Effect of Irrigation on Pastures on Heavy Clay Soil in Hokkaido

By HIDENORI IWAMA*, JIRO WATANABE, and KAZUO OGAWA

Agricultural Chemistry Division, Hokkaido National Agricultural Experiment Station
(Komukai, Monbetsu, Hokkaido, 099-61 Japan)

Heavy clay soil with poor drainage and poor water retention capacity[2] is distributed on the coastal area of Hokkaido along the Sea of Okhotsk. The so-called heavy clay soils are classified into several soil types; mainly Pseudogley soil and Brown Forest soil, and others. They are distributed on the coastal terrace, reflecting differences of water environment due to micro-relief, and composing soil complex. The available moisture in these soils down to the depth of 50 cm from the surface is about 30–60 mm and the TRAM (total readily available moisture) is about 15–30 mm.

In this area dairy farming is undertaken because of the cool weather condition. In the spring–summer season, during which grasses require a plenty of water, there is scanty rainfall. The average rainfall in the period from May to August is about 380 mm with 14°C of average temperature. A long spell of dry weather more than 20 days occurs once in a year in an average between May and August, and that of 30 days once in 2 years. The grass production is unstable there, because pastures on the heavy clay soils are frequently damaged by the dry weather.

In recent years the rate of increasing pasture area has declined due to decreasing area of virgin land while the number of cows bred per hectare of pastures has increased. Intensive management of the pastures is needed for the development of dairy farming in this area.

Present address:
* Tropical Agriculture Research Center
(Yatabe, Ibaraki, 305 Japan)

Deep plowing or other subsoil improvement practiced to prevent water deficiency had shown to increase grass production by 10% in an average, and 20–30% at the maximum. However, these practices could not overcome water deficiency fundamentally.

We investigated the effect of irrigation on pastures on the heavy clay soil with the purpose of knowing a suitable amount of irrigation water for the grass production under the cool weather condition in northern Hokkaido.

Grass growth and soil water conditions[3]

By a pot culture experiment, growth of orchardgrass in the process of soil drying was studied to know the relation between soil water conditions and grass growth. It was observed that the orchardgrass stopped growing and relative turgidity of its leaves (RT) became below 90% when pF of soil moisture was increased to above 3.0 (Fig. 1). The grass kept RT higher than 90% at the condition under which it grew normally.

Observations in the field of Pseudogley soil showed that 15 days of continuous fine weather had elapsed before RT value of the grass lowered to below 90%. At this time, accumulated pan evaporation showed about 50 mm, pF value of the surface soil layer reached 4, readily available water in the soil layer down to 30 cm in depth from the surface had been used up thoroughly (Fig. 2). The soil moisture depletion has reached 40–50 mm, and this soil water depletion was approximately equal to the amount of accumulated

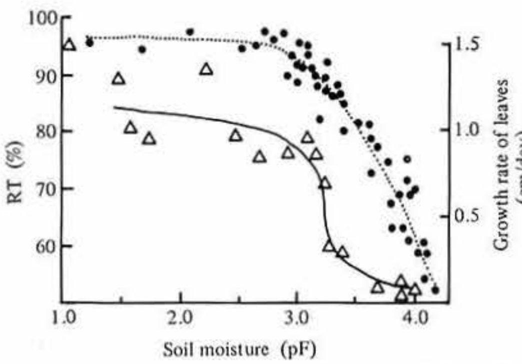

Fig. 1. Effect of soil moisture on RT and growth rate of orchardgrass leaves
● Rt, △ Growth rate

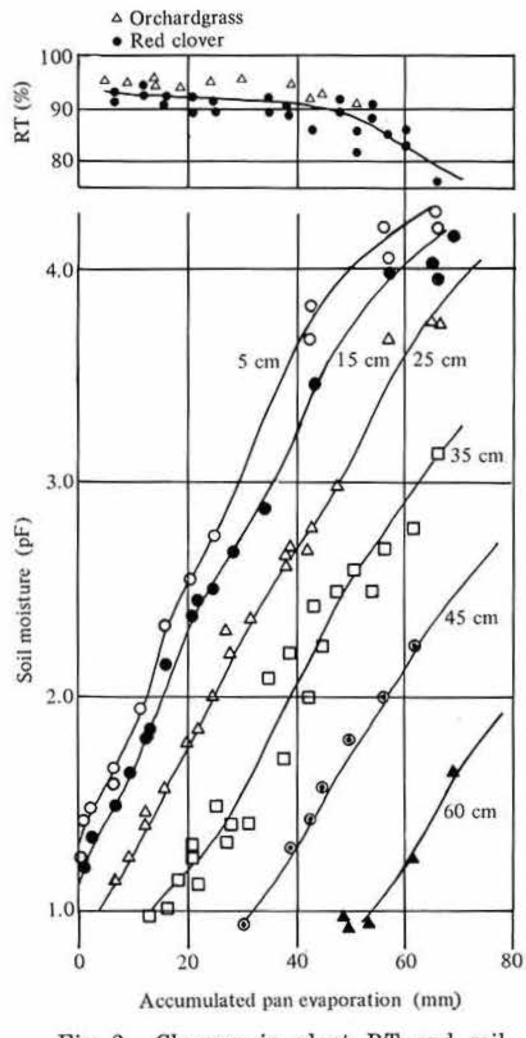

Fig. 2. Changes in plant RT and soil pF during the process of soil drying in a field of Pseudogley soil at Komukai

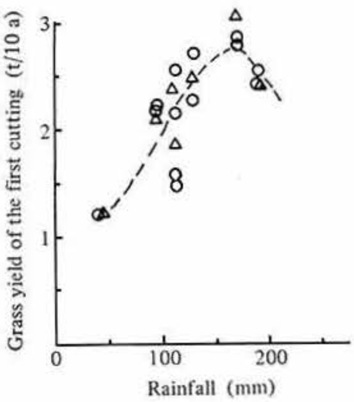

Fig. 3. Yield of the 1st cutting as related to rainfall during the growth period before the cutting in Komukai field (Pseudogley soil)
○ Sand dressing made in establishing grassland, △ No sand dressing

pan evaporation.

Fig. 3 shows one example of the relation between the grass yield and the amount of rainfall in the first regrowth period (ca. 50 days from May to June). It seems that about 150 mm of rainfall is optimum for the grass production during that period. The reason for the occurrence of the supraoptimal rainfall seems to be attributed to the fact that at the beginning of the regrowth, the soil is saturated with water by thawing snow in early spring every year. This optimum amount corresponds to the estimated amount of evapotranspiration in the regrowth period, i.e. 3 mm/day $\times$ 50 = 150 mm. It suggests that the good soil moisture condition for grass growth is near the field capacity, without water excess and minimum leaching loss of nutrients.

Reduction of grass yields observed on several main soils in a dry year is shown in Fig. 4. The first cutting yields were measured on 28 plots of an experimental field in Ohmu-cho in two years, i.e., a dry year 1980 and a wet year 1981. The rainfall and soil moisture conditions in the dry year (1980) are shown in Fig. 5.

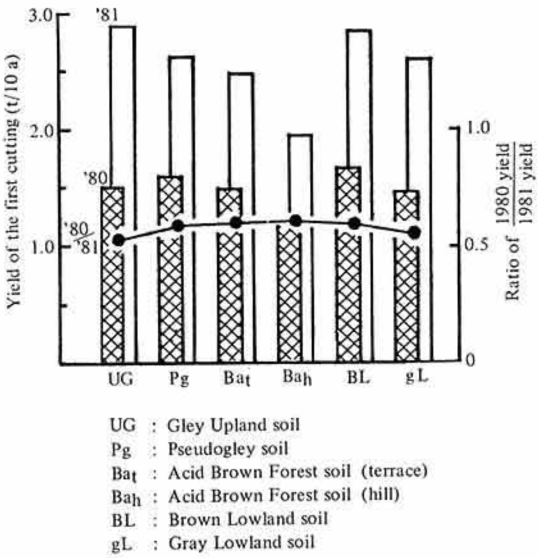

Fig. 4. Grass yields in a dry year (1980) and a wet year (1981) on 6 different soils (Ohmu-cho)

Great differences in grass yields were observed among different soils, because the grass yields were closely related to chemical and physical fertility of each soil. However, the most important point to be noticed is that the ratio of the grass yield in the dry year to the yield in the wet year is quite similar for all soils, irrespective of remarkable differences in water-holding capacity of these soils (Table 1). Particularly, Gley Upland soil has the greatest water-holding capacity due to its thick muck layers. Therefore, it seemed that the grasses on this soil might not be exposed to the same level of water deficit as occurred in other soils. But, the ratio of yield reduction was similar to that in other soils.

Then, what is the reason for this interesting phenomenon? In grasslands, particularly old ones, nutrients are present on soil surface due to surface application of fertilizers. These

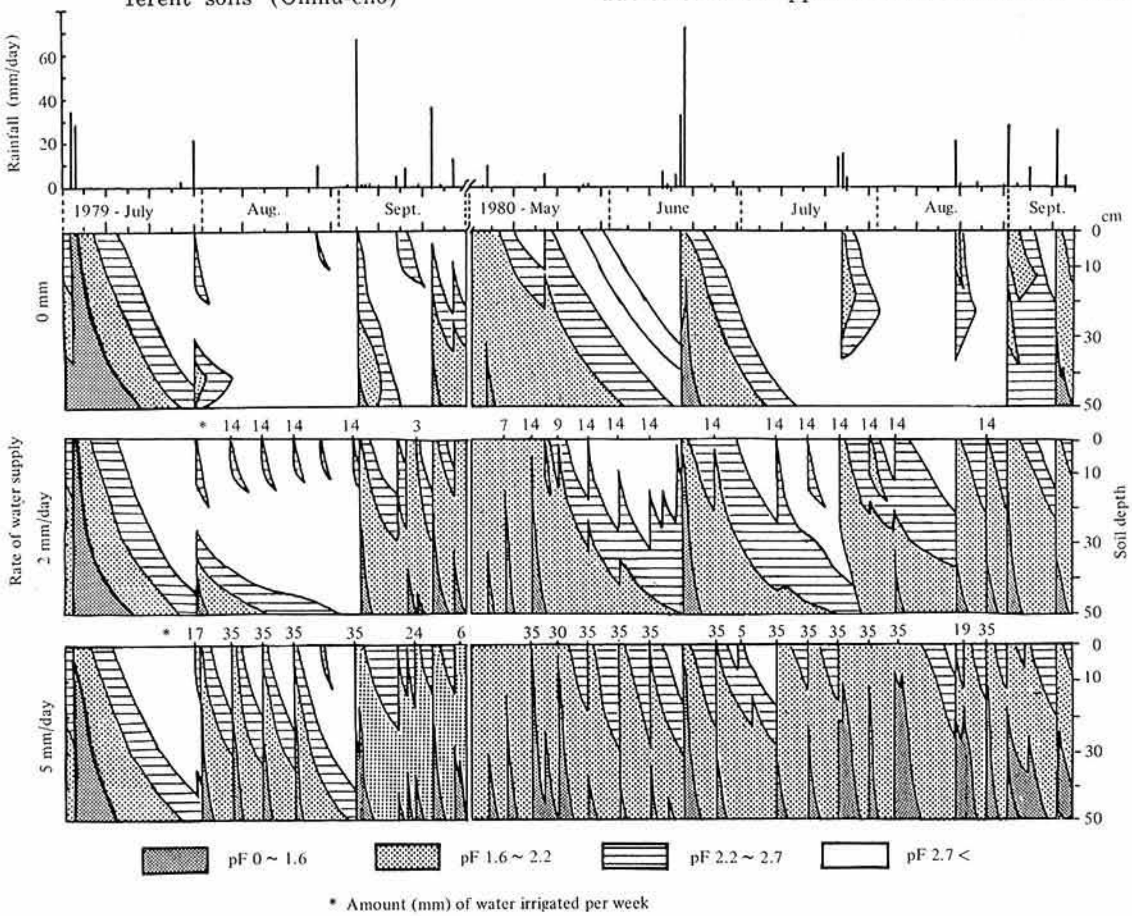

Fig. 5. Changes of soil moisture (pF) at different depth of soil in the plots of 0, 2 and 5 mm/day of water supply

Table 1. Available water content of main soils in Ohmu-cho

(mm/0∼50 cm, soil layer)

	Gley Upland soil	Pseudogley soil	Brown Forest soil (terrace)	Brown Forest soil (hill)	Brown Lowland soil	Gray Lowland soil
Readily avairable water (pF 1.5–3.0)	92	29	46	38	47	46
Total available water (pF 1.5–4.2)	172	84	92	75	93	82
Proportion of area distributed	9.4%	43.0%	18.3%	13.8%	11.5%	1.6%

Table 2. Chemical properties of Acid Brown Forest soil of Ohmu-cho

Layer	(depth cm)	Texture	T-C	T-N	C/N	pH (H_2O)	CEC	Exchangeable castion (me/100 g soil) K	Ca	Mg	Available P_2O_5 (Bray II) (mg/100 g soil)
Ap	(0∼20)	LiC	2.48	0.177	14.0	5.9	28.5	0.96	3.16	1.44	4.3
B_{21}	(20∼35)	HC	1.53	0.138	11.1	5.6	24.5	0.48	2.24	1.46	0.4
B_{22}	(35∼50)	HC	1.26	0.098	12.9	5.3	25.9	0.53	1.39	1.11	0.3
BC_1	(50∼80)	LiC	1.06	0.100	10.6	5.2	25.4	0.69	0.87	0.70	0.2
BC_2	(80∼95)	LiC	0.93	0.088	10.6	5.3	24.9	0.76	0.97	0.88	0.2

Table 3. Available water and TRAM of Acid Brown Forest soil of Ohmu-cho

Depth	Field capacity (pF value)	Available moisture (mm)	Soil moisture extraction pattern (%)	TRAM
0∼19	1.53	8.8	30.1	—
∼20	1.51	9.0	31.1	28.9
∼30	1.51	5.5	18.1	—
∼40	1.51	5.3	11.5	—
∼50	1.49	6.1	4.9	—
∼60	1.45	4.2	3.5	—

nutrients may not be absorbed by grass roots unless they are dissolved in rain water and moved down into soil layers where grass roots are distributed. In other words, the yield reduction of grass in the dry year was mainly caused by insufficient nutrient supply to grass roots due to lack of rain water, rather than by a direct effect of insufficient water supply to roots. Conversely speaking, water absorption not accompanied with nutrient supply is not so effective for plant growth.

For the same reason, the irrigation applied to grasslands in dry season may similarly be effective for all types of soil, with minor relations to water retention capacity of soil.

The effect of irrigation on grass production[4]

A series of experiments were carried out on a pasture of orchardgrass mixed with white clover extending on Acid Brown Forest soil (Dystrochrept) at the coastal terrace of Ohmu-cho, 50 km north of Komukai, at an altitude of about 60 m, during 4 years from 1979 to 1982. The pasture was established in 1969, by sand dressing and underdrainage. The characteristics of the soil are shown in Tables 2 and 3. The spray irrigation was employed. The rate of irrigation was adjusted to enable 0, 2, 5 and 8 mm/day of water supply including irrigation water and effective rainfall (>5 mm/day), during each 7-day period. Therefore, irrigation is made once a week except in the 8 mm/day plots, in which it was made twice a week to prevent loss of water.

In each experimental plot, 25 a in size, several small splinklers were arranged to keep uniformity of irrigation.

Table 4. Grass yield (expressed by percentage), amount of water supply (mm/day), and weather condition

Plots / Cutting	1979			1980			1981			1982			Total of 4 years
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	
Standard fertilizing	Yield (in the parenthesis, ton/ha is given)												
Control (no irrigation)	100%	100	100	100	100	100	100	100	100	100	100	100	100
	(5.75)	(2.31)	(0.89)	(3.16)	(1.90)	(1.60)	(2.68)	(2.17)	(1.35)	(4.02)	(1.52)	(1.05)	(28.40)
2 mm/day	99	141	136	133	128	177	131	131	172	110	157	179	130
5 mm/day	90	167	169	136	132	173	130	119	153	103	188	187	131
8 mm/day	94	161	151	138	136	188	123	116	124	90	193	187	128
Slurry applied													
Control (no irrigation)	100	100	100	100	100	100	100	100	100	100	100	100	100
	(5.75)	(3.04)	(1.99)	(3.52)	(2.57)	(2.46)	(3.86)	(2.53)	(1.82)	(4.01)	(1.63)	(1.42)	(34.60)
2 mm/day	95	130	112	153	99	145	135	104	140	140	224	264	135
5 mm/day	93	139	88	167	107	131	108	104	116	151	198	232	129
8 mm/day	96	146	78	173	96	82	107	105	112	128	168	206	121
	Amount of irrigated water (mm)												
2 mm/day	0	42	17	65	84	28	26	14	0	43	44	0	
5 mm/day	0	123	65	170	210	89	65	35	0	116	124	0	
8 mm/day	0	207	128	235	256	172	88	56	0	168	194	0	
	Weather condition												
Rainfall (mm)	126	108	230	145	48	128	161	308	182	77	94	138	
Pan evaporation (mm)	180	209	114	187	86	127	93	93	118	143	130	75	
Average temperature (°C)	10.6	16.6	15.2	10.1	14.1	15.1	8.2	14.6	14.3	10.6	15.4	16.7	

Effect of irrigation was studied under two different fertilizing levels; standard fertilization and slurry application. In the former, 40 kg/10 a of compound chemical fertilizer, which corresponds to 4 kg N, 8 kg P_2O_5, and 8 kg K_2O per 10 a was applied yearly. A half of chemical fertilizer was applied in early spring and each quarter was dressed after the first and second cutting. The slurry of 2.5 m^3/10 a in volume was applied yearly, in addition to the standard fertilization in slurry plots. The grass was cut three times a year in mid-June, mid-August and mid-October.

Weather condition, amount of water supply, and the yield of grass are shown in Table 4. A remarkable dry weather appeared in the period of 2nd regrowth in 1979, the 1st and 2nd regrowth in 1980, and the 2nd regrowth in 1982. In these periods the amount of evapotranspiration was estimated at 3.5–4 mm/day, and hence a large effect of irrigation was observed in the plots of 5 and 8 mm/day of water supply. Although the yield of 2 mm/day plot was less than that of 5 and 8 mm/day plots, it was fairly high. In the 2 mm/day plot, the small amount of irrigated water which moistened only shallow surface layer seemed to be utilized efficiently by grass roots in spite of the progress of dryness to deeper root zone (Fig. 5). As mentioned before, the distribution of grass roots is concentrated in the shallow surface layer and fertilizers are dressed on the soil surface. This fact can explain why the 2 mm/day plot often showed fairly high yields even under markedly dry weather.

The increase of grass yield of the 3rd cutting by the irrigation was larger than that of other cuttings except in the slurry plot with 8 mm/day of water supply. In the standard fertilizing plots the proportional ratio of clover was increased by the irrigation because the growth of orchardgrass was decreased during the 2nd and the 3rd regrowth while that of clover increased. Even with the less amount of irrigation, the yield of 3rd cutting was high, because pronounced growth of clover contributed the yield. On the contrary, in the slurry plots the large amount of N contained in the slurry and chemical fertilizer stimulated the growth of orchardgrass directly in proportion to the N level, while white clover was suppressed and disappeared. However, the large amount of irrigation water, 5 and 8 mm/day, caused a loss of fertilizer due to increased seepage, resulting in decreased grass yield.

We had much rain in 1981 so that the amount of irrigation water used was less than half of that in other 3 years. Nevertheless, the effect of irrigation was observed distinctly in the order of 2 mm$>$5 mm$>$8 mm/day plot in both of the standard fertilizing plots and slurry plots. The evapotranspiration rate of the grass was estimated at less than 2 mm/day in the rainy and cool weather period. As the rate of water supply was fixed as mentioned above, water supply of 5 and 8 mm/day caused over-irrigation and reduced the irrigation effect during the rainy period. However, in the 2 mm/day plot, no excess of irrigated water occurred even during the rainy period. As a result, the total yield in the whole experimental period was in the order of $2 \fallingdotseq 5 > 8$ mm/day plot.

Influence of fertilizing level on the effect of irrigation

The effect of irrigation differed between two fertilizing levels as discussed above. The slurry plots received a total of 28 kg of N and 45 kg of K_2O per 10 a in a year. The orchardgrass well responded to N but the clover was suppressed by the growth of orchardgrass and disappeared, especially in the irrigated plots. As the concentration of K_2O in the orchardgrass increased and that of CaO and MgO decreased apparently, it can be said that the quality of the grass was deteriorated in terms of K: (Ca+Mg) inspite of increased yield by irrigation.

On the contrary, in the standard fertilizing plots the amount of fertilizer was relatively small and growth of clover was stimulated by the irrigation. The grass harvested was good in quality related to CaO and MgO, although the yield was less than that of the slurry plots. However, the amount of N and K_2O absorbed by the grass was more than that of fertilized N and K_2O, so that the soil fertility declined rapidly in the standard fertilizing plots, especially in the irrigated plots. This tendency was supported by the fact that the amount of K_2O absorbed by the grass was decreased with the passage of years. Ike, M. et al.[1] showed that the decrease of K_2O supply reduces growth of clover. In this experiment too the proportion of clover was reduced after the 3rd year due to decreased K_2O fertility in the standard fertilizing plots.

Conclusion

Effect of irrigation on pastures on heavy clay soil was studied at Komukai and Ohmu, both on a coastal area along the Sea of Okhotsk in northern Hokkaido, under the cool weather condition with 380 mm of rainfall and 14°C of average temperature from May to August.

1) In this experiment, the amount of irrigation water was regulated to enable 0, 2, 5 and 8 mm/day of water supply including irrigation water and effective rainfall. A remarkable effect of irrigation was observed in the period of extremely dry weather even in the plots of 2 mm/day of water supply. On the other hand, in the rainy and cool weather period, 5 and 8 mm/day caused over-irrigation and leaching of fertilizers, resulting in lower yield than the 2 mm/day plot. The total yield for the whole period of experiment was also in the order of $2 \fallingdotseq 5 > 8$ mm/day plot.

2) The reason why the small amount of irrigation, i.e. 2 mm/day of water supply including rain water was almost comparable with the greater amount of irrigation, i.e., 5 and 8 mm/day in the effectiveness to increase grass yield was analyzed as follows: The grassland is characterized by the dense distribution of grass roots in a shallow surface layer of soil, and the nutrients placed on the soil surface by surface application of fertilizers. Therefore, during a long spell of rainless day, even the small amount of irrigation water can play an very important role in making these nutrients available to grass roots, by dissolving and bringing them to the grass roots. Namely, the small amount of irrigation is most efficient in supplying water and nutrients to grass roots.

For the economical planning of the irrigation system of grasslands, this characteristic must be taken into account as an important factor.

3) The nutrient absorption of the grass was increased with the irrigation, and, therefore, the fertility of the soil seemed to decline rapidly when a small amount of fertilizer was applied. However, the application of a large amount of fertilizer such as the use of slurry caused deterioration of grass quality related to the mineral balance. It seems that the method of fertilizer application to irrigated pastures has to be established.

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(Received for publication, November 8, 1984)