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Determining the Harvest Time for Maximum Yield and Quality of Orchardgrass Swards

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Orchardgrass 單播草地의 最高生産과 質的向上을 위한 收穫適期의 決定

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Summary

The harvest schedule for the maximum total yield and quality of orchardgrass swards was studied on the basis of theoretical analysis due to Chang's total yield equation. Harvesting at the 10% bloom stage of morphological development of orchardgrass swards was selected as a criterion which provided highest dry matter (DM) yield in conjunction with high and consistent levels of *in vitro* dry matter digestibility (IVD) and crude protein contents (CP) from harvest to harvest. However, since orchardgrass after the 1st cutting do not bloom, the harvest time for the maximum yield and quality of orchardgrass swards is replaced by the three should time of the ceiling leaf area index (LAI).

I. Introduction

Crops, vegetables and fruits are harvested at their asymptotic stages of the parts required for man. The maximum yield obtained from the seasonal peak standing crop is the annual production in this area. However, in the case of the forage crops, the total yield in the several harvests during the growing season must be increased extremely by the method of the selection of cutting schedules (Chang, 1971; Chang and Yoshida, 1973). Harvest schedules based on growth analyses are important in attaining maximum total yield of DM during the growing season. The number of cuts influences yield (Baumgardt and Smith, 1962; Davies and Tyler, 1962; Meyer and Jane, 1962) and cutting during the autumn rest period markedly reduces persistence of Medicago sativa (Kurst and Smith, 1961; Teel, 1956). The quality of the product decreases with advancing maturity (Brown et al. 1968; Baumgardt and Smith, 1962; Mowat et al. 1965), but some quality must be sacrificed in order to obtain satisfactory yields (Fulkerson et al. 1967; Meyer and Jane 1962).

The purpose of this study was to determine the influence of harvest schedules based on growth analyses of orchardgrass on DM yield, LAI and IVD. The measurements were made on pure sowing of orchardgrass. The appropriate and

theoretical harvest schedules for the pure stand of this grass were selected to be used in a forage conservation programme.

II. Theoretical Procedures and Experiment Method

1. Theoretical procedures

Total yield equation of Chang (1971) and Chang and Yoshida (1973) was fitted by a modification of the general procedure. The Chang's total yield equation fitted was

$$Y = \frac{T}{t}\int_0^t g'(t)\,dt \quad \cdots\cdots\cdots (1)$$

where Y, T, t and g'(t) are total yield, the period of the growing season, cutting time and the weighted growth rate equation, respectively. It is required to find the equation of g'(t) which is

$$g'(t) = w' = \frac{Wake^{-kt}}{(1 + ae^{-kt})^2} \cdots\cdots\cdots (2)$$

$$\text{or} \quad g'(t) = -at^2 + bt + c \cdots\cdots\cdots (3)$$

Integration of the equation (1) is given as follows;

$$Y = \frac{T}{t}\left| g(t) \right|_0^t \cdots\cdots\cdots (4)$$

where g(t) is the weighted growth equation. It is required to find the equation of g(t) which is weighted logistic equation (Robertson, 1907) or cubic regression curve of statistical growth equation;

$$w = \frac{W}{1 + ae^{-kt}} \cdots\cdots\cdots (5)$$

$$\text{and} \quad w' = \frac{Wake^{-kt}}{(1 + ae^{-kt})^2} \cdots\cdots\cdots (6)$$

$$\text{or} \quad w = -at^3 + bt^2 + ct + d \quad \cdots\cdots (7)$$

$$\text{and} \quad w' = -3at^2 + 2bt + c \quad \cdots\cdots (8)$$

The equations(6) or (8) are substituted for g'(t) in the total yield equation;

$$Y = \frac{T}{t}\int_o^t \frac{WaKe^{-kt}}{(1 + ae^{-kt})^2}\,dt \cdots\cdots (9)$$

$$Y = \frac{T}{t}\int_o^t (-3at^2 + 2bt + c)\,dt \quad \cdots (10)$$

From the equations(9) and (10), the cutting time for maximum total yield can be calculated. When the $\frac{dY}{dt}$ equals zero, t is the maximum harvest time.

Therefore, the cutting time (t_c) for maximum total yield can be expressed by the time (t_m) of the maximum growth rate

$$t_c = \frac{3}{2} t_m \quad \cdots\cdots\cdots (11)$$

In this investigations, the cutting time for maximum total yield is estimated by comparing with ceiling LAI.

2. Experimental method

A split-plot arrangement of treatments in a randomized complete block design with 4 replications was selected. The plots were composed of pure sowings of orchardgrass. Subplot treatments, measuring 2.5x5.0m were used for two harvest schedules. One appropriate harvest schedule based on growth analyses of the grass and the other was carried out asymptotic stage of the weighted growth.

Pure stands of orchardgrass were established in Mar. 25, 1981, without a companion crop on a medium textured, well-drained, neutral soil.

Prior to establishment, fertilizer 5-5-5 at the rate of 1kg/10a was worked into the soil. An additional rate of 1kg/10a of fertilizer 5-0-5 was

broadcasted on the area after each cutting.

Calender dates for maximum yield in this experiment were May 29, July 2, July 23, and Sep. 10, 1981 and cutting dates or an asymptotic stage of the weighted growth were June 5, July 16, and Sep. 10, respectively.

DM yields were estimated from the weight of a swath cut lengthwise through each plot at a height of 5 cm. Random samples were removed from each swath, dried in a forced-draft oven at 80°C and used to correct for moisture and for IVD and CP analysis. After drying, the samples were ground through a 0.8mm screen in a mill and analysed for IVD and CP, using the procedures described by Mowat et al. (1965).

III. Results and Discussion

1. Relationship among t_m, t_c and time of ceiling LAI

Weighted growth, changes of LAI and the growth rate of orchardgrass were shown in Fig. 1. According to the results of the growth analyses, t_m was determined by the peak value of the growth rate and by half of asymptotic value of growth. The cutting time for the maximum DM yield was calculated by the equation (11). Application of t_c in the grassland must be based on the morphological character of the orchardgrass at this time. However, post-elongation, head-emerged and bloom stages can not be applied to the orchardgrass, because this grass after the 1st cutting do not bloom. Application of t_c = 3/2 t_m was realized by a modification of the relationship among t_m, t_c and the threshold time of ceiling LAI.

This result suggests that application of t_c = 3/2 t_m was realized by a modification of the relationship among t_m, t_c and the threshold

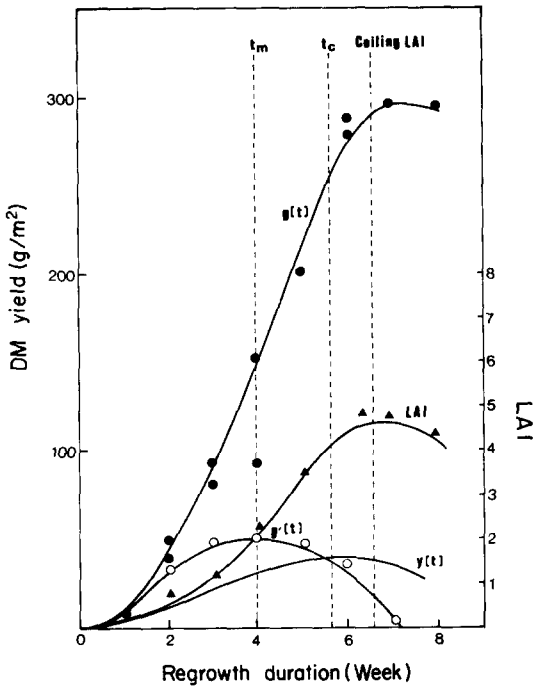

Fig. 1. Relationship among standing crop g(t), productivity g'(t) and total yield Y(t) and LAI, and stages of the maximum productivity (t_m) and of the maximum total yield (t_c).

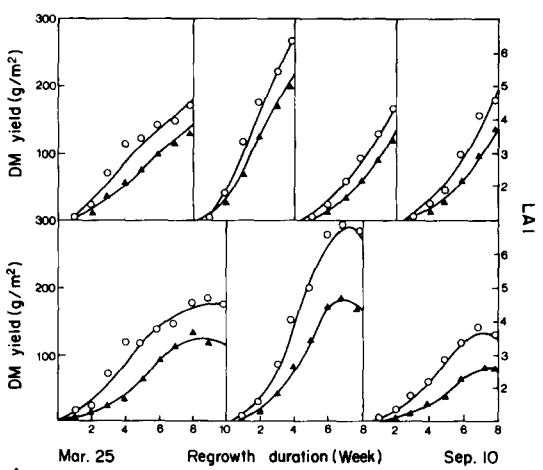

Fig. 2. The growth and regrowth curves of DM yield and LAI of orchardgrass swards during the growing season.

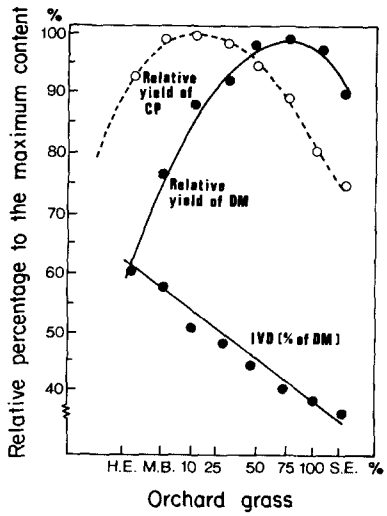

Fig. 3. Cutting time for the maximum yield of CP and DM yield of orchardgrass under H.E. = heads-emerged, M.B.=medium bud, 10%, 25%, 50%, 75%, 100% bloom and S.E.= seed formation stages.

time of ceiling LAI.

Mitamura (1972) reported that the harvest time for the maximum total yield could be estimated at the asymptotic stage of ceiling LAI. Watanabe (1973) reported that the suitable cutting stage in spring and summer can be estimated at the maximum stage of yield growth rate by means of the measurement of plant height, LAI and incident light. From the result of this study, it may be concluded that the harvest time for the maximum total yield of orchardgrass swards in the growing season is the threshold time of ceiling LAI.

2. Growth and regrowth pattern

The results of the growth in spring and the regrowth of the 1st-3rd harvest sward are shown in Fig. 2. In spring and summer, the changes of DM yields of above ground parts and LAI followed well the sigmoid patterns. As shown in Fig. 1 and 2, the growth and regrowth rates were initially slow, and began to increase gradually and reached a maximum. Therefore, the LAI curve instead of DM yield could be applied as a visibly representative index of morphological characteristic of orchardgrass to determine the harvest time for the maximum total yield of DM.

According to Mitamura (1971), the harvest time of orchardgrass sward is the ceiling LAI stage. In this study, cutting schedule based on Chang's total yield equation (1) was selected as criterion which provided the highest DM yield in conjunction with the threshold ceiling LAI based on morphological development of orchardgrass swards.

3. Quality of orchardgrass

The date of cut strongly influenced the DM yield and IVD of orchardgrass (Fig. 3). The later the cutting time is, the lower the digestibility of the material is. The highest values of IVD, 60-62%, were obtained from the 1st harvest of orchardgrass swards, when the harvest schedule of the head-emerged stage was employed. In general, the stages of the medium bud, 10–100% bloom and seed formation tended to have an IVD below that of the head -emerged stage.

The cutting time for the maximum CP yield was head-emerged stage and that for the maximum DM yield was 10% bloom stage. Therefore, to increase the weighted average IVD and to produce the maximum total yield of DM during the growing season, we must determine the harvest time from head-emerged stage to 10% bloom stage. The 10% bloom stage resulted in the highest weighted average CP% and the maximum total yield of DM.

Although any harvest schedule for a species of orchardgrass swards should insure a high yield of DM, factors such as the quality of the DM and the persistence of the species are important in the final assessment of the value of the schedule in a forage conservation programme. Because of the limited capacity of the rumen for ingestion of DM (morrison, 1961), contents of digestible DM and CP must be basic requisites of forage quality. A weighted average content of IVD and CP has been suggested as a criterion for evaluating the consistancy of production of feed over a growing season. The number of harvests per growing season and the date of the last harvest should be considered from the standpoint of persistence (Kurst and Smith, 1961; Twamley, 1960) and weather conditions which are conductive to conservation. With these factors in mind an attempt was made to select the best criterion for scheduling the harvesting of each species.

Ⅳ. 摘　　要

Orchardgrass 單播草地의 最高総生産収量과 質的向上을 위한 収穫適期를 張(1971)의 総生産収量式에 의하여 理論的으로 分析 研究하였다.

Orchardgrass草地의 形態学的 特徵으로 0 % 開花期에 牧穫하는 것이 IDV와 CP의 높은 水準과 함께 最大乾物生産量을 達成할 수 있다는 것으로 判斷되었다. 그러나 orchardgrass는 1次刈取後에는 開花하지 않기 때문에 그 以後에는 極大値의 閾値期로 代置할수 있다고 判定되었다.

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