The Black Soils in Japan.*

I. A Study of their Unproductiveness.

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I. Introduction.

The distribution of black soil in Japan is estimated to be about 20,000 square kilometers extending over the plain valleys or on the hilly places, and the un-

* This subject was assigned by Dr. ARAO ITANO of Ōhara Institute for Agricultural Research, Kurashiki, Japan and the investigation was carried out under his constant advice.

treated black soil is unproductive so that it is largely left uncultivated, which is a serious problem for the Japanese agriculture. In the past, the attempts have been made to improve this soil but frequently failed owing to the lack of scientific knowledge as to the exact causes of unproductiveness. Consequently this investigation was started about ten years ago in order to ascertain the causes from the physico-chemical standpoint together with the microbiological factors considered and accompanied by both the pot and field tests.

This paper gives the results dealing with the first part, namely the physico-chemical properties of the soil and the proposed methods for its improvement.

II. Review of Previous Investigation and the General Description of the Black Soils in Japan.

Only a few reports on the black soils in Japan are available and they are chiefly concerned with the morphology and genesis of the black soil.

The black soil used in this investigation was taken from Daisen-bara valley, uncultivated soil which is one of the most typical soil of this kind. The climate in this valley is rather warm and the rainfall is abundant as indicated in the table :

Climatic Factors.

Locality.	Mean temperature.					Mean annual rainfall.	Rain-factor.*
	Spring.	Summer.	Autumn.	Winter.	Years.		
Sakae.	11.5	24.4	16.3	4.6	14.2	1960.2	138.3
Miyazu.	11.1	24.5	16.7	4.8	13.7	2054.2	149.0

* After LANG[12].

Judging from the data in the above table, the climatic conditions are suitable for the formation of black soil on the surface.

The surface black soil consists of very fine particles of volcanic ash containing a large amount of humus. Its subsoil reaches to the depth of several meters of brownish yellow or greenish yellow ash, sand or lapilli of volcanic origin. According to SEKI[20], the soil of this type was slightly acid and it absorbed both acidic and basic dyestuffs such as methylene blue and fuchsin S. etc., of which the absorption of fuchsin S. might have been due to the presence of free colloidal aluminium ; it lacked in bases, and 20 percent hydrochloric acid extract showed small ki and ba value similar to those of laterite or bauxite.

The author[11] previously studied the soil profiles of Daisen-bara valley. The colors of strata were ; surface-black, second-grayish black, third-brownish yellow and fourth-reddish yellow. Estimation of greater part of it consisted of acid humus containing no. bases. Analysis by WAKSMAN's method[23] showed that the humus consisted largely of lignin with small amount of crude protein and hemicellulose. The degree of humification by RICHARDSON's method[16] was 20—25, and carbon-nitrogen ratio was 22, indicating that the humus contained in this soil exists in a form which is very hard to be decomposed.

HARADA[8] made a geological study on a soil derived from volcanic ash in Tottori Prefecture, and found that the profiles of these volcanic soils consists of three horizons, namely the black upper-, the brown middle, and the yellow lower horizon. Each horizon contained different amount of parent material, lower the horizon, the more crystals was found. Fresh green hornblende and quartz grains were found abundantly in all horizons ; the quartz grains probably were derived from the pseudomorphosis of the plagioclase and the parent material of much weathered biotite which is found much in lower profiles might have been originated from hornblende-biotite-andesite. The presence of free alumina was ascertained by the absorption of fuchsin S., and the estimation of ki values of the fractions soluble in concentrated hydrochloric acid and 5 percent potassium hydroxide. The upper and middle horizons have developed mainly through allophanization and kaolinization, and the lower horizon through allophanization and formation of free alumina. From these reasons he concluded that the formation of these soils is largely due to the intrinsic factors such as the nature and composition of the parent material, and these soils must be regarded as aclimatic.

As to the chemical nature of the organic compounds in the black soil in Tottori Prefecture, Aso and IMAI[1] reported the results of their investigation as shown in the following table :

Compounds isolated.	%
1. Glycerides (lignid). · ·	0.01766
2. Pentose. · · · · · · ·	0.20817
3. Pentosan. · · · · · · ·	0.06000
4. Picolinecarboxylic acids.	0.01813
5. Cytosine. · · · · · · ·	0.05334
6. Dihydroxystearic acid. ·	0.00177
7. Paraffinic acid. · · · ·	0.00652
8. Resin acids. · · · · ·	0.03177
9. Histidine. · · · · · ·	trace
10. Arginine. · · · · · · ·	trace
11. Xanthine. · · · · · ·	trace

Among these organic compounds, picolinecarboxylic acid and dihydroxystearic acids are proven[16] to be harmful for the plant growth. Consequently the presence of these compounds together with some other factors, make these black soils unproductive.

On the other hand, in the midst of these unproductive soil region, one of the richest soils in Japan has been built up by the farmers in a certain locality as the result of an intensive management, producing a large yield of crops of fine quality. However the scientific bases for their practice have been unknown and often failed in their attempts.

For these reasons, the soil samples under various conditions were taken and subjected to the following analyses and tests, as described below.

III. Experimental Procedure:

Part I. Mechanical, Physico-chemical Analysis.

a.) *Samples Used.**

The following samples were used:

Sample AI was taken from the original untreated and uncultivated field which is located about 15 kilometers east of Yonago, Tottori Prefecture.

Sample AII. Came from the same locality as AI but had a treatment of 4,000 kilograms manure per hectare annually for the past 20 years with continuous rice crop; the yield of unpolished rice was 3,000 kilograms per hectare which was nearly an average yield in Japan.

Sample AIII had a treatment of 12,000 kilograms manure per hectare annually for the past 50 years and in addition it had a treatment of superphosphate for the last 6 years; the maximum yield of unpolished rice reached a mark of 7,900 kilograms with an average of 5,000–6,000 kilograms per hectare which ranked the highest yield in Japan. Beside the crops were free from diseases; the quality of straw and grains was superior. It is one of the best improved black soil in Japan.

Sample BI was taken from the uncultivated field which is located about 10 kilometers south-east of Yonago.

Sample BII had received mixed mineral fertilizers predominated with superphosphate for the past 2 years; although BII had shown a slight improvement in comparison with BI the yield of oat, rice and mulberry was low, the quality of products was inferior and the resistance of crops toward the diseases was low. Barley and wheat showed no growth on BII.

Sample BIII had been treated with mixed mineral fertilizers for the past several years until the crops showed no growth. It is a typical example of showing an injurious effect of mineral fertilizers.

Sample C was taken from the field plot of Tottori Agricultural College which is a common alluvial soil type. This is not a black soil but was taken just for the comparison against the black soil.

b.) *Mechanical Analysis.*

The mechanical analysis of the soil was made by SEKI's modification of COPECKY's method after the estimation of humus by chromic acid method by wet combustion, and the results are given in Table 1.

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* The soil samples will be designated hereafter in this paper by using AI, AII, AIII, BI etc., each representing the nature noted in detail here.

Table 1.
Mechanical Analysis.

Soil fractions. \ Soil samples.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
2.0 to 0.25 mm.	5.40	11.83	16.54	5.16	8.33	3.35	9.67
0.25 to 0.05 mm.	12.29	15.23	18.76	8.86	7.05	14.19	12.66
0.05 to 0.01 mm.	22.68	21.36	18.81	16.36	18.87	22.29	20.03
Less than 0.01 mm.	59.63	51.58	45.89	69.62	64.75	60.18	57.64
Humus.	22.89	21.25	18.29	21.22	20.98	20.19	3.88

Table 1 indicates that this is a humus soil containing at around 20 percent humus : but the cultivation decreased both the humus and clay content so that the physical characteristic of the soil may be greatly affected.

c.) *Physical Charactertistics Determined.*

The following physical characteristics of the black soil were determined ; the specific gravity, volume weight, pore spaces, water capacity, water ascending time (time required by the water to make 10 cm. ascending through the soil) in loose and compact condition.

Table 2.
Physical Properties.

Physical properties. \ Soil samples.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
Specific gravity.	1.76	1.80	2.00	1.78	1.85	1.88	2.77
*Volume weight.	59.04	59.89	63.31	64.25	66.32	67.52	78.42
*Pores.	73.82	73.03	72.08	69.46	65.67	65.65	72.49
*Water capacity.	118.83	103.02	102.27	98.72	77.08	74.79	67.40
*Water ascending time.	19 m.	26 m.	27 m.	13 m.	15 m.	15 m.	84 m.
**Volume weight.	69.17	70.94	74.04	77.51	79.63	79.84	108.61
**Pores.	68.89	67.50	66.72	65.79	63.29	63.23	61.51
**Water capacity.	108.43	84.95	81.33	81.51	73.23	71.11	56.71
**Water ascending time.	35 m.	39 m.	52 m.	19 m.	29 m.	31 m.	241 m.

* Loose condition. ** Compact condition.

As indicated in Table 1 and 2, black soil gave considerably low value in specific gravity and volume weight in comparison with the alluvial soil ; though it gave greater water absorbing capacity, the penetration of water was fast and the loss of water by evaporation was great due to greater speed of ascending of water. Thus the soil had shown a danger of getting too dry due to poor water holding capacity. This deffect may be improved to a certain extent by a proper method of cultivation, even though it may not be so good as that of alluvial soil.

d.) *Chemical Characteristics Determined.*

As to the chemical characteristics of the black soil, the following factors were considered and determined:

1. Composition of 20 percent hydrochloric acid extract.
2. Available forms of the soil constituents.
3. Exchangeable bases.
4. Absorbing capacity of soil for phosphoric acid and nitrogen.
5. Acidity and the degree of base saturation.
6. Soluble aluminium.
7. Electrodialysis and rate of removal of ions.

The results of analyses are presented in the following tables 3—12 inclusive.

1. Composition of 20 percent HCl Extract.

By using UTESCHER's method[22], the soluble substances in hydrochloric acid were determined and the results are given in Table 3.

Table 3.

Composition of 20 percent Hydrochloric acid Extract.

(Percentage on air dry basis.)

Composition \ Soil samples.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
SiO_2.	9.426	12.136	15.236	10.072	9.396	8.555	13.322
Al_2O_3.	8.805	7.675	7.520	9.624	7.938	6.560	7.436
Fe_2O_3.	3.051	2.912	3.320	6.060	5.420	3.620	5.672
Mn_2O_3.	0.088	0.071	0.060	0.120	0.114	0.084	0.122
MgO.	0.301	0.331	0.372	0.298	0.254	0.203	0.875
CaO.	0.213	0.549	0.608	0.212	0.246	0.179	0.468
Na_2O.	0.149	0.135	0.149	0.215	0.163	0.130	0.116
K_2O.	0.115	0.139	0.153	0.124	0.114	0 097	0.116
P_2O_5.	0.070	0.191	0.342	0.056	0.109	0.152	0.104
SO_3.	0.147	0.144	0.152	0.068	0.079	0.140	0.029
H_2O.	13.883	15 615	11.559	12.293	12.287	12.047	7.355
Humus.	22.892	21.250	18.250	21.220	20.980	20.194	3.880
Residue.	40.680	39.182	42.819	40.143	43.058	48.543	59.613
ki value.	1.814	2.679	3.434	1.774	2.006	2.201	3.036
ba value.	0.173	0.315	0.328	0.169	0.187	0.177	0.457

Considering the data given above in the light of the nature of soil samples, the following statements may be made: The original black soil contains less silicic acid and more aluminium oxide in comparison with the alluvial soil; the ki value (SiO_2 / Al_2O_3) being 3.036 for C, 1.814 for AI and 1.774 for BI. Among bases, it is poor in lime and magnesia, slightly higher in potash and soda; ba value (base / Al_2O_3) being 0.173 for AI, 0.169 for BI and 0.457 for C. Thus sample B showed very incomplete saturation of bases.

In AII and AIII, soils improved by the application of manure and inorganic fertilizers, showed a gradual increase in silica and lime content and decrease in aluminium; the ki and ba value as well as lime and phosphoric acid content is increased.

Soil improved only by inorganic fertilizers showed a gradual decrease in silica, but, since the decrease in bases were still greater, ki value being only slightly increased as 1.774 for BI and 2.006 for BII and 2.201 for BIII; iron and manganese also showed a gradual decrease and the bases were the highest in BII (the highest ba value) and the lowest in BIII. Although BIII showed decrease in bases, it contained the highest amount of phosphoric and sulfuric acid radicals etc.

2. Available Forms of the Soil Constituents.

The available forms of the soil constituent were estimated by SHEDD's method[19] and noted in Table 4.

Table 4.

0.2 Normal Nitric acid Extract.

(Percentage on air dry basis.)

Soil samples. / Composition.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
CaO.	0.026	0.193	0.418	0.017	0.134	0.057	0.258
K_2O.	0.036	0.046	0.069	0.033	0.024	0.012	0.015
P_2O_5.	0.004	0.042	0.100	0.004	0.008	0.019	0.023
$\frac{\text{Available } P_2O_5}{\text{Total } P_2O_5}$	5.286	21.727	29.152	6.250	7.156	12.631	15.263

Table 4 indicates that the original black soil (AI and BI) showed poor in lime and phosphoric acid content and more potash in comparison with C. An addition of manure and inorganic fertilizers caused an increase in available forms of lime, potash and phosphoric acid, as in AII and AIII, in comparison with C. In case of application of inorganic fertilizers only for the treatment, it contained comparatively higher amount of lime and potash at the initial period of treatment as in BII, but, continuous treatment which caused an unproductiveness of the soil as in BIII gave an indication of decreased lime and potash content, though it had shown more phosphoric acid content.

According to LEMMERMANN and FRESENIUS[13], soils having less than 25 in relative solubility (available P_2O_5 / total P_2O_5) need phosphoric acid treatment. In our soils, only AIII exceeded this value and all others should be rated as phosphoric acid deficiency, especially in original uncultivated soil.

3. Exchangeable Bases.

Exchangeable bases were estimated by HISSINK's method[10]. The results are shown in Table 5.

Table 5.

Exchangeable Bases.

(Mg. eq. per 100 g. of air dry soil.)

Soil samples. / Bases.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
Ca.	0.570	6.494	11.383	0.556	5.353	1.796	7.079
Mg.	1.092	2.660	3.871	1.191	1.052	0.357	2.540
K.	0.635	0.881	1.324	0.649	0.599	0.391	0.323
Na.	1.048	1.358	3.175	0.658	0.781	0.526	0.813
Sum.	3.345	11.393	19.753	3.054	7.785	3.070	11.755

The above data indicate that uncultivated black soil gave abundant potash and soda in comparison with the alluvial soil but was poor in magnesia and especially in lime ; consequently, lack of base resulted. Application of manure to this soil, as in AII and AIII, showed much in basicity, while the treatment of inorganic fertilizers made some increase in basicity, as in BII, over BI, but, the continuance of this treatment, as in BIII, made low basicity reappeared to the extent of BI.

4. Absorbing Capacity of Soil for P and N.

The absorption of phosphoric acid and nitrogen by the soil was estimated by adding 200 cc. of 2.5 percent ammonium phosphate to 50 grams soil, shaken for 1 hour and left over night. Phosphoric acid and nitrogen content in this filtrate was then estimated ; it is calculated to 100 grams of dry soil.

Table 6.

Absorbing Capacity for Phosphoric acid and Nitrogen.

Soil samples.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
P_2O_5.	2.889	2.550	1.856	2.472	2.574	2.690	0.792
N.	0.836	0.728	0.414	0.704	0.739	0.825	0.463

As shown in Table 6 the absorption of these two compounds were much greater in black soil than in alluvial soil. The absorption of phosphoric acid was great, especially in black soil ; e. g. AIII gave twice as much more absorption than C, and further treatment of this soil with inorganic fertilizers made still greater phosphoric acid absorption. It seems to be one of the special characteristic of black soil to show high phosphoric acid absorption ; in practice, however, it may not be necessary to saturate the soil with phosphoric acid since a very improved soil like AIII still gives great phosphoric acid absorption.

5. Acidity and the Degree of Base Saturation.

The pH value of soils was estimated by adding 2 volumes of water for a volume of soil. The degree of base saturation of soil was then calculated by HISSINK's method[9] the exchangeable acidity and hydrolytic acidity were determined by KAPPEN's method. The results are given in Table 7.

Table 7.
Soil Acidity and the Degree of Base Saturation.

Soil samples.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
pH. · · · · · · ·	5.03	5.36	6.06	5.01	5.25	4.35	6.13
Exchangeable acidity. ·	11.75	4.00	0.95	11.63	20.75	29.73	1.27
Hydrolytic acidity. · · ·	89.10	71.05	20.15	88.13	105.00	132.02	21.25
T—S.* · · · · ·	201.20	193.26	130.81	196.56	181.26	186.05	42.09
T.** · · · · · ·	204.55	204.65	150.56	199.61	187.15	189.12	54.65
Degree of saturation. · ·	1.64	5.67	13.12	1.53	4.16	1.62	21.51

* T—S. · · · · · Exchangeable hydrogen.
** T. · · · · · · Base exchangeable capacity.

As noted above the original black soil gave pH 5.0 ; exchangeable acidity and hydrolytic acidity were greater than the alluvial soil, and it gave an indication of fairly strong acid soil. A considerable decrease of this acidity was found in case of manure treated soil, while the treatment with inorganic fertilizers gave a tendency to increase it as in BIII. The amount of base required for the black soil to reach at saturation point by HISSINK's method (T−S) was very high and though this amount could be decreased by the treatments, yet AIII required 3 times as much more base than C, indicating that the black soil has high absorption of base. In spite of showing such high absorption of base, it has shown a very small degree of saturation due to an extremely small amount of total exchangeable base. The degree of saturation of the soil with manure treatment was comparatively high as the amount of base absorbed was high, but that of unproductive soil, BIII, with continuous inorganic fertilizer treatment had shown the same degree of saturation as that of original uncultivated soil due to lower absorption of the base.

6. Soluble Aluminium.

The soluble aluminium content in the soils was estimated by two methods, namely SEKI's[21] and PARKER's[15] and the results are given in Table 8 and 9 respectively.

Table 8.

Free Aluminium Determined by Seki's Method.

(Percentage on air dry basis.)

Soil samples.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
SiO_2.	0.120	0.084	0.104	0.150	0.142	0.024	0.300
Al_2O_3.	4.264	2.712	1.740	4.120	3.862	4.415	0.740
$\frac{SiO_2}{Al_2O_3}$	0.048	0.051	0.102	0.062	0.062	0.009	0.680

Table 9.

Soluble Aluminium Determined by Parker's Method.

(Percentage on air dry basis.)

Soil samples. / Solvents.	AI.	AII.	AIII.	BI.	BII.	BIII.	C.
20% HCl.	8.805	7.679	7.520	9.624	7.938	6.560	7.436
10% Na_2CO_3. . .	4.246	2.712	1.740	4.120	3.869	4.415	0.740
0.5 N. CH_3COOH.	0.223	0.078	0.060	0.196	0.119	0.363	0.038
1 N. NH_4Cl. . . .	0.120	0.066	0.041	0.016	0.089	0.225	0.004
H_2O.	0.0003	0	0	0.0004	0.0001	0.0034	0

Table 8 indicates that the soluble aluminium content was about 4 percent which is higher than the average (around 3 percent) given by SEKI[21] in most of the Japanese volcanic soil. This amount was decreased by manure treatment and the continued use of inorganic fertilizers caused the decomposition of soil complexes by the increased acidity which caused the loss of silicic acid as noted in the case of BII and BIII.

Soluble aluminium in hot 20 percent hydrochloric acid, active aluminium by the extraction with 0.5 normal acetic acid[3], exchangeable aluminium by washing with 1 liter of 1 normal ammonium chloride and the aluminium containing in the soil solution by PARKER's method[15] was estimated as shown in Table 9.

As shown in Table 9, aluminium soluble in hot 20 percent hydrochloric acid decreased by increasing the numbers of cultivation both in all cases, free-, active-, and exchangeable aluminium showed no such changes, though they gave lower value by manure treatment. Inorganic fertilizer treatment showed a slight decrease as in B_{II}, and B_{III} gave more than B_{I}. B_{III} gave the highest aluminium in aqueous extract.

Relation of p_H value and solubility of aluminium was determined as follows: extraction of 100 grams soil A_I with 250 cc. sulfuric acid of various concentrations was prepared getting different p_H and the results are noted in Table 10.

Table 10.

Relation of pH Values and Solubility of Aluminium of Soil Sample A_I.

Concentration of H_2SO_4.	Acidity.	Saluble Al_2O_3.
Normality.	p_H.	%.
0	5.03	0.0003
0.002	5.00	0.0023
0.004	4.82	0.0074
0.006	4.71	0.0274
0.008	4.50	0.0380
0.012	4.38	0.0596
0.016	4.25	0.1406
0.020	4.18	0.1958
0.024	4.00	0.1990
0.028	3.81	0.2084
0.032	3.70	0.2390

As shown above, the aluminium in this soil was very soluble and the solubility was greater as the concentration of hydrogen ions increased.

7. Electrodialysis and Rate of Removal of Ions.

Electrodialysis of untreated soils (Soil sample A_I and A_{III}) and the soils saturated with sodium phosphate was made by using cellophane as a diaphragm and using 110 volts in MATTSON's apparatus. After a certain period, base was titrated by using methyl red as an indicator and that of acid with phenolphthalein; from these values mg. e. was calculated.

The results are noted in Table 11 and 12.

(See Table 11 and 12 on next page.)

As indicated in Table 11 and 12, dialysis of bases in uncultivated soil was so fast that they passed out within 30 minutes while that of A_{III} which had manure treatment required 16 hours. Dialysis of acid was difficult as they were strongly adsorbed by the soil; that of A_I required more time than that of A_{III}.

e.) *Discussion of the Results obtained in Part I.*

From the foregoing experiments, the following information were obtained and are discussed here briefly: Uncultivated "black soil" in Japan is a light humus clay containing about 20 percent humus and it is very light in comparison with alluvial soil. Though it has high water absorbing capacity, the penetration of water up and down is also high; the soil become quickly dry for this reason. Cultivation improved such defect as it decreased both in humus and clay content. Analysis showed that silicic acid in uncultivated black soil is washed out and alumina is increased so as to give $SiO_2/Al_2O_3 < 2$; the amount of base, especially the lime, is deficient to bring incomplete saturation of bases as indicated by the degree of saturation by HISSINK's method. Therefore the soil belongs to a fairly strong acid soil.

Table 11.

The Rate of Removal of Ions by Electrodialysis of the Soil.

(Soil sample, AI, $P_H = 5.03$.)

Dialyzates changed after.	Cations mg. e.		Anions mg. e.		P_H of the soil suspension.	Al mg. e.
	Per fraction.	Average per hour.	Per fraction.	Average per hour.		
15 minutes.	3.81	15.25	0.12	0.48	4.30	0.041
30 "	0.61	2.44	0.08	0.32	4.35	0.012
45 "	0	0	0.05	0.20	4.40	0.011
60 "	0	0	0.03	0.12	4.57	0
4 hours.	0	0	0.16	0.05	4.48	0
8 "	0	0	0.12	0.03	4.50	0
16 "	0	0	0.25	0.03	4.76	0.024
32 "	0	0	0.35	0.03	4.81	0.031

(Soil sample, AIII, $P_H = 6.21$.)

Dialyzates changed after.	Cations per fraction	Cations average per hour	Anions per fraction	Anions average per hour	P_H	Al mg. e.
15 minutes.	8.25	33.00	2.48	9.92	5.15	0
30 "	4.31	17.24	1.26	4.04	5.01	0
45 "	2.70	10.08	0.59	2.36	4.86	0
60 "	0.50	2.00	0.05	0.20	5.15	0
4 hours.	1.31	0.44	0.07	0.02	5.24	0
8 "	0.79	0.20	0.08	0.02	5.16	0.013
16 "	0.32	0.20	0.07	0.01	5.20	0.015
32 "	0.15	0.10	0.11	0.01	5.24	0.024

Absorbing power for nitrogen and phosphoric acid is extremely high and the amount of available phosphoric acid is deficient according to the theory of LEMMERMANN and FRESENIUS.

The black soil contains a large amount of unstable alumina which dissolves out rapidly even in the presence of the least amount of acid. It exceeded the amount of active aluminium which is injurious to plant growth and it is higher than any soil found in United States as shown by BURGESS[8]. Exchangeable aluminium which is soluble in neutral salt solution is also high and the aluminium contained in soil solution, in case of BIII, gave 34 p.p.m. These aluminiums may cause the decrease of fertilizer efficiency of phosphoric acid and it is also directly injurious to plant growth.

Though the black soil is unsaturated with base and has high absorbing power, electrodialysis of the soil indicates that it has the least holding power

Table 12.

The Rate of Removal of Ions by Electrodialysis of the Soils Saturated by Sodium phosphate.

(Soil sample, AI, $p_H = 7.35$.)

Dialyzates changed after.	Cations mg. e.		Anions mg. e.		p_H of the soil suspension.	Al mg. e.
	Per fraction.	Average per hour.	Per fraction.	Average per hour.		
15 minutes.	24.21	96.84	10.50	42.00	5.34	5.151
30 „	4.30	17.20	3.15	12.50	5.15	0.058
45 „	0.22	0.88	1.34	5.73	4.01	0.048
60 „	0	0	1.02	4.08	4.05	0.028
4 hours.	0	0	3.42	1.14	4.15	0.160
8 „	0	0	3.35	0.84	4.22	0.148
16 „	0	0	2.80	0.32	4.38	0.200
32 „	0	0	5.83	0.36	4.40	0.341
(Soil sample, AIII, $p_H = 7.40$.)						
15 minutes.	22.44	89.76	16.03	64.12	5.48	0
30 „	12.53	49.12	9.83	39.32	5.45	0
45 „	4.30	17.20	2.15	9.60	5.28	0.016
60 „	1.15	7.04	0.83	3.32	4.82	0.013
4 hours.	4.25	1.41	1.55	0.51	5.01	0.033
8 „	1.70	0.42	0.85	0.21	5.21	0.044
16 „	0.80	0.10	0.62	0.08	5.24	0.124
32 „	0	0	1.25	0.08	5.36	0.140

for absorbed bases, while it has great combining power for phosphoric acid. Harmful effect of inorganic fertilizer treatment may be explained by the fact that the treatment caused the washing off the bases, leaving acid behind to give higher acidity and soluble aluminium. Manure treatment, on the contrary, improved fundamental characteristics of the soil, increased the holding power for bases, prevented the loss of plant nutrients, lowered the acidity of soil, decreased soluble alumina and increased silicic acid.

In the following part, various experiments will be conducted to eliminate these probable causes of unproductiveness found and to find some methods of improvement.

Part II. Methods of Improvement Investigated.

On the basis of findings in the foregoing experiments, the following tests were carried out in pots using the rice plants, as will be noted below.

1. *Effect of Addition of $CaCO_3$.*

From the foregoing experiments, it was found that the lack of base and high acidity is one of the factors of unproductiveness of the black soil. In order

Table 13.

The Effect of Calcium carbonate on Rice.

Pot No.	Remarks.	Amount of $CaCO_3$ added.	p_H of soil.	Height of plant.	Yield of Grain.	Yield of Straw.	Yield total.
		g.		cm.	g.	g.	g.
1—2.		0	4.63	38.15	0.32	3.15	3.47
3—4.	a)	16.52	5.02	45.30	1.06	5.81	6.87
5—6.	b)	30.03	5.68	47.12	0.89	5.19	6.08
7—8.	c)	45.92	6.04	44.20	0.65	4.65	5.30
9—10.	d)	77.70	6.42	40.15	0.58	4.24	4.82
11—12.	e)	159.61	7.53	40 01	0.52	3.18	3.70
13—14.	f)	677.60	7.92	Died. ·	. . . . .	. . . . .	. . . . .
15—16.		NPK + 0	4.52	121.65	33.46	89.91	123.37
17—18.	a)	NPK + 16.52	5.18	140.08	49.36	103.50	152.86
19—20.	c)	NPK + 45.92	5.49	150.30	43.08	86.56	130.64
21—22.		Manure + 0	5.21	72.65	4.56	9.26	13.81
23—24.	a)	Manure + 16.52	5.73	80.30	7.60	12.31	19.91
25—26.	c)	Manure + 45.92	5.86	78.62	5.31	8.98	14.29

Estimation of lime was made by: a), DAIKUHARA's method; b), JONES's method; c), HUTCHINSON and MACLENNAN's method; d), Neutralization method of hydrolytic acidity; e), HARADA's method and f), HISSINK's method as noted in the table.

to confirm whether such factor is related to the plant growth, Daisen-bara uncultivated soil which is one of the most typical unproductive soil was taken, neutralized with calcium carbonate and the rice was grown in pots as follows :

To a pot containing 7 kilograms air dried soil was placed and 9 plants were planted, and an average of 3 years tests (1931—1933) was taken and are given in Table 13.

As indicated in Table 13, only a slight improvement was noted with the use of a small amount of the lime and it was best when the amount of lime added just enough to neutralize the exchangeable acidity by DAIKUHARA's method ; and when the addition of lime exceeded this amount, was injurious to plant.

Though the treatment on unfertilized pot improved the plant growth slightly, the condition of plant was such that it was merely kept alive. Therefore, the unproductiveness of this soil could not be improved by mere means of adding calcium carbonate alone.

2. *Effect of Saturation of Soil with Acid or Base.*

In order to study the relation between the exchangeable bases and the growth of plant, Daisen-bara uncultivated soil was saturated with 1 normal

Table 14.

The Effect of Various Acids and Bases on the Plant Growth.

Pot No.	Acid or base used.	Unfertilized.			Fertilized (NPK).		
		Height of plant.	Yield of		Height of plant.	Yield of	
			Grain.	Straw.		Grain.	Straw.
		cm.	g.	g.	cm.	g.	g.
1—2.	K.	38.31	0.078	2.10	81.37	4.71	12.36
3—4.	Na.	28.18	0.033	2.11	84.21	3.23	6.72
5—6.	NH_4. . . .	28.28	0	1.51	58.36	0.59	2.49
7—8.	Mg.	29.15	0.079	2.20	80.25	5.86	10.62
9—10.	Ca.	37.76	0.185	2.83	87.17	5.89	14.13
11—12.	Fe.	28.16	0.085	2.10	71.38	2.68	11.24
13—14.	Al.	25.31	0.041	1.00	70.51	1.00	4.15
15—16.	Mn.	27.87	0.063	2.06	69.36	2.62	5.81
17—18.	HCl. . . .	53.61	0.278	2.51	83.15	4.95	18.53
19—20.	H_2SO_4. . .	49.36	0.395	2.68	79.21	5.48	18.12
21—22.	HNO_3. . .	48.75	0.281	2.78	76.50	6.62	17.51
23—24.	N_3PO_4. . .	Died. .	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
25—26.	Nothing. .	25.18	0.037	1.83	91.65	4.18	9.98

ammonium, sodium, potassium, calcium, magnesium, aluminium, ferric and manganese chloride, respectively. It was then washed with distilled water until free from chloride. In the test of solution of soil with acids, 1 normal sulfuric, nitric, hydrochloric and phosphoric acid, respectively, was added to the soil and it was washed with distilled water until the wash water showed no change on Litmus paper.

One kilogram of soil thus treated was placed in a small pot and the rice was grown in fertilized and unfertilized pots, and the results are given in Table 14.

As indicated in Table 14, the saturation of black soil with various bases had no great effect on plant growth ; among the bases, Ca, K, Mg etc. were slightly effective, while Na, Fe or Mn had little or no effect and rather injurious to plant, and the saturation of soil with NH_4 and Al were decidedly injurious. Since the saturation of the soil with bases had no great benefit but injurious to plant as in the case of NH_4 or Al and the saturation of soil with acids, HCl, HNO_3, H_2SO_4 etc. gave unexpectedly good result, it is unwise to consider that an unproductiveness of this soil is due to its acidity and unsaturation of bases, but the presence of soluble aluminium is more likely responsible for its ill effect.

Consequently the removal of soluble aluminium with acid treatment seems to have more benefit than the loss of bases. The cause of very poor result obtained by the phosphoric acid treatment might have been due to an exceedingly high absorbing power of phosphoric acid by the soil, and the acidity of soil became too high even though the washings were repeated till the wash water was neutral.

3. *Effect of Application of N, P and K Fertilizers.*

Inasmuch as the unproductiveness of the soil may be related to the lack of nitrogen and available phosphoric acid, uncultivated Daisen-bara soil was taken for the study of fertilizer efficiency during 1931—1933. The method of experiment was similar to that of neutralization test ; the amount of fertilizers given per pot annually was 1.25 gm. N as ammonium sulphate, 1.25 gm. P_2O_5 as superphosphate and 1.25 gm. K_2O as potassium sulphate. The conditions of growth and the yield were nearly alike in each year, therefore, only the results of 1932 are given in Table 15.

As shown in the table nitrogen had no benefit when it was used alone or with potash but its efficiency was increased when it was used with phosphoric acid and it gave twice as much yield than the single use of phosphoric acid ; this efficiency was still greater when nitrogen, phosphoric acid and potash were combined and the yield was 2.5 times as much more than the single use of phosphoric acid.

Potash showed no fertilizer efficiency when it was used alone or with nitrogen and a slight increase in yield to the extent of 10—20 percent was noted when it was combined with phosphoric acid.

Phosphoric acid showed great efficieney even in case of its single use. The yield of grain was about 40 times as much more than the unfertilized pot ; the

Table 15.
Fertilizer Experiment on Nitrogen, Phosphoric acid and Potash.

Treatment.	Height of plant.	Yield of		
		Grain.	Straw.	Total.
	cm.	g.	g.	g.
Complete (NPK).	117.00	31.25	81.05	112.30
No K (NP).	118.01	25.65	66.06	91.72
No P_2O_5 (NK).	41.52	0.37	3.02	3.39
No N (PK).	96.51	13.70	35.25	48.95
N only (N).	35.00	0.30	4.15	4.44
K only (K).	33.15	0.42	4.50	4.92
P_2O_5 only (P).	91.26	12.10	31.52	43.62
Nothing.	30.06	0.28	2.75	3.03

yield of straw and total dry matter also proved good efficiency of phosphoric acid. Potash and nitrogen showed their efficiency only when they were combined with phosphoric acid.

The above results showed that superphosphate gave prominent efficiency; potassium sulphate and ammonium sulphate gave no efficiency in their single use unless they were combined with phosphoric acid.

4. *Effect of Application of Phosphoric acid and Lime.*

a) Fertilizer Efficiency of Phosphoric acid.

Since superphosphate showed great efficiency in the preceding experiment, the following experiment was made in order to confirm whether the efficiency was due to its lime or phosphoric acid. The efficiency of phosphoric acid was tested by using 1/10 mol. of various phosphates per pot and rice plants were grown and the results are presented in Table 16.

Table 16.
Fertilizer Efficiencies of Different Phosphates.

Treatment.	Height of plant.	Yield of		
		Grain.	Straw.	Total.
	cm.	g.	g.	g.
Ammonium phosphate.	120.12	29.15	94.76	123.90
Sodium phosphate.	85.56	12.62	31.25	43.87
Potassium phosphate.	90.58	16.95	47.25	64.20
Calcium phosphate.	101.26	18.70	47.70	65.73
Magnesium phosphate.	96.57	15.35	42.16	57.51
Ferric phosphate.	94.56	15.35	42.15	57.50
Aluminium phosphate.	81.61	6.55	18.00	24.55
Phosphoric acid.	95.32	15.15	40.75	55.90
Nothing.	30.16	0.28	2.05	2.33

As indicated in Table 16 the height of plant and the yield was the highest in pot with ammonium phosphate; the yield was twice as much greater than from the pot with phosphoric acid. This is in good agreement with the result that the yield from the pot with superphosphate and ammonium sulphate was twice as much more than from the pot with single use of superphosphate. Thus the yield by the use of phosphoric acid was increased twofold if it was combined with nitrogen. The yield by the use of the other phosphates was in the following order; calcium, potassium, iron, hydrogen and sodium, but there was no great difference among themselves. Only aluminium phosphate showed less height of plant and the yield was 1/2 of that of phosphoric acid; however the yield was much greater than unfertilized pot. In general all the phosphate showed good efficiency, though there were some differences by the use of different cations.

b) Fertilizer Efficiency of Lime.

In order to test the fertilizer efficiency of lime, various calcium salts were used as in the preceding experiment and the results are given in Table 17.

Table 17.
Fertilizer Efficiencies of Calcium salts.

Treatment.	Height of plant.	Yield of		
		Grain.	Straw.	Total.
	cm.	g.	g.	g.
Calcium chloride.	22.12	0.25	2.20	2.45
Calcium sulphate.	32.15	0.26	3.25	3.51
Calcium nitrate.	24.52	0.18	2.45	2.63
Calcium acetate.	31.51	0.27	3.15	3.42
Calcium oxide.	33.51	0.27	3.35	3.62
Calcium carbonate.	41.62	0.65	4.01	4.70
Calcium phosphate.	101.26	18.70	47.03	65.73
Nothing.	30.06	0.28	2.05	2.33

The height of plant and the yield, as indicated in Table 17, was the highest in pot with calcium phosphate and the result from using the other salts were nearly alike as that of unfertilized pot. Among the acids, phosphoric acid showed remarkable high efficiency and all other acids were not efficient. Bases gave little or no efficiency in their single use unless they were combined with phosphoric acid as in the case of ammonia, and the efficiencies of the other bases were in the order named; Ca, K, Fe, H, Na and Al. The efficiency of Al was about 1/2 of that H.

5. *The Relation between P and Al.*

It was previously proven that the black soil contained high free-, active-, and exchangeable aluminium and also more aluminium in the soil solution.

Especially when the soil had inorganic fertilizer treatment, so that the injurious effect of aluminium on plant growth was considered in relation to this study. The unproductiveness of the soil on account of having such aluminium which can be improved by the treatment with phosphoric acid, has been proven already by BLAIR and PIERRE[2], BURGESS[4] and MIRASOL[14]. In this experiment, soluble forms of aluminium sulphate and aluminium chloride were added to this soil in order to study the relation between aluminium phosphoric acid, as follows: To a pot containing 7 kilograms Daisen-bara soil, 10 grams each of superphosphate and aluminium salt were added and the rice was grown. The results are shown in Table 18.

Table 18.
Toxic Action of Aluminium salts.

Treatment.	Height of plant.	Yield of		
		Grain.	Straw.	Total.
	cm.	g.	g.	g.
Superphosphate.	84.15	13.25	26.52	39.77
Superphosphate + $Al_2(SO_4)_3$.	81.62	12.75	25.53	38.31
Superphosphate + $AlCl_3$.	84.00	13.56	26.86	40.42
$Al_2(SO_4)_3$.	25.50	0	1.25	1.25
$AlCl_3$.	26.12	0	1.25	1.25
Nothing.	27.17	0.28	2.05	2.33

The results indicate that pots containing aluminium salts showed less height of plant and less yield than unfertilized, and the plant merely kept alive with no yield of grain ; pots with superphosphate in addition gave no indication of aluminium injury, showing that an aluminium injury can be prevented by adding phosphoric acid.

6. *The Optimum amount of P to be Used.*

Inasmuch as the preceding experiment gave high efficiency of phosphoric acid, 1 kilogram Daisen-bara soil was taken in each pot and different amounts of superphosphate was added to each pot in order to determine the optimum amount of phosphoric acid to be used. The rice was used as a test plant. Estimation of phosphoric acid in the straw was also made in order to determine the availability of phosphoric acid, and obtained the results noted in Table 19.

Table 19.

Estimation of Optimum amount of Phosphoric acid.

P_2O_5 used.	Phosphoric acid only.				Complete.			
	Height of plant.	Yield of		P_2O_5 in straw.	Height of plant.	Yield of		P_2O_5 in straw.
		Grain.	Straw.			Grain.	Straw.	
g. 0	cm. 4.5	g. 0.30	g. 4.20	% 0.035	cm. 4.7	g. 0.32	g. 4.26	% 0.032
0.10	10.8	3.35	7.51	0.025	101.2	13.25	16.91	0.023
0.20	11.2	3.40	7.80	0.041	107.5	14.35	18.01	0.045
0.50	11.6	3.42	8.20	0.050	108.0	14.60	21.00	0.062
1.00	11.6	3.42	8.16	0.138	110.6	15.38	22.78	0.136
2.00	12.3	3.80	8.50	0.145	112.8	16.19	26.11	0.158
5.00	10.7	3.40	8.09	0.143	109.8	15.02	24.31	0.158

Table 19 indicates that an addition of 0.1 gram phosphoric acid only or in combination with nitrogen and potash gave an exceedingly good result; increase of phosphoric acid more than this amount, gave more yield, but the rate of increase in yield was not proportional with phosphoric acid added. Phosphoric acid content in the straw was very small, and it was increased suddenly when 1 gram phosphoric acid was used. Applying 0.1 gram phosphoric acid gave more yield while the phosphoric acid content in the straw was the least.

7. *Neubauer's Test for P Assimilation.*

Preceding experiment showed clearly that only phosphoric acid gave a remarkable efficiency for the growth and yield of rice on black soil and the other elements gave efficiency only when they were used with phosphoric acid. The black soil, inspite of having great absorbing power for phosphoric acid as indicated in Experiment 1, required only a small amount of phosphoric acid to give a desired increase in yield and the fact that the phosphoric acid content in the straw was the least in the case, raised a question whether the phosphoric acid efficiency was due to a direct fertilizer value as a supplement for available phosphoric acid or its indirect value as to prevent the toxic action of soluble aluminium in the soil. A test for phosphorus assimilation was made by using NEUBAUER's technic and the rice was used in order to solve this question. The results are given in Table 20.

Table 20 gave an indication that an application of 121 milligrams phosphoric acid to 100 grams black soil was unavailable to the rice and it was likely that all phosphoric acid turned into unavailable form in the soil.

These findings indicated that the rice seems unable to utilize phosphoric acid when the content is less than 8.47 grams P_2O_5 per 7 kilograms soil. In the

Table 20.

Phosphorous Assimilation by Neubauer's Method.

P_2O_5 added.	Weight of 100 seeds.	Germination.	P_2O_5 absorbed by seedlings.	Availability of P_2O_5.
mg.	g.	%	mg.	%
0	2.5012	100.0	−1.3	
12.1	2.4852	99.0	−1.5	−12.405
31.3	2.4925	98.5	−1.3	−4.167
62.5	2.5125	100.0	−0.9	−1.440
90.5	2.4920	100.0	−0.6	−0.660
121.0	2.4892	98.5	−0.8	−0.660
312.5	2.5136	99.0	2.5	0.300
625.0	2.4523	98.5	4.5	0.720

test for fertilizer efficiencies of nitrogen, phosphoric acid and potash, however, 1.25 grams P_2O_5 per 7 kilograms soil gave the good growth and yield, and moreover, in the studies for estimation of optimum amount of phosphoric acid 0.1 gram P_2O_5 per 1 kilogram soil showed remarkable fertilizer efficiency. From these data and the results of this experiment, it is justified to consider that the benefical effect of using phosphoric acid to this soil is not as a supplement for plant nutrient but to its indirect action on soluble toxic aluminium to form an insoluble aluminium phosphate.

8. *Contents of P_2O_5, Al_2O_3 and SiO_2 in the Rice straw.*

In order to confirm the view reached in the preceding experiments, the rice straw obtained in the experiment of fertilizer efficiencies of nitrogen, phosphoric acid and potash were analyzed for P_2O_5, Al_2O_3 and SiO_2 content and the result were compared with those of the straw obtained from alluvial soil (Experiment 1, Sample C). The results are given in Table 21.

Table 21.

SiO_2, Al_2O_3 and P_2O_5 Content in the Rice straw.

Treatment.	Black soil.			Alluvial soil.		
	SiO_2.	Al_2O_3.	P_2O_5.	SiO_2.	Al_2O_3.	P_2O_5.
	%	%	%	%	%	%
Complete.	2.709	0.044	0.053	5.856	0.024	0.183
No K.	3.353	0.048	0.050	7.178	0.024	0.179
No P_2O_5.	9.641	0.062	0.036	6.801	0.022	0.133
No N.	3.473	0.048	0.054	9.513	0.022	0.159
N only.	10.561	0.058	0.038	6.236	0.020	0.133
K only.	12.168	0.062	0.032	9.265	0.020	0.134
P_2O_5 only.	4.057	0.048	0.057	9.634	0.022	0.153
Nothing.	9.469	0.054	0.039	9.385	0.022	0.139

As the above results indicate, the rice straws grown on the black soil contained very much less silicic acid when phosphoric acid was used and this difference was remarkable in comparison with the one obtained from the alluvial soil.

The upland and lowland rice grown on the black soil zone have a characteristic soft straw and have lower resistance to diseases, especially for the Blast and Helminthosporiose, of which lower silicic acid content in the straw may have something to do with the susceptability. The rice grown on the alluvial soil was less in silicic acid content when nitrogen was used and showed slight increase with the use of phosphoric acid.

Aluminium content of the rice straw grown on the black soil was two times as much greater than the one grown on the alluvial soil and its amount was still greater in the absence of phosphoric acid. Phosphoric acid content of the straw from both the black soil and alluvial soil was increased slightly by the phosphoric acid treatment, but the content of all the rice straw grown on the black soil was around 1/3 or 1/4 of that one grown on the alluvial soil. This means that nearly all phosphoric acid applied as fertilizer changed to an unavailable form for the plant.

9. *Effect of Addition of Silicic Acid.*

Experiment 1 showed that the black soil contained different amount of silicic acid and the preceding experiment showed that the rice grown on this soil gave an extremely small amount of silicic acid in the straw. On assuming that an unproductiveness of the black soil is caused by the action of soluble aluminium and silicic acid in the soil may be precipitated as aluminium silicate as in the case of aluminium phosphate in the case of phosphoric acid. An experiment was made to study the effect of using "Sokuhiso" (a commercial preparation containing magnesium silicate) on the black soil and the rice was grown, and obtained the following results (Table 22).

Table 22.

The Effect of Using "Sokuhiso" on Rice.

Treatment.	Black soil.				Alluvial soil.			
	Height of plant.	Yield of Grain.	Yield of Straw.	SiO_2.	Height of plant.	Yield of Grain.	Yield of Straw.	SiO_2.
	cm.	g.	g.	%	cm.	g.	g.	%
Nothing.	30.06	2.40	8.40	9.469	121.31	28.80	61.80	9.385
"Sokuhiso". . . .	48.31	6.20	14.24	12.934	120.98	29.02	63.15	9.812
NPK.	117.00	29.15	73.30	2.709	138.45	82.65	164.95	5.856
NPK+"Sokuhiso".	109.38	35.05	93.55	7.145	137.93	81.89	159.38	6.132

As the above data indicate, "Sokuhiso", though it had no beneficial effect on the rice grown on the alluvial soil, made better growth, more yield, increased the strength and improved the color of the straw, and increased the resistance toward diseases on the rice grown on the black soil.

Next the various amounts of calcium silicate were used for the same purpose on 1 kilogram Daisen-bara soil, and the conditions of growth and the yield of rice are shown in Table 23.

Table 23.

The Effect of Calcium silicate on Rice.

Calcium silicate added.	Unfertilized.				Fertilized (NPK).			
	Height of plant.	Yield of		SiO_2.	Height of plant.	Yield of		SiO_2.
		Grain.	Straw.			Grain.	Straw.	
g.	cm.	g.	g.	%	cm.	g.	g.	%
0	28.2	0	3.0	7.381	88.0	12.8	18.7	2.135
0.5	43.2	1.1	4.2	7.453	87.0	14.3	18.9	3.253
1.0	40.0	1.3	4.2	7.404	86.5	14.5	17.8	3.492
2.5	47.0	1.8	5.0	8.362	88.0	18.6	19.6	5.498
5.0	48.5	2.4	5.4	8.849	90.6	24.2	21.6	7.352
10.0	55.5	2.7	5.5	9.215	93.2	31.5	24.0	8.125

Application of calcium silicate on the black soil, as in the case of using "Sokuhiso", better growth and more yield were obtained and increased the silicic acid content of straw were obtained in proportion to the amount used.

10. *Discussion of the Results obtained in Part II.*

Since the defective chemical and physical characteristics of the black soil were outlined in Part I of this investigation, the laboratory findings are contrasted with the pot experiments in Part II.

All the laboratory findings such as lack of bases, especially in lime, and high acidity are corrected by neutralization of exchangeable acidity and hydrolytic acidity; the deficiency of lime is supplied by using the methods of JONES and HUTCHINSON and MACLENNAN and the unsaturation of base is corrected by using HARADA's calcium carbonate method or by HISSINK's baryta method. The result indicated that lime was most effective with the least amount of application which was just enough to neutralize its exchangeable acidity was used and an increase of lime more than this amount was injurious. Beside, experiment of saturating the soil with various acids and bases proved that the saturation of the soil with acids other than phosphoric acid was most effective than using bases. These findings suggest that the acidity and lack of base in black soil are not so greatly related to the growth of rice.

Since the carbon-nitrogen ratio of uncultivated black soil was 22 and the soil had twice as much greater absorbing power of nitrogen than alluvial soil, it would have given correspondingly greater nitrogen efficiency. But, fertilizer experiment for nitrogen, phosphoric acid and potash indicated that nitrogen gave no efficiency when it was used singly or with potash ; the efficiency, however, was increased when it was used with phosphoric acid and it gave twice as much yield than single use of phosphoric acid. Potash also gave efficiency when it was used with phosphoric acid. Phosphoric acid, on the other hand, gave great efficiency without any supplement or more with potash and nitrogen.

There was no efficiency of lime supplied with various calcium salts, except that of calcium phosphate.

Phosphoric acid played such great rôle on the growth and yield of rice on the black soil and the other fertilizer components gave their efficiency only when they were supplied with phosphoric acid.

Phosphoric acid efficiency, however, was not for directive value as a supplement of the plant nutrient, but it was of indirective value for preventing the toxic action of aluminium present in the soil in large quantity with the following reasons :

1. Weathering of black soil reached to such an extent that silicic acid and bases are lost by washing and an accumulation of aluminium caused the liberation of free aluminium ; the soil complex is in a very unstable form which may set free aluminium even in the presence of very weak acid. In fact, this soil contained higher active aluminium than any soil found in the United States ; the soil solution contained also higher amount of aluminium. This is especially true in soil with the treatment of chemical fertilizers.

2. In case of solution of black soil with various acids and bases, saturation with aluminium found to be very toxic.

3. It seems that saturation of black soil with acids may give an injurious effect on plant growth as it causes an increase in acidity and loss of bases ; experimental result, however, gave an unexpectedly good effect which might have been due to the loss of soluble aluminium together with the other bases.

4. Usually, nitrogen gives high efficiency when it is applied on soils poor in this element, but, it showed no benefit to this soil unless it is applied with phosphoric acid.

5. Injurious effect of soluble aluminium contained in black soil can be prevented by the use of phosphoric acid.

6. Black soil is poor in lime, high in acidity and in phosphoric acid absorption. According to CAMERON and HURST[4] and FRED[5], application of phosphate to the soil poor in calcium carbonate made the formation of insoluble aluminium and iron phosphate ; GAARDER[6] has a view that the precipitation of phosphate in the soil will be iron and aluminium phosphate under acid condition and calcium

phosphate under neutral condition. These theories suggest that an availability of phosphoric acid in black soil should be notriously low, yet the plant made good growth with surprisingly small application of phosphoric acid.

7. NEUBAUER's test for available phosphoric acid indicated that the rice was unable to take it when the application was 8.47 grams per pot containing 7 kilograms soil; yet in the test to determine the fertilizer efficiencies of nitrogen, phosphoric acid and potash, only 1.25 grams and in the determination for optimum amount, only 0.1 gram phosphoric acid gave superior efficiency.

8. In the experiment to determine the optimum amount of phosphoric acid for the best growth and yield, rice straw grown in pot containing 0.1 percent phosphoric acid which showed remarkable efficiency contained less phosphoric acid; phosphoric acid content was increased by the increased use, but the growth and yield were not proportional to the amount of application.

9. Test on fertilizer efficiency of nitrogen, phosporic acid and potash indicated that the content of phosporic acid in rice straw was around 1/3 or 1/4 of that grown on alluvial soil; and it is rather doubtful if the plant utilized the phosphoric acid as a plant nutrient, even in case when the fertilizer efficiency is shown.

10. The efficiency of silicic acid which has chemical similarity with phosphoric acid is great for black soil; it made the straw stronger, increased the resistance to insects and diseases, and better growth and yield.

11. Aluminium content of the rice straw grown on black soil was two times as much greater than that grown on alluvial soil.

IV. Summary.

From the results obtained in this investigation, the following summary may be made:

The black soil has the mechanical and physico-chemical characteristics listed below:

1. It is extremely light due to its lower density and volume weight.

2. Though it has high water absorbing capacity, the absorbed water passes out quickly due to its large pore spaces and consequently it is susceptable to drouth.

3. It is in a condition of basal unsaturation and high acidity with the result of washing off the bases, especially of lime.

4. Though the soil has high absorbing capacity for nitrogen and phosphoric acid, it lacks in these plant nutrients.

5. Washing off silicic acid and an accumulation of aluminium caused the liberation of colloidal free aluminium to the extent of 4 percent.

6. Aluminium contained in the soil is in a very unstable form which can be dissolved out largely with even an extremely small amount of acid; the amount

of active aluminium and the aluminium soluble in neutral salt solution. The content of aluminium in soil solution is high, especially in soil which became unproductive with continuous use of chemical fertilizers.

As to the causes of unproductiveness, the following factors were observed:

1. The primary cause of unproductiveness is due to an injurious action of soluble aluminium, directly or indirectly.

2. The secondary cause is the lack of plant nutrients, especially of nitrogen, phosphoric acid, lime and silicic acid; the soil is in the condition of basal unsaturation and high acidity.

3. Poor physical properties of the soil.

The following methods are suggested to improve the black soil in question:

1. Fundamental improvement of the soil is made by continuous application of manure or barnyard manure, with the addition of mixed fertilizers, containing mainly of superphosphate.

2. Proper selection of drouth resistant crops.

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