*Studies on the Improvement of Upland Soil by Means of Irrigation Practice**

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I. Introduction

Generally speaking, upland fields of Japan are comprised of relatively poor soil of low productivity. This is particularly so in the clearings in volcanic ash soil zones. It is, therefore, extremely difficult by means of common soil fertilization and management methods to bring about notable gains in productivity in a few years, and many years are invariably required. Consequently, in Japan it is a great problem to find the most satisfactory method of increasing the productivity of such poor field soils.

The author has undertaken studies on this problem, and has made it evident that it is possible through the intensive irrigation of such relatively unfertile soil to rapidly and notably improve and increase its productivity.

The present paper reports the results of the investigations on the principal factors of the excellent effect of irrigation on the increasing of soil productivity.

II. Experimental Results

1. *Field experiments*

The soils used in the experiments were of the volcanic ash soil at Gōshi and Kuma in Kumamoto Prefecture. Both soils are rich in humus and low in base status. Other characteristics are remarkably high phosphoric acid fixing power and extremely low silica-alumina molecular ratio, etc. Both soils are extremely low in productivity and are typical of Japanese unfertile soil.

The irrigation waters used for irrigation experiments came from the Shira and Kuma Rivers in Kumamoto Prefecture. The contents of chemical constituents of irrigation waters are presented in Table 1.

Table 1. Chemical composition of river waters used for irrigation experiments

River	pH	Concentration in ppm.				
		Total solids	CaO	MgO	K_2O	SiO_2
Shira	6.9	229	29.8	14.6	6.4	45.4
Kuma	7.0	67	13.0	2.6	1.1	18.3

* Read at the 6th Congress of the International Society of Soil Science, Paris, August, 1956.

a) Experiment using water of the Shira River[1]

The test field was irrigated for a total of 15 days (irrigation practiced in such way that during the watering period the test field is flooding under the condition of keeping about 10 cm depth of water over the surface of field).

After irrigation samples of soil were collected from the test fields and investigated for the changes of some chemical properties of soil by irrigation. For the cultivation experiments, both irrigated and nonirrigated plots were used. These plots were furthermore divided according to the fertilizer treatments as shown in Table 2, and naked barley was sown and cultivated. During the period of cultivation of crop, irrigation was not practiced. The results are presented in Table 2.

Table 2. Changes of some chemical properties of soil and yields of naked barley in field experiment (at Gōshi)

Plot	Depth of soil samp-ing	pH		Cation exchange capacity (me./100g.)	Exchangeable bases*** (me./100 g.)		Absorption power of P_2O_5 (mg/100 g. of dry soil)	Fertilizer treatment	Yields of grain (bu./acre)
		(H_2O)	(KCl)		Ca	Mg			
	cm								
Non-irri-gated	0–10 10–25	5.2 5.4	4.8 5.2	42 3 —	1.0 0.7	0.4 0.4	2744 2813	N-P-K N-P-K, C* N-P-K, Ca** N-P-K, C, Ca	0.82 17.22 12.30 19.27
Irri-gated	0–10 10–25	6.3 5.6	5.9 5.2	47.4 —	10.6 6.4	4.0 1.8	2462 2799	N-P-K N-P-K. C N-P-K, Ca N-P-K, C, Ca	46.12 49 20 42.02 53.29

* C…compost, ** Ca…$CaCO_3$, *** By Schollenberger's NH_4-acetate method.

b) Experiment using water of the Kuma River

The irrigation water from the Kuma River contains distinguishly less mineral constituents than that of the Shira River as shown in Table 1.

In this case the test field was irrigated for a total of 28 days. For the cultivation tests, irrigated and nonirrigated plots were provided and wheat seeds were planted. The changes of characteristics of the irrigated soil and the yields of wheat are given in Table 3.

Table 3. Changes of some chemical properties of soil and yields of wheat in field experiment (at Kuma)

Plot	Depth of soil samping	pH		Cation exchange capacity (me./100g.)	Exchangeable bases (me./100 g.)		Fertilizer treatment	Yields of grain (bu./acre)
		(H_2O)	(KCl)		Ca	Mg		
	cm							
Non-irri-gated	0–15 15–30	4.8 4.7	4.4 4.2	56.2 56.9	1.5 1.2	2.2 1.8	N-P-K N-P-K, C N-P-K, Ca, C	1,23 23.78 39.16
Irri-gated	0–15 15–30	6.6 6.0	5.6 5.1	61.0 60.0	14.8 8.6	5.3 5.3	N-P-K N-P-K, C N-P-K, Ca, C	46.74 63.14 63.76

c) Amount of water necessary for soil improvement

As a great quantity of water is necessary for soil improvement by means of intensive irrigation, the problem of water volume is important. In the above-mentioned tests, the quantities of irrigation waters were large as equal to the amounts corresponding to a total of 15 days' irrigation at Gōshi and 28 days' at Kuma respectively.

In order to determine the minimum amounts of irrigation waters required for soil improvement, field irrigation experiments were conducted, and it was found that the results differed according to the quality of water used. With such water as that derived from the Shira River, which is high in mineral components, the quantity can be small, while with water of the Kuma River, which is low in minerals, the quantity used must be large. It was clarified that the Shira River would adequately bring about soil improvement by a total of 5 days' irrigation, while the Kuma River water needs for at least 10 days'. The results of field experiment using water of the Shira River are presented in Table 4.

2. *Pot culture experiments*

In order to determine the direct effect as plant nutrient of magnesium and

Table 4. Quantity of water from the Shira River necessary for soil improvement (at Gōshi field)

Days of irrigation	Depth of soil samping (cm)	pH (H_2O)	pH (KCl)	Exchangeable bases (me./100 g.) Ca	Exchangeable bases (me./100 g.) Mg	Absorption power of P_2O_5 (mg./100 g. of dry soil)	Fertilizer treatment	Yields of grain (bu./acre)
Non-irrigated	0 - 10	5.2	4.8	1.0	0.3	2944	N-P-K, C*	1.7
5 days' irrigation	0 - 10	6.2	5.4	7.4	4.3	2603	N-P-K, C	48.4
10 days' irrigation	0 - 10	6.3	5.8	8.5	4.6	2515	N-P-K, C	49 2
15 days' irrigation	0 - 10	6.4	6.1	13.1	6.2	2374	N-P-K, C	51.1

* C…Compost.

Table 5. Yields of wheat and upland rice in pot experiments (g./pot)

Treatment	Black volcanic ash soil				Yellow brown volcanic ash soil (so-called "*Akahoya*" or "*Imogo*")			
	Wheat		Upland rice		Wheat		Upland rice	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
N-P-K	0	0	10.1	17.8	0	0	0	4.1
N-P-K, $CaCO_3$	0	0	12.4	26.3	7.6	16.6	3.3	4.3
N-P-K, $CaCO_3$, $MgSO_4$	13.1	17.6	21.0	31.3	14.2	23.0	22.5	28.1
N-P-K, $CaCO_3$, $MgSO_4$, SiO_2*	15.4	18.7	24.8	32.9	18.0	26.4	24.8	32.6

* Added the silicic acid solution which was obtained by removal of Na from Na_2SiO_3 solution by means of ion-exchange resins.

silicic acid among the ingredients accumulated in soil by irrigation, pot culture experiments were carried out, using the same soil as that used for the field experiments. The results are presented in Table 5. It was clarified from the Table 5 that both elements were distinctly effective to promote the crop growth, especially the effect of the added magnesium was particularly great. From the results it was concluded that the effect of magnesium provided by the irrigation water is of extraordinary magnitude.

3. *Laboratory experiments*

a) Accumulation of inorganic components in soil[2],[3]

Laboratory experiments of intensive irrigation of soil were undertaken in order to ascertain the manner in which mineral constituents contained in irrigation waters accumulated in the soil. The results are presented in Table 6. It was found that although accumulation of bases and silicic acid varied according to the nature of the soil, intensive irrigation resulted in high absorption and accumulation in soil of these ingredients.

b) Availability of the components accumulated in the soil

In order to determine the availability to plant life of the ingredients accumulated in the soil as a result of irrigation, tests were conducted by using the Neubauer's young plant method. The results are given in Table 7. It is evident

Table 6. Accumulation of minerals in soil by irrigation
(Kg per acre, 10 cm.)

Soil	Elements estimat'd	Quantities of irrigation water (mm.)							
		430	1290	2150	3010	4730	6450	8170	10000
Black volcanic ash soil	CaO	26.7	82.5	135.0	179.6	252.6	321.5	393 0	474.0
	SiO_2	32.0	68.7	87.6	104.0	136.5	166.0	205.3	246.5
Yellow brown vol. ash soil	CaO	28.5	85.2	126.9	152.4	188.1	221.1	253.9	294.0
	SiO_2	33.6	97.7	145.9	188.9	274.8	365.0	458.9	541.7

Table 7. Availability of various constituents accumulated in the soil by irrigation

Soil treatment		Uncultivated soil	Nonirrigated field soil	Irrigated field soil
Air dry weight of total wheat plant per pot (g.)		2.47	2.24	2.95
% on an air-dry basis	Ash	3.44	3.79	5.28
	SiO_2	0.301	0.447	1.130
	CaO	0 097	0.120	0.060
	MgO	0.041	0.042	0.062
	K_2O	0.625	0.495	1.438
Amounts of each element absorbed by plant per pot (mg.)	Ash	45	45	120
	SiO_2	6.2	8.1	23.4
	CaO	2.4	2.7	3 7
	MgO	0.6	0.5	1.4
	K_2O	15.4	11.0	42.1

from the Table 7 that ingredients added to the soil by intensive irrigation are easily absorbed and utilized by plants.

III. Discussion

In general, so-called field irrigation practice in Japan is chiefly aimed at the effect of the prevention of drought by supplementing moisture of about 10-20 inches during the period of plant growth, but in this case, it aimed mainly at the direct supply of nutrients to plant and improvement of soil by intensive irrigation (equivalent to about 200-400 inches of water).

The data from the irrigation experiments indicated that the productivity of poor soils was increased rapidly and remarkably by irrigation using great quantities of water. This is in all likelihood due to absorption in large quantities of various constituents contained in irrigation water, such as CaO, K_2O, MgO, SiO_2, and etc., and it is considered that these components added to the soil are not only readily available to plant as nutrient, but also they contributed greatly to the improvement of the properties of the soil. By accumulation of bases the acidity of soil is corrected, while the addition of CaO and SiO_2* weaken the phosphoric acid fixing power of soil and increasing the availability of phosphates of soil. SiO_2 added by irrigation heightens the base exchange capacity and the silica-alumina molecular ratio of soil.* These things tend directly to improve the characteristics of the soil and contribute indirectly toward better plant growth.

As for the direct effect on plant growth of magnesium and silicic acid supplied by irrigation, pot experiments indicated evidently that they contributed notably toward plant growth. Especially outstanding was the effect of magnesium, and it was found that when this substance was deficient plant growth was retarded appreciably. Because most of the unfertile volcanic ash soil of Japan is deficient in magnesium, it is believed that the remarkable effect of the intensive irrigation method is largely due to the addition to the soils of this specific ingredient.

As has been mentioned above, SiO_2 absorbed from the irrigation water not only directly improve the properties of the soil, but also seems to contribute toward plant growth when ingested by plant.

IV. Summary

Research was conducted of the intensive irrigation in fields as one possible method of improving the relatively unfertile and unproductive upland fields of Japan.

The results of these studies were the conclusion that by means of intensive irrigation the inorganic components contained in the water, such as CaO, MgO, K_2O, SiO_2, and etc., are accumulated in large quantities in the soil, replenishing it with ingredients it lacks; that these accumulated components not only directly benefit plant growth in a nutritional way, but also contribute in a direct way toward improvement of soil characteristics, and consequently increasing soil productivity rapidly and remarkably.

* Read at the Conference of the Society of the Science of Soil and Manure, Japan, April, 1955.

References

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