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Study on the Salt Tolerance of Rice and Other Crops in Reclaimed Soil Areas (VII)

On the Optimum Ratio of Phosphate and Potash to N Fertilization for Rice Plant in the Reclaimed Salty Areas.※

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干拓地에서 水稻 및 其他作物의 耐鹽性에 關한 硏究 (第7報)

鹽分干拓地에서 水稻의 N 施肥의 變動에 따르는 P와 K의 反應에 關하여

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ABSTRACT

The rice variety, Nongkwang was used in two factorial experiments with the combination of 15 kg and 20 kg of N per 10 a, 3 levels of P_2O_5 (0, 4 and 8 kg per 10 a) and 4 levels of potash (0, 2, 4 and 8 kg per 10 a) in the reclaimed soil areas containing 0.48% on the average salt content throughout the year (0.67% at the end of April).

The absorption of N, K and Ca was accelerated by increased N applications. The absorption of P itself was not enhanced by the increased application of P_2O_5 but the absorption of K_2O reduced the absorption of Mg was affected. The increased application of K_2O reduced the absorption of Si and seemed to increase the content of carbohydrate in the rice plants.

Twenty kg of N and 4 kg of P_2O_5 per 10 a produced satisfactory yields of rough rice, potash applications are ineffective in this experiment on rice grain production.

INTRODUCTION

The results of the first year experiments (Im, 1967) revealed that an increased application of fertilizer over the standard application (N 10 kg, P_2O_5 8 kg and K_2O 8 kg per 10 a) did not increase the rice yield in the non-salty area, while 2 and 1.5 times of the standard application of N showed outstanding effect in both low-salty area (0.5% of salt content at the end of April) and high-salty area (1.0% of salt content at the end of April), respectively. The yield was not increased by any treatment over 8 kg per 10 a of P_2O_5 in the above two plots while K_2O did not show any effect on each salty plot.

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Reports indicate the satisfactory results of an increased N application in the reclaimed soil area on increasing rice yields (Im, 1967; Shimose, 1956 a, b, 1958). According to Yoneda (1958 a,b) and Shimose (1965), 1.5 and 2 times the standard fertilization rate of N is favorable for the growth of the rice and barley in the reclaimed area. They also reported that an additional application of N reduces salt damage when the damage symptoms appear.

According to the report of Honam Crop Experiment Station(1966), 9 to 12 kg of N per 10 a brought about satisfactory productivity and the largest yield was produced with 12 kg of N per 10 a application. It was further reported that by strip fertilization four times during the growing season was most favorable to high rice yields.

It is considered that the high effectiveness of N fertilization in the salty area may involve less N in soil, acceleration of N absorption and a check or decline in the Na absorption (Im, 1967) in the reclaimed salty soil. However the basic mechanism has not been clearly understood(Shimose, 1963 a, b, 1956; Shimose & Mifune, 1956). Although it is apparent that 1.5 to 2 times the standard application for the non-salty area produce good yields in the reclaimed soil area, there has been few experiment conducted on the fertilization of rice with phosphatic and potassic materials (Im, 1967).

The first year experiments (Im, 1967) showed that the higher the salt concentration the larger the phosphate content present in the experimental plots. According to Yoneda (1953 a, b), the effectiveness of P_2O_5 becomes high due to the formation of acid phosphoric alkali in the reclaimed soil area of alkalic Na-Mg clay and Cl absorption is checked when a large amount of P_2O_5 is supplied. Yoneda and Shigeda(1957) indicated that P_2O_5 leaching occurs together with alkalic leaching as time passes after reclamation. Therefore it is desired to pay a special attention to the application of P_2O_5 in the reclaimed salty soil area.

As observed in the first year experiment (Im, 1967), K_2O absorption was checked throughout the full growth stage in the salty area (Im, 1967; Pearson, 1959). Shimose(1959, 1958) reported that K_2O absorption varies differently at the later growth stage of rice plant than the early growth stage. The reclaimed area contains originally a large amount of K_2O (Im, 1967) and it may be readily presumed that the antagonism of K^+ absorption occurs due to an excessive Na^+ absorpton. However, considering the symptom of salt damage that is commonly similar to the deficiency of K_2O. The function of K_2O as an activator of enzyme within the plant body and disturbance of metabolism by the deficiency of K_2O, the study on K_2O nutrient and fertilization of rice plant is considered to be of great importance. It is reported that the disturbance of Ca and Mg absorption except K also occurs and the SiO_2(Im, 1967; Shimose, 1959) absorption is accelerated in the salty area (Im, 1967; Shimose, 1956, '58, '64).

As described above the nutritional absorption of mineral elements substances and their metabolism by the rice plant is not simple in the salty area. Therefore, the present experiments are intended to investigate the optimum application of P_2O_5 and K_2O fertilizers to N levels and its effect on the metabolism of inorganic nutrients and yield components.

MATERIALS AND METHODS

This experiment was performed by dividing the combination of the following treatments of the three fertilizer elements into the first and second experiments:

N:	N	15, 20	2 levels(Kg/10 a)
P:	P_2O_5	0, 4, 8	3 levels(〃)
K:	K_2O	0, 2. 4, 8	4 levels(〃)

First experiment:

Treatment number	N—P—K	Treatment number	N—P—K
F_1:	15—8—0	F_5:	20—8—0
F_2:	15—8—2	F_6:	20—8—2
F_3:	15—8—4	F_7:	20—8—4
F_4:	15—8—8	F_8:	20—8—8

Second experiment:

Treatment number	N—P—K	Treatment number	N—P—K
F_9:	15—0—4	F_{12}:	20—0—4
F_{10}:	15—4—4	F_{13}:	20—4—4
F_{11}:	15—8—4	F_{14}:	20—8—4

The rice variety, Nongkwang, was sown in the seed bed on April 27. The standard method normally used in the non-salty area for the fertilizing management of the seed bad was practiced. Transplantation was done with 7 plants per hill at intervals of 21 cm by 15 cm on June 13. The salt concentration at the transplanting period of the silt loam soil was 0.61%. The plot size was 6m×3m. Each plot in the factorial design was replicated 3 times. The ratio of N application for basal, tillering and heading was 3 : 4 : 3.

RESULTS AND DISCUSSION

1) Absorption of mineral nutrients

Investigation was conducted on the absorption of mineral nutrients and the content of carbohydrate at the time of increased fertilization with N, P_2O_5 and K_2O in the salty area (0.41% of salt content at hending stage).

As observed in the first year experiment(Im, 1967), an increased application of N accelerated the absorption of N, K and Ca in the salty area (Im, 1967). Shimose (1965) reported that the increased application of N under salty soil condition increased the total N, soluble N, carbohydrate and phosphate of the rice plants However, there was observed no increase in the content of carbohydrate in the present experiments.

It is considered that the absorption of N and P may be generally enhanced by N fertilization in the salty area (Gauch & Wadleigh, 1944; Im, 1967; Shimose, 1958, 1963). According to Shimose (1956 a, b), the N treatments bring about changes in the free amino acid and amides within the plant body and increases the content of the N compounds such as amides and amino acids.

Although the increased application of phosphates did not affect the absorptioin of other ions as observed in the first year experiment (Im, 1967), it did affect the Mg absorption. It seemed also to reduce the content of carbohydrate.

It is reported that the increased application of P_2O_5 accelerates generally the P absorption (Im, 1967, Omori & Kawanaka, 1966; Shimose, 1958, 1963). According to Lagerwerff and Holland (1960), the P absorption is affected rather by SAR than salinity under salt conditions. Increased applications of K reduced the absorption of Si and increased the carbohydrate content. It is a widely known fact that K is significantly concerned with the physiological function in the metabolism of carbohydrate. However, a further study is considered necessary on the disturbance of Si absorption by the increased application of K_2O in the salty area. It is reported that the absorption of Si is accelerated, in general, under salty conditions(Im, 1967; Shimose, 1956, '58, '59).

Table 1. Chemical Analysis Data of Plant Materials(Heading stage, dry weight, %)

N-P-K	Total N	P_2O_5	K_2O	CaO	MgO	Na_2O	SiO_2	Total Carbo-hydrate
15-8-0	0.54	0.14	1.54	0.28	0.23	0.95	10.00	30.3
15-8-4	0.58	0.15	1.32	0.32	0.16	1.01	8.10	30.3
15-8-8	0.58	0.17	1.38	0.28	0.22	1.00	6.94	38.8
15-0-4	0.54	0.14	1.39	0.25	0.23	0.92	8.97	38.8
15-4-4	0.70	0.15	1.58	0.32	0.21	0.96	8.17	43.4
15-8-4	0.58	0.15	1.32	0.32	0.16	1.01	8.10	30.3
15-8-8	0.58	0.17	1.38	0.28	0.22	1.00	6.94	38.8
20-8-8	0.73	0.22	1.64	0.42	0.26	0.92	7.00	36.6

There are many reports (Bernstein, 1964; Kim, 1958; Pearson, 1959; Shimose, 1956, '58, '59, '63, '64) indicating that the incresed absorption of Na^+ and Cl^-(Bernstein, 1964; Im, 1967; Kim, 1958; Omori & Kawanaka, 1966; Shimose, 1956) affects the K^+ in the rice plant under salty condition. According to Osawa (1961), a large amount of Na^++K^+ in the leaves of vegetables indicated a strong salt tolerance. It is considered, therefore, that the effect of K absorption is closely related to the mechanism causing salt damage to rice. There are some different reports (Kim, 1958; Im, 1967; Omori & Kawanaka, 1966; Shimose, 1956, '63, 1964 a, b; Shimose & Miyake, 1957) maintaining that the increased, reduced and does not affected the Ca absorption etc. in many plants grown in salty area. It has also been reported that the absorption of Mg is not affected or accelerated etc. by salty conditions (Im, 1967; Kim, 1958; Osawa, 1960, 1961; Shimose, 1963).

Most of these results were obtained from water and pot culture. As discussed previously it seemed that the absorption and accumulation of cations vary and the results observed were also vary according to the composition of each cation of the culturing soil in addition to salt content

Table 2. The Effects of N, P and K on the Yield Components.

	K_2O (kg/10a)					P_2O_5 (kg/10a)			
	0	2	4	8	Aver.	0	4	8	Aver.
Culm length (cm)									
N_{15}	110.3	111.6	111.2	114.0	111.8	112.3	112.9	111.2	112.1
N_{20}	115.7	119.3	114.6	115.9	116.4	118.0	118.8	114.6	117.1
Aver.	**113.0**	**115.5**	**112.9**	**115.0**	**114.1**	**115.2**	**115.9**	**112.9**	**114.6**
Length of panicle (cm)									
N_{15}	20.6	20.3	20.7	21.3	20.7	20.8	21.1	20.7	20.9
N_{20}	21.8	22.1	21.2	21.2	21.6	22.0	21.9	21.2	21.7
Aver.	**21.2**	**21.2**	**21.0**	**21.3**	**21.2**	**21.4**	**21.5**	**21.0**	**21.3**
No. of panicle									
N_{15}	10.6	10.4	10.0	10.5	10.4	10.6	10.6	10.0	10.4
N_{20}	11.3	12.3	12.8	11.9	12.1	12.6	11.9	12.8	12.4
Aver.	**11.0**	**11.4**	**11.4**	**11.2**	**11.3**	**11.6**	**11.3**	**11.4**	**11.4**
Wt. of panicle (g)									
N_{15}	1.55	1.73	1.79	1.76	1.71	1.52	1.71	1.79	1.67
N_{20}	1.69	1.63	1.52	1.60	1.61	1.40	1.63	1.52	1.52
Aver.	**1.62**	**1.68**	**1.66**	**1.68**	**1.66**	**1.46**	**1.67**	**1.66**	**1.60**
1,000 grains weight (g)									
N_{15}	26.4	25.8	24.5	25.0	25.4	25.3	25.9	24.5	25.2
N_{20}	24.4	25.4	24.3	23.8	24.5	24.4	24.6	24.3	24.4
Aver.	**25.4**	**25.6**	**24.4**	**24.4**	**25.0**	**24.9**	**25.3**	**24.4**	**24.8**
No. of grains per panicle									
N_{15}	65	75	85	80	76	69	71	85	75
N_{20}	85	78	72	80	78	68	75	72	72
Aver.	**75**	**77**	**79**	**80**	**78**	**68**	**75**	**79**	**74**
Ratio of matured grain (%)									
N_{15}	87.0	86.1	81.2	85.1	84.9	83.4	89.7	81.2	84.8
N_{20}	78.0	75.9	80.7	82.1	81.2	84.7	82.8	80.7	82.7
Aver.	**82.5**	**81.0**	**81.0**	**83.6**	**83.1**	**84.1**	**86.3**	**81.0**	**83.8**
Wt. of rongh rice (kg/10 a)									
N_{15}	494	540	537	554	531	483	554	537	525
N_{20}	575	601	583	572	583	558	582	583	574
Aver.	**535**	**571**	**560**	**563**	**557**	**521**	**568**	**560**	**550**

especially the SAR, growth stage, and kinds of plants (Omori & Kawanaka, 1966).

2) Yield components

Table 2 shows that increased fertilization with N increased the length of culms and panicle, increased the number of panicles and reduced the panicle weight. It also reduced the weight of 1,000 grains and the ratio of matured grains while the number of grains per panicle was little affected. The tendency indicated by these characteristics was almost the same as that observed in the first year experiment (Im, 1967).

According to Park (1965), the increased application of N to the non-salty paddy field brought about an increase in the number of panicles, reduced the ratio of matured grains and the number of grains per panicle was decreased. In the present experiments, however, the number of grains per panicle was not decreased even by an increased N fertilization from 15 kg of N to 20 kg in the salty area (Matsushima & Manaka, 1962).

Tsuno and Shimizu (1962) reported that the number of grains per panicle is closely correlated to the N content of the leaf blades at the heading stage and to the number of the secondary rachis from the morphological point of view (Matsushima & Manaka, 1962). It was considered that higher living activity (Im, 1967) at the later growth stage of the rice plants in the salty area may have been influenced to a great extent. As reported by Park (1965), a negative correlation was observed between the content of N and Mg in the rice plants and the ratio of matured grains in the salty area.

It was observed within the scope of the present experiments that the panicle weight and the number of grains per panicle seemed to be enhanced by the increased application of phosphate. In the first year experiments (Im, 1967) there was observed no effect of phosphate fertilization on the above two factors. It is felt necessary that a further investigation should be carried out.

The potash fertilization in the salty area increased the number of grains per panicle. It may be interesting to further investigate the mechanism of this phenomenon.

3) Yield of rough rice

The increased application of N showed a significant difference of 1% in both the first and second experiments. This is illustrated in Fig. 1 as the fertilization with 20 kg of N per 10 a increased significantly the yields than the 15 kg of N application.

In the compound experiment(Im; 1968) of planting density with 8 kg of P_2O_5, K_2O per 10 a and three N fertilizing levels (10 kg, 15 kg and 20 kg per 10 a) on the rice variety Kusabue, no significant difference was observed in the yield of rough rice between the fertilization 15 kg of N and 20 kg. This phenomenon is considered to appear by the different reaction of N fertilization on different rice varieties.

Yoneda (1958) indicated that the nitrogen economy of the reclaimed soil is not simple; i.e. (1) the available nitrogen content is very small because of meager number and weak activity of *Azotobacter*, (2) the N fertilizer is absorbed and fixed in the soil and (3) the soil at the early stage of reclamation requires a large amount of N because of the occurrence of smaller amount of disintegration than N required for the formation of humus. Bernstein and Ogata(1966) reported the delay of the nodulation of the leguminous plants and the ammonification and nitrification activities in the salty area (Kapp, 1947; Yoneda, 1958).

According to the report of UNDP (SF)(1965, 1968) on many replicated experiments conducted in paddy fields throughout Korea, 10 kg of N per 10 a appears to be the optimum rate of N fer-

Table 3. Yields of Rough Rice and Various Agronomic Characteristics from the Fertilization Experiment.

Treatment	Culm length (cm)	Length of panicle (cm)	No. of panicle	Wt. of panicle (g)	1,000 grain weight (g)	No. of grains per panicle	Ratio of matured grain (%)	Wt. of rough rice (kg/10a)
F_1 (15-8-0)	110.3	20.6	10.6	1.55	26.4	65	87.0	494
F_2 (15-8-2)	111.6	20.3	10.4	1.73	25.8	75	86.1	540
F_3 (15-8-4)	111.2	20.7	10.0	1.79	24.5	85	81.2	537
F_4 (15-8-8)	114.0	21.3	10.5	1.76	25.0	80	85.1	554
F_5 (20-8-0)	115.7	21.8	11.3	1.69	24.4	85	78.0	575
F_6 (20-8-2)	119.3	22.1	12.3	1.63	25.4	78	75.9	601
F_7 (20-8-4)	114.6	21.2	12.8	1.52	24.3	72	80.7	583
F_8 (20-8-8)	115.9	21.2	11.9	1.60	23.8	80	82.1	572
F_9 (15-0-4)	112.3	20.8	10.6	1.52	25.3	69	83.4	483
F_{10}(15-4-4)	112.9	21.1	10.6	1.71	25.9	71	89.7	554
F_{11}(15-8-4)	111.2	20.7	10.0	1.79	24.5	85	81.2	537
F_{12}(20-0-4)	118.0	22.0	12.6	1.40	24.4	67	84.7	558
F_{13}(20-4-4)	118.8	21.9	11.9	1.63	24.6	87	82.8	582
F_{14}(20-8-4)	114.6	21.2	12.8	1.52	24.3	72	80.7	583

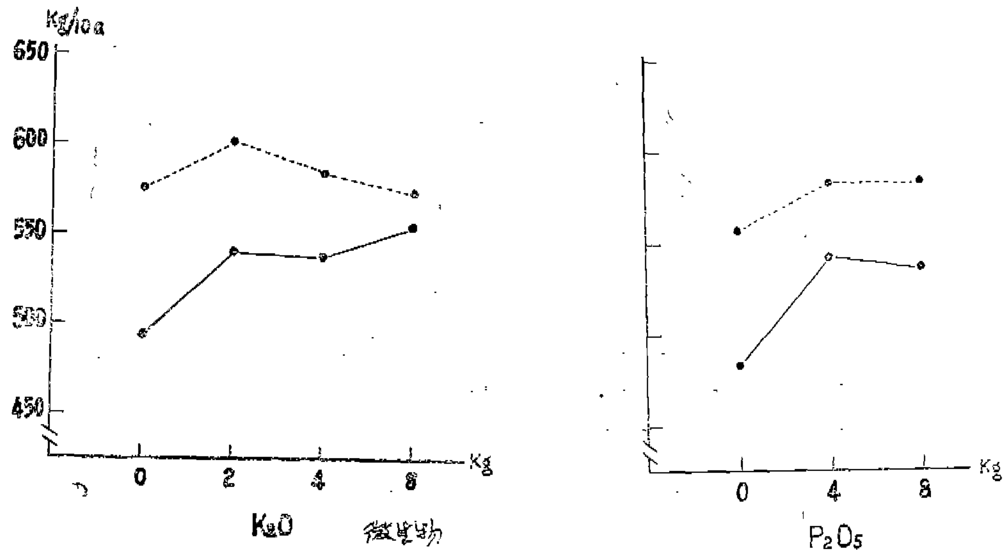

Fig. 1. Effects of phosphate and potash treatments on yields of rough rice.
●——● : N 15kg/10a, ●……● : N 20kg/10a

tilization for non-salty areas. It indicated further that the maximum point of rough rice yield is N 12 kg, P_2O_5 6 kg and K_2O 8 kg per 10 a. The present experiments have show that the N requirement is much greater in the salty area than the non-salty area.

The fertilization of phosphate showed a significant difference of 5 %. Fig. 1 shows that 4 kg and 8 kg of P_2O_5 per 10 a produced almost the same rough rice yields. Therefore, it is considered that the optimum amount of fertilization is 4 kg per 10 a of P_2O_5 in the reclaimed salty paddy fields.

Lee et al. (1968) indicated that the effect of phosphorus carrying fertilizer on rice plant in the ordinary paddy field in Korea is lower that than in other countries. The UNDP (SF) report (1965) also points out this fact and that 6 kg per 10 a of P_2O_5 is effective in increasing rough rice yield in non-salty paddy fields. Yoneda (1957) and Shimose (1966) cited the phenomenon of alkalic leaching of phosphate on the reclaimed area and reported that the optimum amount of phosphoric acid on wheat is 6. 5 kg per 10 a. The experiment on the fertilization of phosphate in the reclaimed salty area of Korea has been rarely studied.

As observed in the first year experiment (Im, 1967), effect of potash fertilization was also negative in the present experiment. The increased application of K_2O at the peak of 2 kg per 10 a reduced markedly rough rice yields in the 20 kg of N per 10 a plots as illustrated in Fig. 1, while the application of K_2O over 2 kg increased rough rice yield by 35 kg per 10 a on the 15 kg of N plots when compared with the non-potash plots. Therefore, it was felt necessary to continue experiment on the potash.

The UNDP (SF) report (1965) indicated that increased K_2O fertilization (Hong, 1966; Kapp, 1947; Oh, 1963) in the ordinary paddy field of Korea is less effective and that the maximum point of rough rice yield is 8 kg (The Association for Potash Research 1966) per 10 a of K_2O. Park (1966) reported that the application of 4 to 8 kg per 10 a was significantly effective in increasing rough rice yields in the alluvial deposit compared with the nonpotash plots. Shimose and Miyake(1957) indicated that the optimum amount of potash for rice plants is 4 kg per 10 a and that excessive applications reduce the rough rice yields in the reclaimed paddy fields of Japan.

Some fertilizing experiments (Agr. Exp. Stat., 1922, 1930, 1938) in the reclaimed paddy fields of Korea were conducted with clacium cyanamide, ammonium sulfate, compost and calcium phosphate in 1920s during which the Japanese implemented reclamation projects in the southwest coastal areas. According to the results of these experiments, increased applications of potash in the reclaimed soil area are more effective than in the alluvial deposit. However in 1967 (Im) and 1968 there was no effect of potash applications.

摘　　要

水稻 品種 農光을 供試하여 鹽分濃度 生育期間中 平均 0.48%(四月末 0.67%)의 干拓地 微砂質壤土에서 10 a當 N 15 kg과 20 kg의 2水準, P_2O_5 O, 4 kg 및 8 kg의 3水準 그리고 K_2O O, 2 kg, 4 kg 및 8 kg의 4水準을 組合한 두개의 要因實驗을 하여 아래와 같은 結果를 얻었다.

N 增肥로 N, K의 吸收가 促進되었다. P_2O_5의 增肥로 P의 吸收는 늘지 않았으며 Mg의 吸收가 阻害되는 것 같았다. K_2O 增肥는 SiO_2의 吸收를 抑制하며 稻體內 含水炭素 含量을 많게 하는것 같았다.

N 增肥로 穗數가 增加되었다. 또한 穗重과 千粒重이 줄며, 稔實率이 低下되는 傾向을 나타냈으나 穗當粒數에는 影響하지 않았다. P_2O_5 增肥로 穗重이 무거워지며 穗當粒數가 많아지는 傾向을 나타냈으며 K_2O 增肥는 穗當粒數를 增加시키는 傾向을 나타냈다.

10 a當 N 20 kg, P_2O_5 4 kg가 精租生産에서 좋은 結果를 나타냈고 K_2O는 施肥의 効果가 없었다.

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