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Studies on the Trace Elements in Soil-Plant-Animal System. 1. Trace Mineral Status in Kawatabi Farm.

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Summary

The status of trace minerals in soil, herbage and cattle blood was surveyed in Kawatabi farm of Tohoku University. Kawatabi soil was low in Cu and Zn. The mineral concentrations differed among herbage species such as orchard grass, red top and white clover, but Cu level was low in all herbage species. The legume is not always richer in Cu than grasses in this tame pasture. Compared with Japanese Feeding Standard, orchard grass and white clover did not satisfied minimum requirement in Cu content for either dairy or beef cattle. All of the herbage species satisfied Zn requirements for beef cattle but not for dairy cattle. Fe and Mn contents in all herbage species showed satisfactory levels for both cattles. The mineral concentrations in cattle blood, Holstein and Japanese Black breed, showed low levels of Cu, especially, during grazing period.

It is concluded that the grazing cattle in Kawatabi farm exhibit a subclinical Cu deficiency and that this is ascribed to low level of available Cu in soil.

Studies of the trace elements in soil-plant-animal relationships are important because of their implications for animal production, but we have very little information on them in Japan.

In recent years, a number of large improved grasslands have been established in Japan and most of the feeds for livestock are yielded by fields within the region. Consequently, the trace nutrition of the livestock has been directly affected by the regional mineral circumstances.

A large number of the improved grasslands in the Tohoku district are located in regions where Andosol originated from the acid volcanic ash which has poor contents of the trace elements such as Cu, Zn and Bo. Therefore, the surveying of trace element status of soil, herbage and livestock in these regions is needed in order to attain good production of livestock. This is a study of several trace elements in the relationship between soil, herbage and cattle at Kawatabi farm of

Tohoku University, which has been recognized as a Cu deficient region from earlier studies (1, 2).

Materials and Methods

This study was carried out in Kawatabi farm of Tohoku University from 9 May 1972 to 23 May 1973 and a total of 12 steers (six Japanese Blacks and six Holsteins) was used. Each of the two breeds were respectively divided into halves. One group (three Japanese Blacks and three Holsteins) was reared on the tame pasture in an arable area and another group on the native pasture at Katsurashimizu area during grazing period of 9 May through 14 November 1972. All cattle were fed with hay and concentrate in a barn except during the grazing period.

Blood samples were collected from all of the cattle once a month. Herbage and soil were collected from four points in the tame pasture, seven times for herbage and four times for soil, during the grazing period. Herbage samples such as orchard grass, red top and white clover were dried at 80°C overnight and then ground with a stainless steel mill. One gram of the milled samples was ashed with HNO_3 and $HCLO_4$ after pre-dry ashing at 450°C for four hours, and followed by HF treatment to remove silica. The residue was dissolved in a solution of 1 N hot HCL and filtered and washed to make it into a solution of 0.5 N HCL. 20 ml of blood samples was wet-ashed with HNO_3 and $HCLO_4$ on a hot plate and dissolved in 1:1 HCL and diluted to a solution of 1 N HCL. The minerals in soil were extracted with 0.1 N HCL for Zn, Fe and Mn, but with 1 N HCL for Cu because of content too low to be measured in extraction with 0.1 N HCL. The Cu, Zn, Fe, Ca and Mg concentration of blood, and Cu, Zn, Fe and Mn of herbage and soil were measured by atomic absorption spectrophotometer.

Results and Discussion

1. Minerals in soil

Table 1 shows the extractable Cu, Zn, Fe and Mn concentrations in soils which have been taken from 0 to 40 cm in depth. According to the mean mineral concentrations in the soils during grazing season, Cu and Mn accumulated in the surface horizon of 0–20 cm and decreased progressively with increase of the soil depth. A marked difference in Mn concentration between soil 0–20 and 20–40 cm in depth was noticed. Zn and Fe were widely distributed in soil from 0 to 40 cm in depth and appeared to be high in the upper part of the profile, in particular soil 10–20 cm in depth. But the concentration of Zn and Fe in each soil layer showed large standard deviations as compared with those of both Cu and Mn. Seasonal variations of mineral concentrations were investigated in surface soil 10 cm in depth. The Cu and Zn concentrations tended to increase from summer to autumn and Fe was high in spring. But the amount of variation was small in every element.

TABLE 1. *Concentrations of extractable trace elements of soil from tame pasture.*

(ppm)

Soil depth	Sampling time	Cu	Zn	Fe	Mn
0-10	May	1.52±0.28	2.42±0.67	4.07±0.48	89.4±12.1
	June	1.65±0.17	2.90±0.55	3.63±0.48	69.0±10.9
	August	1.61±0.14	4.41±1.54	3.26±0.98	77.2±20.2
	November	1.85±0.28	3.44±0.91	3.44±0.79	64.2± 6.7
	Mean*	1.61±0.13	3.20±0.99	3.69±1.38	66.6±10.7
10-20	Mean	1.62±0.11	5.00±2.39	4.13±1.92	63.1± 2.2
20-30	Mean	1.09±0.13	3.42±2.58	3.67±1.05	12.9± 3.6
30-40	Mean	1.06±0.07	2.61±1.31	3.52±1.14	10.1± 2.0
>40	Mean	1.23±0.03	1.97±0.44	3.31±2.89	6.7± 2.8

* Mean was calculated from the concentration in soils at four times of sampling, in May, June, August and November.

The extractable mineral concentrations in Kawatabi soil were about 1/10 in Cu and 1/8 in Zn of alluvial soil, 16.5 ppm in Cu and 24.7 ppm in Zn by the same measurement, which were taken from a paddy field in Minamikoizumi. Concentrations of Fe and Mn were similar in both soils. The shortage of Cu and Zn of Kawatabi soil was also noted.

Tsutsumi et al (2) proposed that the extractable Cu with 0.1 N HCL was suitable for available Cu in soils by use of Kawatabi soil, but Takahashi reported that the correlation between 0.1 N HCL soluble Cu in soil and Cu content of plants was not recognizable in the grassland soils in our country. The extractable Cu with 1 N HCL may or may not correspond to available Cu in soil. According to our preliminary experiment, the extractable Cu in soils with 1 N HCL was about eight times that with 0.1 N HCL, but the variation patterns of Cu extracted with two strengths of HCL solution resembled one another. In this experiment, Cu in soils have been measured in extracts with 1 N HCL because levels of the extractable Cu with 0.1 N HCL were too small for regular monitoring by the method of atomic absorption spectrophotometer.

2. *Minerals in plants*

The seasonal variation and means of mineral concentrations in herbage are exhibited in Fig. 1. The mean mineral concentrations differed distinctly among herbage species. Red top was the richest in most minerals except Zn of orchard grass, and it was especially rich in Mn. Orchard grass was superior to white clover in Cu, Zn and Mn contents. White clover was richer than orchard grass only in Fe. That is to say, the mean Cu contents were in the order red top>orchard grass>white clover, Zn; orchard grass>red top> white clover, Fe; red top> white

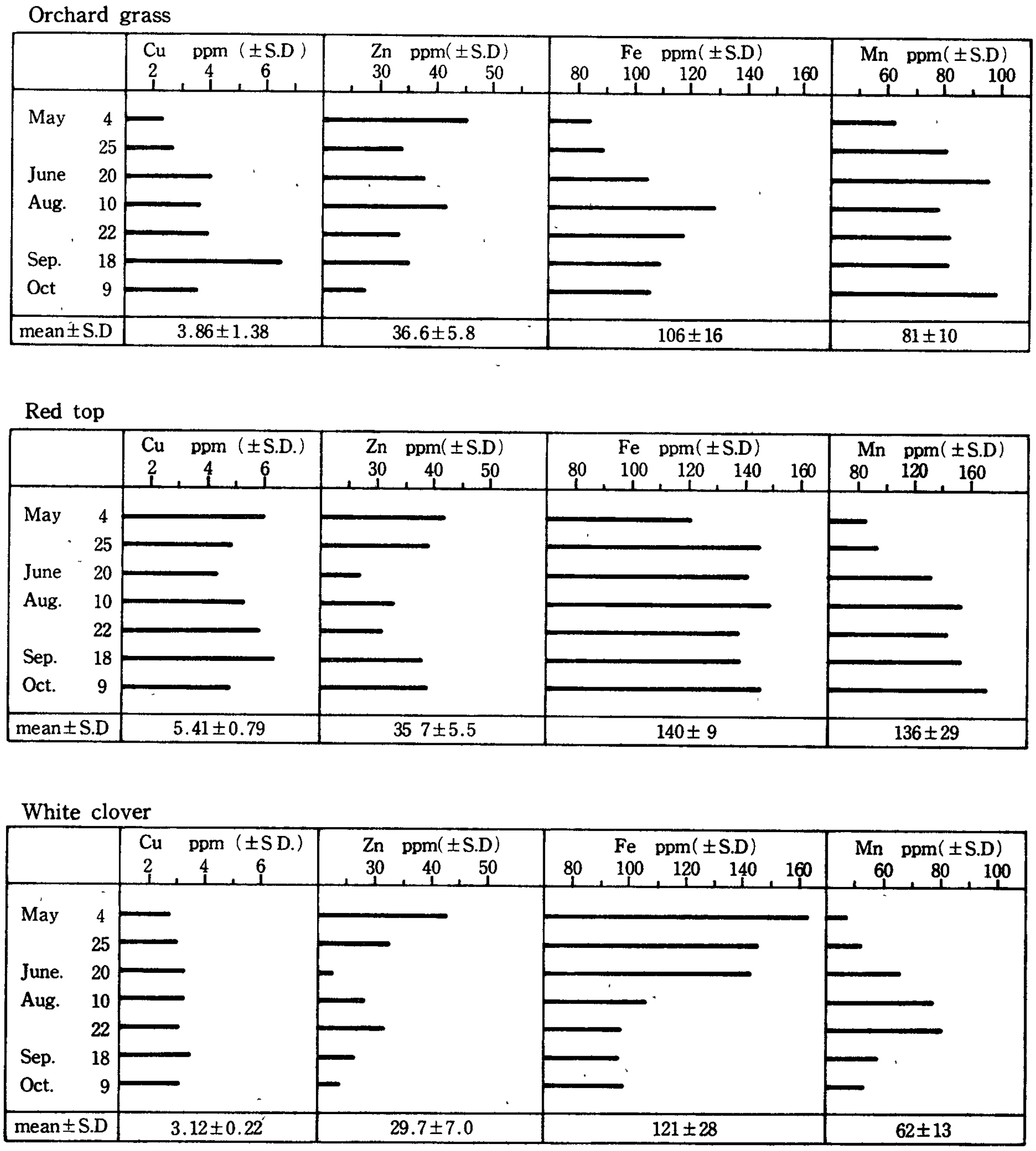

Fig. 1. Mineral concentrations of herbages in tame pasture.

clover >orchard grass and Mg; red top>orchard grass>white clover. The seasonal variations of mineral concentrations also showed a different pattern among herbage species. Cu concentration changed more in orchard grass than in both red top and white clover during grazing period and variation in white clover was very small. All herbages tended to accumulate Cu through summer into early autumn. Zn concentrations in both orchard grass and white clover were high in spring and decreased in autumn, but Zn in red top showed a lower level during summer than in both spring and autumn. The seasonal variation of Fe content was small in red top and large in both orchard grass and white clover. The highest Fe concentration in orchard grass was in summer and in white clover in spring. Mn concentrations in both orchard grass and red top were poor in spring and increased through summer into autumn, but that in white clover decreased again in autumn after attaining a high concentration in summer.

The mineral concentration of herbage in Kawatabi was significantly low in Cu and a similar level in the other three elements as compared with the mean mineral concentrations of herbages sampled from 76 tame grasslands in Japan by Takahashi (3). This low Cu content in herbage can be regarded as reflecting the poor available Cu in soil. But the seasonal variation of mineral concentration in herbage did not show similar pattern to that of extractable mineral concentration in soil because the mineral contents in plant tissue at each growth stage were primarily affected by seasonal production of herbage.

Legumes have been known to tend to be richer in Cu than grasses (4), but red top and orchard grass were richer in Cu than white clover in our investigation. This is similar to experiments which were carried out on soils of low levels of available Cu by Beck (5) and Forbes et al (6).

The minimum requirements given by Japanese Feeding Standard (7, 8) were 10 ppm for dairy cattle and 4 ppm for beef cattle in Cu, 40 and 10–30 ppm in Zn, 100 and 10 ppm in Fe, and 20 and 1–10 ppm in Mn, respectively. Comparing mineral contents of herbages in Kawatabi with Japanese Feeding Standard, the orchard grass and white clover did not satisfy the minimum requirements in Cu for either dairy or beef cattle. All of the herbage species satisfied Zn requirements for beef cattle but not always for dairy cattle. Fe and Mn in all herbage species were above the minimum requirement.

3. Minerals in blood of cattle

The mineral concentrations in blood were surveyed in cattle on both the tame and the native pasture about once a month during the experiment period. The data were divided into those of grazing period and housing period, and the means are shown in Table 2.

In the group of cattle on the tame pasture, the mean Cu concentration of blood was higher in housing period than in grazing period in both cattle breeds, and higher in Japanes Black breed than in Holstein breed through the experiment period. The Zn, on the contrary, was higher in the grazing period than in the housing period in both cattle breeds, and the differences between two cattle breeds were slight. Ca concentration was slightly higher in grazing period than in housing period and higher in Holstein breed than in Japanese Black breed. The Fe and Mg in blood did not show an obvious difference in concentration between housing and grazing period, but there is a little variation between the two cattle breeds. Fe concentration was higher in Japanese Black breed than in Holstein breed, and Mg was higher in Holstein breed than in Japanese Black breed.

In the group of cattle reared on the native pasture, the concentration of blood minerals was generally similar to that of cattle reared on the tame pasture. But there are some differences between cattle reared on the tame pasture and on the

TABLE 2. *Mineral concentrations in blood of cattles*

		Native pasture	
		Whole period	Grazing period
Cu	H	70±3	70±2
	J.B.	73±9	69±6
Zn	H	286± 76	310± 79
	J.B.	342±100	368±113
Fe	H	$31.9\pm3.0\times10^3$	$31.8\pm2.8\times10^3$
	J.B.	$33.7\pm4.3\times10^3$	$34.4\pm4.3\times10^3$
Ca	H	$65.8\pm5.4\times10^2$	$66.8\pm5.9\times10^2$
	J.B.	$61.0\pm6.8\times10^2$	$61.8\pm7.9\times10^2$
Mg	H	$26.4\pm4.6\times10^2$	$26.4\pm4.6\times10^2$
	J.B.	$25.6\pm5.9\times10^2$	$24.8\pm4.5\times10^2$

H: Holstein breed

native pasture. Cu concentration in blood of the Holstein breed on native pasture was kept on the same level as that of housing during grazing period, and Zn concentration of the Japanese Black breed was considerably richer than that of the Holstein breed throughout the experiment period.

Fig. 2 shows seasonal variation of Cu, Zn and Fe in blood of cattle reared on the tame pasture. Cu and Zn contents in blood showed a similar pattern of variation in both cattle breeds, such as high in Cu and Zn in spring and autumn and low in Cu in August and Zn in July. Fe showed low concentration in May and July and began increasing in autumn.

The seasonal variations of blood minerals in grazing cattle were not always parallel with that of minerals in herbages shown in Fig. 1. The poor concentration of blood minerals in summer seems to be due to other factors beside mineral contents of feeds, such as shortage of herbage intake and physiological response of animals to climate. The herbage intake of grazing cattle is very difficult to estimate and the establishment of a method of doing this will improve studies concerned with the grazing of domestic animals.

In the present study, Fig. 2 showed the seasonal variation of the mineral concentrations in whole blood. The mineral concentrations in blood serum which were determined in the same blood samples also showed a similar variation pattern to that of whole blood, although they were not shown in detail. The mean mineral concentrations in blood serum of grazing cattle in Kawatabi were as follows. On the tame pasture, Cu was 37±8 μg/dl in Holstein breed and 53±5 μg/dl in Japanese Black breed, Zn was 195±43 and 197±68, and Fe was 260±38 and 278±40, respectively. On the native pasture, Cu was 54±5 μg/dl in Holstein breed and 52±7 μg/dl in Japanese Black breed, Zn was 171±50 and 199±63, and Fe was 219±35 and 240±36, respectively.

reared on tame and native pasture. (μg per dl.)

	Tame pasture		
Housing period	Whole period	Grazing period	Housing period
69 ± 6 81 ± 9	54 ± 13 74 ± 9	47 ± 8 71 ± 7	69 ± 8 83 ± 5
232 ± 32 289 ± 44	312 ± 67 319 ± 72	323 ± 74 338 ± 82	288 ± 47 281 ± 26
$31.9\pm3.9\times10^3$ $32.2\pm5.0\times10^3$	$31.7\pm3.8\times10^3$ $35.4\pm4.0\times10^3$	$31.2\pm3.4\times10^3$ $34.4\pm3.8\times10^3$	$32.9\pm5.4\times10^3$ $37.7\pm4.1\times10^3$
$63.4\pm3.5\times10^2$ $59.5\pm3.7\times10^2$	$66.2\pm5.4\times10^2$ $63.4\pm6.1\times10^2$	$67.8\pm4.8\times10^2$ $64.5\pm6.7\times10^2$	$62.4\pm5.6\times10^2$ $60.9\pm4.2\times10^2$
$26.3\pm5.7\times10^2$ $27.6\pm9.2\times10^2$	$27.1\pm3.4\times10^2$ $25.5\pm4.5\times10^2$	$27.1\pm3.0\times10^2$ $24.9\pm3.4\times10^2$	$27.0\pm5.1\times10^2$ $26.8\pm7.2\times10^2$

J.B: Japanese Black breed

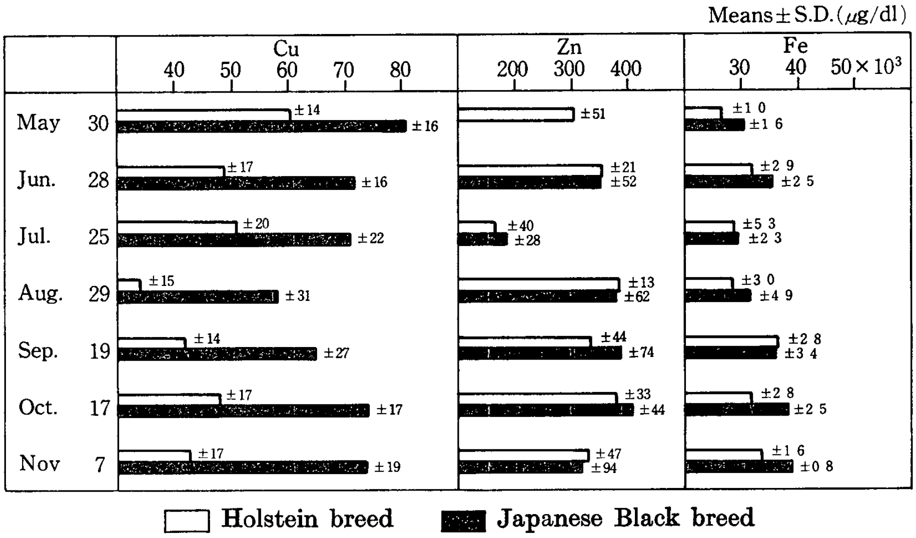

FIG. 2. Seasonal variation of mineral concentration in blood of cattle reared on tame pasture.

Ogura (9) has reported that the mean mineral cncentration of blood serum of grazing cattle was $68\pm11\sim83\pm20$ μg/dl in Cu, $83\pm12\sim121\pm22$ in Zn, and $201\pm38\sim235\pm30$ in Fe. Compared with these, our data suggest that the blood mineral content of cattle in Kawatabi was poor in Cu and rich in Zn. The low concentration of blood Cu was derived from Cu deficiency in soil of grazing fields in Kawatabi, but we could not explain why the Zn level of cattle blood in Kawatabi was high.

In this field experiment, the visible symptoms of Cu deficiency can not be identified in livestock. But the present study suggests that the grazing cattle in

Kawatabi farm exhibit subclinical Cu deficiency, although the production losses of livestock are not obvious, and that this is derived from poor Cu level of soil of grazing field. Additional tests are needed to confirm the influence of Cu deficiency of soil for grazing livestock in Kawatabi farm.

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