period.

**84-day feeding period.

TABLE VIII

DIGESTIBILITY COEFFICIENTS OF ORCHARDGRASS HAY AT DIFFERENT STAGES OF MATURITY BY INDIVIDUAL SHEEP (FIRST PHASE)

	Stage of Maturity								
	Early			Medium			Late		
	Animal No.			Animal No.			Animal No.		
Nutrient	1	2	3	4	5	6	7	8	9
Dry matter, percent	62.57	62.29	62.91	64.17	67.65	62.75	52.83	53.28	56.52
Acid-detergent fiber, percent	59.32	60.64	63.73	63.24	68.43	62.16	50.68	51.25	57.04
Cell-wall constituents, percent	65.74	65.92	66.71	66.17	71.24	64.18	53.75	53.54	57.81
Crude protein, percent	68.07	69.69	69.32	64.75	67.36	62.42	55.29	56.44	56.71
Energy, percent	61.22	61.41	62.12	60.56	64.38	59.66	49.18	51.22	52.68

TABLE IX

DIGESTIBILITY COEFFICIENTS OF ORCHARDGRASS HAY AT DIFFERENT STAGES OF MATURITY BY INDIVIDUAL SHEEP (SECOND PHASE)

	Stage of Maturity								
	Early			Medium			Late		
	Animal No.			Animal No.			Animal No.		
Nutrient	1	2	3	4	5	6	7	8	9
Dry matter, percent	63.17	63.47	62.29	62.99	65.47	59.94	53.97	54.46	54.78
Acid-detergent fiber, percent	59.79	62.59	59.01	60.44	65.59	56.32	50.93	55.76	53.42
Cell-wall constituents, percent	68.42	68.54	67.84	64.49	69.48	60.08	55.18	56.27	56.54
Crude protein, percent	70.91	71.09	70.13	65.05	65.61	64.48	57.40	56.38	56.24
Energy, percent	62.24	61.32	61.10	60.57	62.53	58.19	48.55	50.00	50.16

VITA

Threepone Jawjit was born June 25, 1945, at Nakornsrithammaraj, Thailand. He was graduated from Benjamarachutid High School in 1964. He then left Nakornsrithammaraj for Bangkok to obtain a higher education. Four years later he was rewarded a Bachelor of Science degree in Animal Science from Kasetsart University. While at the Kasetsart University, he received a scholarship from the university and was a member of the Animal Science Club.

He came to The University of Tennessee in September, 1970, on a Thai Government Scholarship. He began study under the guidance of Dr. M. J. Montgomery. He received the Master of Science degree in June, 1972, with a major in Dairy Nutrition.

He was married to the former Wimol Pongsutham in September, 1969, and they presently have a son, Wittapone Jawjit.