The Relation between Palatability and Chemical Composition of Herbages Cultivated in the Shading Condition

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Summary

This study was examined on the relation between palatability of shaded herbages and their chemical constituents, such as total nitrogen, true protein nitrogen, nitrate nitrogen, water soluble carbohydrate and total soluble carbohydrate. Palatability trials with 48 pairs of herbages, using sheep by a two-choice preference method, were carried out to compare differences between non-shaded and shaded herbages, differences among four herbage species and among herbages which were applied fertilizers with different levels of nitrogen and phosphorus and different forms of nitrogen during shading culture. The consumption rate of herbage by sheep was significantly lower (8.0–40.8%) on the herbage containing high concentration of nitrate nitrogen than that of low nitrate nitrogen in every type of experiment. Total nitrogen tended to show a negative relation to herbage consumption. On the other hand, water soluble carbohydrate and total soluble carbohydrate partly showed a positive relation to that value. It is thought that nitrate nitrogen should be the most important factor influencing on the palatability of shaded forage plants, presumably because of a defense of sheep against nitrate poison.

Introduction

According to the survey on the forest grazing by the Rinseisōgōkenkyūjo in 1976, about 55,000 beef cattle were reared on woodland pasture and the forests where the grazing is practiced went up to 100,000 hectare in Japan. Of these forests, 85,000 hectare, including 31,000 hectare of afforested land of Japanese cedar and Japanese cypress, consist of a stocked land[23]. The improvement of undergrowth by introducing the improved pasture to forest floor will be expected for intensive use of forests for grazing[9,22]. But, we have very little information, particularly on the utilization of improved pasture under middle-aged forest by grazing animals.

In a series of our study on the productivity and utilization of developed pasture under Japanese red pine forest[4,5,6,7,8], we have found that in the 20–25 year old red pines, herbages under ordinarily thinned woods were less acceptable for grazing cattle than that under 25 and 50% more heavily thinned woods[6], while in the 40–45 year old trees, even the herbages under ordinarily thinned woods were prefered very well. In other field experiments, it has been also shown that the palatability of herbages cultivated by shading treatment could be considerably varied by the application rates and the form of nitrogen fertilizer and by the species of herbages introduced[7,8].

The decrease of palatability of shaded herbages suppresses a voluntary intake and the utilization of woodland pasture by grazing animals, and it might cause a failure of farm management depending upon forest grazing. Martz et al.[14] mentioned that the chemical composition of forages should influence their palatability, and Heady[11] stated that the chemical composition was presumably the most important factor

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for the palatability of forages. This study was examined on a relation between the palatability of shaded herbages and their chemical constituents, such as total nitrogen (T–N), true protein nitrogen (TP–N), nitrate nitrogen (NO_3–N), water soluble carbohydrate (WSC) and total soluble carbohydrate (TSC).

Materials and Methods

Palatability trials, using sheep, with 48 pairs of herbages were conducted on plants with different experimental treatments and cutting time from April 1979 to June 1980. All combinations of palatability test are shown in **Table 1** and were characterized into three categories as follows; 1) Comparisons between non-shaded and shaded herbages (Exp. A), 2) Comparisons among herbage species; orchardgrass, meadow fescue, perennial ryegrass and tall fescue, in shaded culture (Exp. B) and 3) Comparisons among herbages (orchardgrass) which were applied fertilizers with different levels of nitrogen and phosphorus and different froms of nitrogen under shaded condition (Exp. C). Herbages were cultivated at Kawatabi farm of Tohoku University as described in detail in our previous papers[7,8]. The shading treatment, 50% omission of solar radiation, was carried out by covering the herbage plants with cheese-cloth in the field.

Palatability was examined by a two-choice preference method[10] of feeding test with six or seven sheep (Corriedal breed). Comparisons of palatability of each herbage pair were done from the standpoint of chemical compositions in herbage, i.e. herbages were classified into two (high or low) groups in respect

Table 1. All combinations of palatability trials with 48 pairs of herbage

Herbage and fertilization	Date				
Exp. A. Comparisons between herbage cultivated under 50% shading of solar radiation and the non-shading					
	1979				1980
Orchardgrass (*Dactylis glomerata* L.)	May. 11	Jul. 7	Aug. 28	Oct. 22	Jun. 5
Meadow fescue (*Festuca elatior* L.)					
Perennial ryegrass (*Lolium perenne* L.)			Aug. 28	Oct. 22	Jun. 5
Tall fescue (*Festuca arundinacea* SCHREB.)					
Exp. B. Comparisons among four herbage species cultivated under 50% shading of solar radiation					
	1979				1980
Orchardgrass vs. meadowfescue					
Orchargrass vs. perennial ryegrass					
Orchardgrass vs. tall fescue					
Meadow fescue vs. perennial ryegrass			Aug. 30	Oct. 23	Jun. 6
Meadow fescue vs. tall fescue					
Perennial ryegrass vs. tall fescue					
Exp. C. Comparisons among orchardgrass cultivated with the different amount or type of fertilizer under 50% shading of solar radiation					
	1979				
Levels of N and P ferfilizer (N-P-K)					
12-2-2 kg/10a vs. 2-2-2 kg/10a					
12-2-2 kg/10a vs. 4-2-2 kg/10a					
4-2-2 kg/10a vs. 2-2-2 kg/10a	May. 11	Jul. 7		Oct. 21	
4-6-2 kg/10a vs. 4-1-2 kg/10a					
4-6-2 kg/10a vs. 4-3-2 kg/10a					
4-2-2 kg/10a vs. 4-1-2 kg/10a					
Types of N fertilizer (4-2-2 kg/10a)					
Ammonium sulfate vs. Ammonium nitrate					
Ammonium sulfate vs. Urea		Jul. 3	Aug. 25		
Ammonium nitrate vs. Urea					

of chemical constituents such as T-N, TP-N, NO_3-N, WSC and TSC, and the mean values of herbage consumption by sheep were calculated in each group. Actual values were employed for calculating the mean consumption rate of herbage group when the differences in palatability between herbages were significant, but the theoretical value, 50%, was used when not significant[7,8].

Herbage samples were dried at 60°C for more than 18 hours and then ground with a Wiley mill. Samples were analyzed for T-N by the Kjeldal method, TP-N by the method of Warstein[24] and NO_3-N by the ion-selective electrode method[15]. Carbohydrates were extracted with water and 0.7N HCl, and analyzed by the Somogi method[20].

Results and Discussion

The mean consumption rates of herbage group which is high content of chemical constituents are shown in **Table 2**. The mean value of high T-N group was significantly lower (27.8%, $p<0.05$) than that of low T-N group in Exp. A, but not significant in both Exp. B and Exp. C. There were not differences between high and low TP-N herbage group on the mean value of consumption rate. On the other hand, the mean values of herbages containing high NO_3-N were significantly lower (8.0–40.8%, $p<0.10$) than those of low NO_3-N in all experiments.

Table 2. The relation between the palatability and several chemical constituents.

Chemical constituent	The consumption rate of herbage group high in each chemical constituent (%, Mean±S. D.)		
	Experiment A	Experiment B	Experiment C
Nitrogen			
Total nitrogen	27.8±36.4***	43.9±29.1	45.3±18.8
True protein nitrogen	44.1±43.4	50.6±35.2	52.9±19.2
Nitrate nitrogen	8.6± 7.2***	33.8±24.9***	40.8±17.1**
Soluble carbohydrate			
Water soluble carbohydrate	80.2±30.0***	39.6±27.8	55.1±18.7
Total soluble carbohydrate	92.0± 7.2***	39.6±27.8	61.9±15.3

a) *** and ** are significant at 5% and 10% level respectively.

The mean value of high WSC group was significantly high (80.2%, $p<0.05$) in Exp. A, but tended to be low (39.6%) in Exp. B. In Exp. C, there was not difference between herbages containing high and low WSC. The mean value of the high TSC groups appeared to be high in Exp. A (92.0%) and Exp. C (61.9%), but low in Exp. B (39.6%).

As shown in our previous papers[6,7], non-shaded herbages had always low NO_3-N content and high WSC and TSC content, and also were more acceptable than the shaded ones. That is to say, the result in Exp. A showed that the reduction of palatability of herbages cultivated under shading attributed to the decrease of soluble carbohydrates and the increase of nitrate nitrogen. In addition, T-N showed the negative relation to palatability. But, it is considered that T-N is not a conclusive factor to influence the palatability. That substance seem to be a factor to increase NO_3-N content in shaded herbages[13].

Of the comparisons among shaded herbages in Exp. B and C, only NO_3-N was related to the palatability. In general, WSC and TSC tended to give a similar effect on the consumption rate of herbages cultivated under shading. TSC was negatively related with the consumption rate of herbages in Exp. B, but positively in Exp. C. There are many evidences that soluble carbohydrates enhance the palatability of herbage[1,3,16,17]. Therefore, it is also likely that the correlation between soluble carbohydrates and palatability would be positive if the differences among herbage species were examined in many species, because the negative relation in Exp. B was considerably influenced by the low palatability

of tall fescue containing high soluble carbohydrates.

In addition to the above results, we often observed that the decrease of consumption rate did not result from less acceptability but refuasl by sheep wich rummaged in trough and finally left from it. For example, the high concentration of nitrate nitrogen seems to be the most important factor on the decrease of consumption rate, presumably because of the defending of animals against nitrate poison. Davison et al.[2] reported that alfalfa-timothy hay added 3.4% nitrate was unpalatable. Accordingly, the low acceptability of herbage introduced on the floor of the middle-aged Japanese red pine forest seems to be caused by nitrate accumulation in herbage due to the decrease of nitrate reduction[21] and protein synthesis activity by the shortage of solar radiation.

We will suggest that it is suitable to introduce low accumulate herbages of NO_3-N, such as orchardgrass and meadow fescue into woodland, and to apply ammonium nitrogen rather than urea or nitrate as a nitrogen fertilizer. Particularly, we will recommend to use such middle-aged woodland pasture in combination with tame or native grassland in order to offer various forage component for grazing cattle, since Satō et al.[18] and Toda et al.[19] reported that the shaded herbages were rich in crude protein, crude fat and crude ash, but poor in crude fiber and nitrogen free extract, and that those were unbalanced in mineral components such as extraordinarily high potassium content.

In the future, it is necessary to develop the thinning practice method as the light condition in woods is well kept for long time, since in 25 and 50% more heavily thinned Japanese red pine forest both the quality and quantity of herbage decrease soon after thinning owing to a rapid crown closing[5]. And also, it is needed to improve the application method of fertilizer which reflects upon the uptake and restoration by trees.

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要　　旨

庇蔭牧草の嗜好性と草中の化学成分含有率との関係について

後藤　正和・鵜田　英作・菅原　和夫

林内牧草の嗜好性低下と草中の化学成分（全窒素，蛋白態窒素，硝酸態窒素，水溶性炭水化物，熱0.7規定塩酸可溶炭水化物）との関係について検討した。すなわち，寒冷紗を用いた庇蔭下で圃場栽培した牧草について，施肥条件や牧草種の違いによる嗜好性差異，ならびに無庇蔭栽培のものとの嗜好性差異を調査して比較検討した。

庇蔭牧草の嗜好性低下は，硝酸態窒素含有量の増加と，可溶性炭水化物含有量の減少が関連しての現象と推察された。とくに，嗜好性試験中における緬羊の硝酸態窒素含有率の高い牧草に対する回避的行動から，硝酸態窒素の多量な集積が庇蔭牧草の嗜好性低下に関わる第一の要因と考えられた。また，全窒素との間にも負の関係がみられたが，この場合，全窒素は庇蔭牧草の嗜好性低下に関わる直接的要因としてよりも，むしろ草中の硝酸態窒素の集積に関連している要因であると考えられた。