"Effect of nitrogen fertilization on the crude protein and total carbohydrates yields of 6 Orchardgrass varieties."

By

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Orchardgrass (*Dactylis glomerata* L.) is grown throughout Hokkaido as pasture and hay grass. Information about the effects of N fertilization and cutting management on dry matter, crude prtein and total carbohydrates content in leaf bases of orchardgrass varieties is necessary for it's management, especially with reference to crude protein and TAC (total available carbohydrates) content. The effect of nitrogen fertilizer on yields and protein production (1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 19, 20, 22) and on carbohydrates (3, 10, 18, 21) had been studied by many investigators. The review of recent literature reported that, in general increase in yield have been accompanied by increases in the percentage of crude protein forage and increasing level of N fertilization generally results in a reduction in carbohydrate level in the storage organs.

Holmes (14) have shown that the response to N in dry matter yield is almost linear over the range 0−300kg N/ha, where the N is applied at intervals during the season and that the response is still substantial up to at least 400 kg N/ha (4, 15).

According to Donohue *et al.* (7), dry matter yield was increased up to 336kg/ha of applied N. At the higher N rates, yields leveled off or declined, apparently due to stand reduction by nitrogen. Fertilization also increases total N content of orchardgrass. Mortenson (16) noted the efficiency of N fertilizer in crude protein production was constant, regardless of N rate or cutting frequency, and yield response was almost linear up to about the 300 pound N level with 5 cuttings and up to the 200 pound N level with 3 cuttings. The percent of cude protein in the forage was directly related to N rate.

Willhite, Rouse and Miller (22) studied the effects of N fertilization on crude protein production of grass meadows, and observed that 179kg/ha or more of N was necessary for significant increase of crude protein production in the year N was applied. Crude protein/ha was increased by increasing N rates to 717kg/ha.

Scholl, McIntosh and Fredrick (17) applied N as ammonium nitrate to orchardgrass at the rate of 0, 45, and 90kg/ha of N the first year of a 2−year study, then orchardgrass yields incresed signficantly with each added increment of N. The highest nitrogen content obtained at the first cutting and nitrogen content of the forage increased with increasing rates of N and was greater in the second harvest than the first.

Dotzenko (12) evaluated 5 orchardgrass varieties in Colorado. Results indicated forage yield were closely associated with the amount of N applied, with most variety showing increased yield of the higher rates of N with early maturing varieties (19).

Davis (6) evaluated yield and protein content of 40 orchardgrass varieties in British Columbia. He found that medium-maturing varieties had the highest protein production and dry matter yield per acre.

Burton and DeVane (2) applied nitrogen from 4 sources at the rate of 50, 100, 200, and 400 pounds of N per acre, to coastal burmudagrass. Crude protein content was increased from 7% in unfertilized hay to 13% by appling 400 pounds of N annually.

The N content of the herbage is negatively correlated with duration of growing (20) and positively correlated with the level of N applied.

Griffith *et al.* (11) reported that TAC levels were reduced by increased increment of applied fertilizer N. Colby *et al.* (3) showed at the initial harvest highly significant reductions in TAC were produced by high levels of N and by early cuttings. At the high levels of N fertilization quite the opposite was true for the application of N consistently lowered the levels of TAC. White *et al.* (21) noted that the TNC (total nonstructural carbohydrates)level of clipped plants at all sampling dates was less than that of unclipped, and the seasonal variation of TNC, however, was similar for both treatment. The TNC of clipped plants decreased to a low of 9% on July 10, which was 12 days earier than the lowest TNC level in unclipped plants. The TNC of clipped plants increased similarly to unclipped plants after July 22. The TNC level of clipped plants on all N treatment decreased following autumn growth. The decrease of TNC was greater in plant not fertilized or fertilized with 70kg of N than in plants fertilized with 140kg of N.

Sullivan (18) showed the production of the aftermath of orchardgrass was not dependent on the carbohydrates content of the leaf base. Nitrogen fertility has long been known to stimulate growth which is accompanied by a reduction in carbohydrates (10).

The object of this investigation was to evaluate the response of 6 orchardgrass varieties grown under different cutting systems and different nitrogen fertilizer levels with respect to yields, crude protein and TAC content under environmental conditions of Hokkaido.

Material and Methods

The present experiment was conducted basing on the materials of the previous experiment by Abe and Gotoh (1) in 1970.

The 6 orchardgrass varieties used in previous study were Kitamidori, Latar, Masshardy, Pennlate, Phyllox and Potomac. Ammonium sulfate at the rate of 20, 40, 80, 160, and 320kg/ha/yr were applied in three equal doses. In hay type management, just before growth in the spring and immediately after the first and the second harvests the fertilizers were applied. The first application was made in early spring with subsequent application immediately after second and fourth cutting in pasture type management. The cuttings were made with respect to optimum yiled and quality. A uniform application of 240kg P/ha and 200kg K/ha were made at the time of N application.

In the 2 cuttings treatment, the first cutting (2−Ⅰ) was made for early heading varieties on June 5, and for late varieties on June 11 and the second cutting (2－II) was on Aug. 27 in all varieties. Dates for 4 cuttings treatment were on May 25 (4－ I), July 6 (4－II), Aug. 6(4－III) and Sept. 28(4－IV), in 1970.

These samples were taken approximately 5cm above the ground level including leaf and stem tissue. After recording the fresh weight, the samples were dried to constant weight in a forced air oven at 80°C for 48hrs. Then they were finely grinded and sealed in plastic bottles and stored at room temperature. Total carbohydrate content was measured by the Shaeffer-Somogyi tiltration method and results were reported as a mg/g of dry weight using a glucose standard. TAC yield was calculated by TAC content mg/g x dry matter yield. Samples were also analyzed for N by the semi-micro Kjeldahl procedure from which crude protein was calculated (% total N x 6.25=% crude protein) and crude protein yield was calculated by crude protein content % x dry matter yield.

Results and discussion

The average yields of the 6 orchardgrass varieties under different N levels and cutting frequency are shown in Fig. 1.

In the previous experiment, there were significant differences for fertillizer, varieties, cutting frequencies and interactions of N x cutting and variety x cutting, while those of N x variety was not significant.

1. Dry matter yield.

The response curves of yields were almost similar with two cutting systems. In 2 cuttings with maximum N dose (320kg/ha), it seemed to have reached the highest value, but in 4 cuttings there was linear relationship up to 320kg/ha. The mean yield of 6 varieties, however, increased by 22kg DM/kg N under 4 cuttings and 27kg DM/kg N under 2 cuttings, respectively (Fig. 1). These results were in agreement with the conclusions obtained before (5, 13).

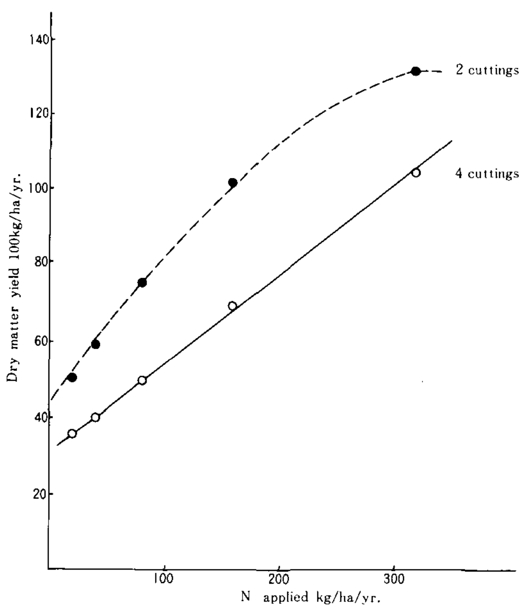

Fig. 1. Effect of N rate and cutting frequency on the dry matter yield of 6 orchardgrass varieties. (Abe & Gotoh, 1975)

2. Crude protein content.

Average contents of crude protein for N fertilization and cutting frequencies are given in Fig. 2.

The crude protein content of orchardgrass ranged from 13.1% to 21.2% for 4－ I , from 8.7% to 11.8% for 4－II,

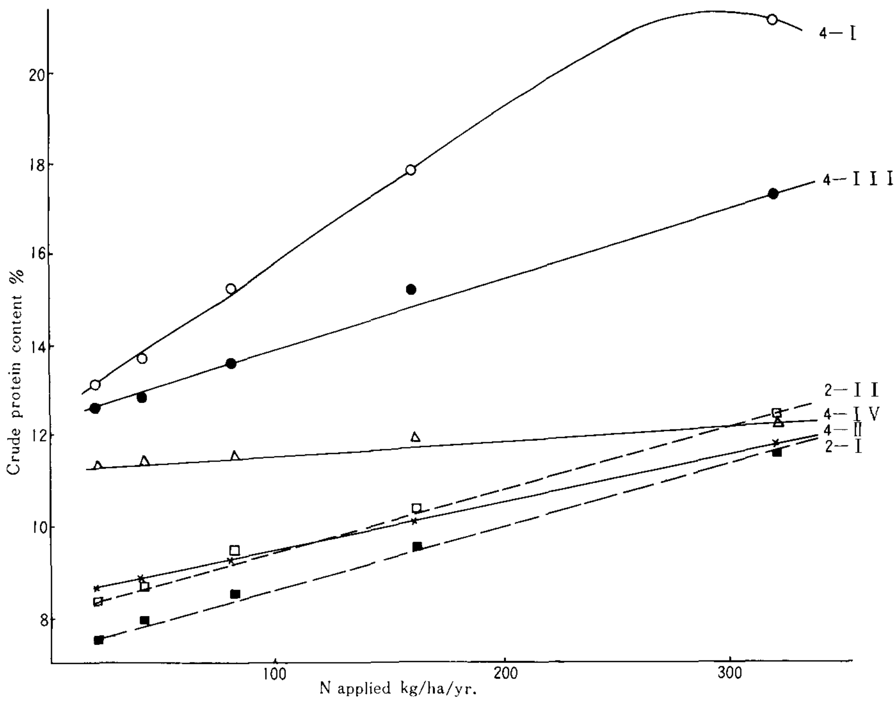

Fig. 2. Effect of N rate and cutting frequecy on the crude protein content of 6 orchardgrass varieties. (N was applied before the cutting of 2-I, 2-II, 4-I and, 4-III)

from 12.7% to 17.4% for 4—III, and from 11.4% to 12.3% for 4—IV in 4 cuttings and from 7.6% to 11.8% for 2—I, from 8.4% to 12.3% for 2—II in 2 cuttings, respectively.

Maximum content of crude protein (4—1) as obtained at the 320kg N/ha level. The crude protein content of orchardgrass increased with increasing rates of N and was greater in 4 cuttings than 2 cuttings.

The total nitrogen absorbed from the soil was translocated to the leaves for metabolism. But at the time of first cutting, the nitrogen in the leaves, perhaps was not greatly translocated to other plant parts. While, late on during subsequent cuttings, the nitrogen from the leaves might have translocated to other parts, so there were higher percentage of nitrogen in the leaves during first cutting than the subsequent ones.

In 4 —II, no nitrogen was applied before cutting, while in 4 — I nitrogen was applied before cutting. So, the crude protein content was higher in 4— I.

In 2 cuttings the time interval was long, so the crude protein content was lower (20).

The content of crude protein in 4—III was increased in 4 cuttings by additional N application before cutting. The trend of crude protein content in 4—IV was almost constant under all N levels, but was still better than the crude protein content of 2 cuttings. The reason for this low crude protein in 4—IV may be orchardgrass plants utilized only the residual effect of N, as there was no nitrogen application before cutting.

3. Crude protein yield.

The efficiency of N fertilization on crude protein yield and dry matter yield was practically the same with both cutting frequencies, as shown in Figure 3.

Moreover, the linear relationship between N applied and crude protein yield indicated that there was no decrease in efficiency of crude protein yield up to the highest rate of N applied.

The yield of crude protein shows a close relation with the amount of N fertilizer applied as all varieties showed marked increase in yield with increased rates of fertilizer. All the varieties of 4 cuttings showed only slight increase in crude protein yield from 20kg to 160kg N level. Especially, significant differences were found among the 6 orchardgrass varieties in the crude protein yield.

The high production of crude prtein by the Potomac and Kitamidori varieties can be attributed in part, for their early maturing habit. Early maturing varieties showed high yields in this experiment. But, the Phyllox variety yielded the lowest crude protein through the cutting frequencies.

The crude protein yield and dry matter of Latar variety was high with 2 cuttings, but it was low with 4 cuttings. The reason for this may be that the growth capacity after cutting was poor. In contrast, the yield was more with 2 cuttings than with 4 cuttings in Masshardy. The crude protein yield with 2 cuttings was more than 4 cuttings up to 320kg N level. So the lesser the number of cuttings, the more the crude protein yield. But the mode of curve indicated that 2 cuttings had almost reached the limiting (critical) level at 320kg N/ha, while 4 cuttings showed almost linear tendency even up to 320kg N level.

The regrowth time between cuttings was longer in case of 2 cuttings than that in 4 cuttings. So the varieties could get more time for utilizing the N from soil, so 2 cuttings yielded more. Average of crude protein yield was increased by 2.93kg per kg N under 4 cuttings and 3.03kg per kg N under 2 cuttings. These results suggested that the less frequent harvest improved the efficiency of N in terms of dry matter production but had negligible effect on crude protein yield (16).

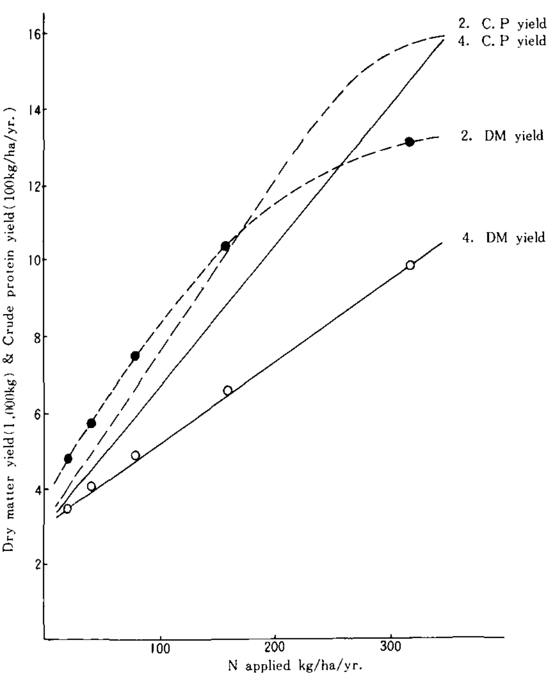

Fig. 3. The relationships between crude protein yield and dry matter yield under different N fertilization.

4. TAC content

The extent to which the increased rate of N application affected the TAC content in orchardgrass in the 2 and 4 cuttings is shown in Figure 4.

Generally, at high level of N fertilization consistently lowered the content of TAC. In this experiment, the TAC content of the orchardgrass under a low level of N during the growth seasons was exellent with a negative relationship. The reasons may be the high internal N provided a ready supply of organic N for leaf growth and axillary bud development. Concurrently, the high amounts of N would provide a sparing effect on the low content of carbohydrates. Especially, at the initial there was highly significant reduction in TAC content at high levels of N and early cutting.

The reducing rates were from 97.5 mg to 78.7mg/g in 2 cuttings and 90.2mg to 59.5mg/g in 4 cuttings by the increments of N applied from 20kg to 320kg/ha N in first cutting, than during other cutting frequency. But, the TAC content of the leaves of 4－II increased slightly during the growth period from May 25 to July 6. The highest content of this cutting, was 87.5mg/g around 160kg N level. The reason for this may be the increasing of regrowth period (cutted 40 days later), especially after the first cutting, and it should provide a favorable effect on increasing of the content of TAC. But the 2－II and 4－III had reduced TAC content from 81.7mg to 76.1mg/g and 76.3mg to 72.8mg per g, respectively, by increase of N fertilizer. It may be postulated that there is generally an inverse relationship between additional fertilization and reserve total carbohydrate content of leaves in orchardgrass.

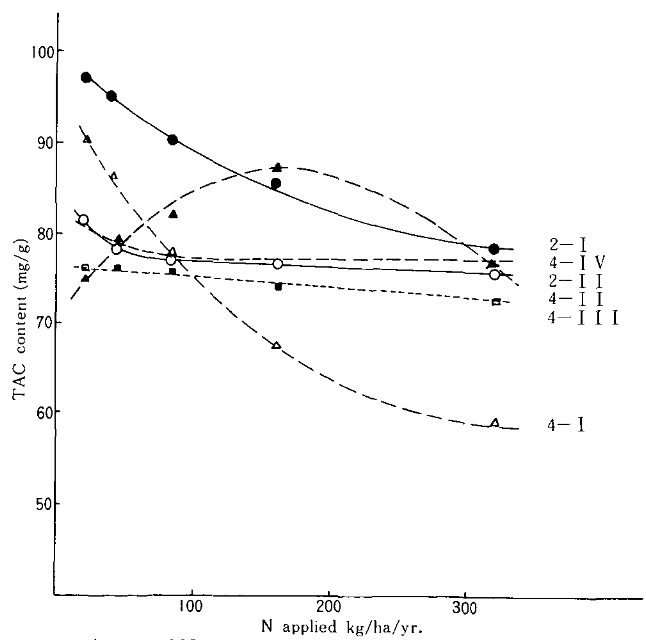

Fig. 4. Effect of N rate and cutting frequency on the TAC content.

5. TAC yield.

TAC yield responds positivety to the N applied, as shown in Figure 5. The peak had reached around 280kg N level per hectar with 2 cuttings but 4 cuttings showed a linear trend even up to 320kg N level.

TAC was produced by 2.99kg per kg N under 2 cuttings, whereas 1.90kg per kg N under 4 cuttings. The trends of response curve of N applied with protein yield and TAC yield were similar (Fig. 5).

There was significant positive correlation between TAC yield of first cutting and dry matter yield of second cutting from 2 cuttings r = 0.9390* ($p<0.05$) and TAC yield of the second and dry matter yield of the third cutting from 4 cuttings, r = 0.9735** ($P<0.01$).

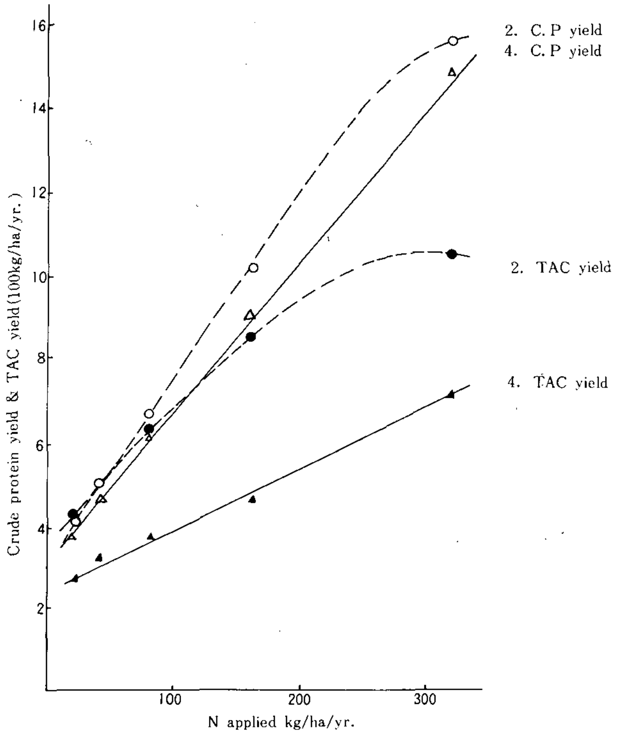

Fig. 5. Effect of N rate and cutting frequency on the crude protein yield and TAC yield in 6 orchardgrass varieties.

Additional N fertilizer was applied after first cutting in 2 cuttings, and after second cutting in 4 cuttings. Thus, the increased amount of TAC may stimulate the N availability.

Such correlation value was not significant for first cutting in 4 cuttings, even though the "r" value (r=0.8464) was high. The early and late blooming habit of varieties may influence the final result. Also, such correlation value was not significant for third cutting, even though the "r" value (r=0.8711) was high.

Summary

This study was conducted basing on the materials of the previous experiment by Abe and Gotoh in 1970.

Samples were taken from these materials and analyzed for crude protein and TAC content in 1975.

The results are summarized as follows :

1. The crude protein contents of all varieties were increased by increment of N fertilization in both cutting frequencies.

2. The crude protein yield of 2 cuttings had almost reached the limiting(critical) level at 320 kg N level, and 4 cuttings showed linear tendency even up 320kg N level. Average of crude protein yield was 3.03kg under 2 cuttings and 2.93kg under 4 cuttings per N kg, respectively. There was a significant difference in crude protein yield between orchardgrass varieties ($P<0.05$). The highest yield of crude protein was obtained in the Potomac variety.
3. TAC content was negatively related with N applied, but the TAC content of 4—II was slightly increased up to 160kg N level.
4. TAC yield showed significant positive correlation between N fertilization. The peak had reached around 280kg N level per hectar with 2 cuttings, but 4 cuttings showed linear response up to 320kg, directly. The production of TAC was 2.99kg under 2 cuttings and 1.90kg under 4 cuttings per kg N, respectively. There was signficant positive correlation between TAC yield of 2— I and dry matter yield of 2—II, and TAC yield of 4—II and dry matter yield of 4—III.

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Literature cited.

1. Abe, J., and Gotoh, K. (1975)
Response of orchadgrass varieties to nitrogen under different cutting systems. Res. Bull. 112, Hokkaido Natl. Agr. Exp. Stat : 175—182.
2. Burton, G. W., and DeVane, E. H. (1952)
Effect of rate method of applying different sources of nitrogen upon the yield and chemical composition of bermudagrass.
Agron. J. 44 : 128—132.
3. Colby, W. G., Mack, D., Field, D. L., and Kreowski (1965)
Seasonal pattern of fructosan in orchardgrass stubble as influenced by nitrogen and harvest management. Agron. J. 57 : 169—173.
4. The response of herbage yield and quality to a wide range of nitrogen application rates. Proc. 10th Int. Grassld. Congr., Helsinki (1966) pp. 209—213.
5. Davies, H., and Thomas, B. V., and Aldrich, D. T. A. (1966)
The effect of different levels of nitrogen fertilizer on the yields of varieties of perennial ryegrass and cocksfoot.
6. Davis, W. E. P. (1961)
An evaluation of varietal characteristics of orchardgrass subjected to a silage-pasture type vegetation.
Can. J. Plant Sci. 41 : 653—663.
7. Donohue, S. J., Rhykerd, C. L., Lolt, D. A., and Noller, C. H. (1973) Influence of N fertilization and N carryover on yield and N concentration of *Dactylis glomerata* L. Agron. J. 65 : 671—674.
8. Dotzenko, A. D. (1961)

Effect of different nitrogen levels on yield, total nitrogen content and nitrogen recovery of six grasses grown under irrigation.
Agron. J. 53 :131−133.

9. Frank, K. D., and John Pesek. (1973)
Influence of applied nitrogen on the performance of 23 orchardgrass varieties. Agron. J. 65 : 685−688.
10. Green, D. G., and Beard, J. B. (1969)
Seasonal relationships between nitrogen nutrition and solubble carbohydrates in the leaves of *Agrostis Palustris Huds.,* and *Poa Pratensis L.* Agron. J. 61 : 107−111.
11. Griffith, W. K., Tell, M. R., and Parker, H. E. (1964)
Influence of nitrogen and potassium on the yield and chemical composition of orchardgrass. Agron. J. 56 : 473−475.
12. Henderson, K. E., and Dotzenko, A. D. (1964)
Performance of five orchardgrass under different nitrogen treatment. Agron. J. 56 : 153−155.
13. Holmes, W., and Maclusky, D. S. (1955)
The intensive production of herbage for crop drying.
J. Agric. Sci. 46 : 267−286.
14. Holmes, W. (1968)
The use of nitrogen in the management of pasture for cattle.
Herbage Abstract. 8−4 : 265−277.
15. Inkson,R. H. E.,Stewart, A. B., Holmes, W., and Maclusky, D. S.(1961) The effects of fertilization herbage production.
I. The effects of nitrogen, phosphate and potash on yield.
J. Agric. Sci. Camb. 56 : 17−29.
16. Mortenson, W. P., Baker, A. S., and Dermanis, P. (1964)
Effects of cutting frequency of orchardgrass and nitrogen rate on yield plant nutrient composition and removal. Agron. J. 56 : 316−320.
17. Scholl, J. M., Meintosh, T. H., and Frederick, L. R. (1960)
Response of orchadgrass (*Dactylis glomerate* L.) to nitrogen fertilization and time of cutting. Agron. J. 52 : 587−589.
18. Sullivan, J. T., and Spraque, V. C. (1953)
Reserve carbohydrate in orchardgrass cut for hay.
Plant Physiology 28 : 304−313.
19. Sumio Kumai, Taturo Nomoto and Todai Nagasawa. (1968)
Study on the effect of orchardgrass on the yield and botanical composition under different management in intensive grassland. J. Japanese Soc. of Grassland Sci. 14−2 : 89−99.
20. Thomas, B., Thompson, Oyenuga, V. A., Armstrong, R. H. (1952)
The ash constituents of some herbage plants at different stages of maturity. Emp. J. Exp. Agric. 20 : 10−22.
21. White, L. M., Brown, J. H, and Cooper, C. S. (1972)
Nitrogen fertilization and clipping effects on green needgrass.
III. Carbohydrates reserves. Agron. J. 64 : 824−828.
22. Willite, F. M., Rouse, H. K., and Miller, D. E. (1954)
High altitude meadow in Colorado. III. The effect of nitrogen fertilization on crude protein. Agron. J. 47 : 117−121.