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

Responce of Rice Population to Varying Plant Density and N Levels in Reclaimed Salty Area*

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干拓地에서 水稻 및 其他作物의 耐鹽性에 關한 研究 (第10報)

干拓地에서 栽植密度와 N 水準 變動에 對한 水稻個體群의 反應에 關하여

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ABSTRACT

Field studies were conducted with Kusabue variety and factorial design of 12 treatments composed of 3 levels, 10 kg, 15 kg and 20 kg of N per 10 a, and 4 levels of 80, 100, 120, and 140 hills per 3.3 m^2 plot in reclaimed salty area having an average of 0.48 % salt concentration.

The law of spacing effect was observed in the increase of the number of stems at any application levels of N, and the increased N application exceeding 15 kg N per 10 a did not increase the number of stems in maximum tillering stage. The light recieving efficiency of plant population was greatly reduced by close planting when compared with the effect of increased N applications in heading stage.

The spacing effect on the C/F ratio was not noted but was reduced markedly by the increased N applications, accordingly the spacing effect on rough rice yields to the LAI was less than by the increase N application. Closer spacing increased the number of panicle, and non-effective stems, decreased the number of grains per panicle and panicle weight.

The increased N applications also increased the number of panicle, reduced the weight of 1,000 grains and the ratio of matured grains. It is recommended to plant 100 hills per 3.3m^2 with the application of 15 kg N per 10 a in the reclaimed salty area of Korea.

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INTRODUCTION

There were some experiments(Buller *et al.*, 1955; Canode, 1968; Carlson, 1964; Colville, 1968; Hoag *et al.*, 1968; Miller *et al.*, 1967; UNDP, 1965) reported in recent years regarding the combined effects of N fertilization levels and plant spacings and their interactions.

The effects of planting densities on grain yields and other yield components of pea and sorghum were reported by Gritton and Eastin(1968) and Atkin *et al.* (1968). Colville (1968) investigated the micro-climate of lightness, relative humidity and temperature within plant populations of corn grown at various planting densities. He emphasized especially the effect of lightness on the ecosystem in corn farm. Kanda and Sato (1963) and Kanda and Nishizawa (1967) studied LAI and growth of rice plant populations with different planting densities. Horie *et al.* (1967 a,b) studied morphological characteristics of rice plant population with different planting densities and N fertilization levels. However, none these experiments has ever been conducted under salty soil conditions.

MATERIALS AND METHODS

The sample variety of Kusabue was cultured in an ordinary season with 12 treatments of 4 levels of plant densities and 3 levels of N dressing on reclaimed salty area (0.67% of salt content as of the end of April) with silt loam.

No. of hills per 3.3m²……………………………………………80, 100, 120, 140
N level per 10 a ……………………………………………………10 kg, 15 kg, 20 kg

The seedling grown uniformly by the standard management were transplanted in 7 plants per hill with the above planting density on June 12. The fertilizer dressing ratio for basal, tillering and heading was 3:4:3 with the basal dressing P_2O_5 8 kg and K_2O 8 kg per 10 a. The standard method of the non-salty area was applied to the maintenance and management of the plots.

EXPERIMENTAL RESULTS

1) The number of stems and plant height at the maximum tillering stage;

The number of stems per 3.3m² was remarkably increased by raising the density level per 3.3m² with changes at 10 kg, 15 kg and 20 kg levels of N per 10 a. The increase in the number of stems by the increase of density was greater in the 15 kg plot than that in the 10 kg plot, while it was not so great in the 20 kg plot when compared with that of the 15 kg plot.

The number of stems was increased evidently by an increased N dressing in each density plot, and it was more remarkable in case of sparse plantation than close plantation. The effect of increase in the number of stems per unit area was more great by close plantation with an increased number of hills than by increased N dressing.

Although there seemed no density effect, in particular, on the increase of the plant height within the treatment scope of the present experiment, the plant height was promoted by increasing the N dressing level. For instance, the average plant height in the 10 kg plots was 66.5cm,

Table 1. N Dressing Level and Planting Density Effects at the Maximum Tillering Stage

	Number of stems/3.3m²				Plant height, cm			
	N_{10}*	N_{15}*	N_{20}*	**Aver.**	N_{10}*	N_{15}*	N_{20}*	**Aver.**
D_1, (80)	1,008	1,072	1,080	**1,053**	65.6	68.8	70.1	**68.2**
D_2, (100)	1,080	1,090	1,300	**1,157**	67.0	68.2	70.7	**68.6**
D_3, (120)	1,272	1,404	1,356	**1,344**	66.7	69.9	69.3	**68.6**
D_4, (140)	1,470	1,596	1,498	**1,521**	66.5	67.7	70.4	**68.2**
Average	1,208	1,291	1,309	**1,269**	66.5	68.7	70.0	**68.4**

* N_{10}, N_{15} and N_{20}—kilograms N per 10 a.

while it was 70.0 cm, in the 20 kg plots. The effect of an increased N dressing on the plant height was also greater by sparse plantation than close plantation.

2) **Productive structure and leaf area index of plant population;**

The dry matter production of various plant populations is generally in proportion to leaf area before heading stage. However, it often correlates negatively to leaf area after heading stage. Such negative correlation is remarkable in case of close plantation with mass-fertilization. In this case the enhancement of photosynthetic efficiency by the balanced assimilation part(photosynthetic system) and non-assimilation part (non-photosynthetic system), optimum leaf area of plant population and optimum space distribution of leaf will be one of the most important factors for an increased yield under a given environmental condition.

The productive structure and LAI (leaf area index) of plant population were investigated at the panicle differentiation stage (on August 6) and heading stage(August 26), respectively. Figure 1 illustrates the productive structure when the number of hills is changed to 80, 100, 120 and 140 per 3.3m² plot with N 15 kg, per 10 a fixed and when N is varied 10 kg, 15 kg and 20 kg with planting density fixed at 100 hills per 3.3m² plot.

The left side of the center line indicates the space distribution of the assimilation part cut by stratum at 15cm intervals in each treatment plot and the right side shows the non-assimilation part and panicle part including stem and leaf sheath indicated in the weight of dry matter per 1 m². The left line represents the variance of the productive structure when the planting density is changed and the right line represents the same when the level of N fertilization is changed.

When the number of hills per 3.3m² was varied with N fertilization fixed at 15 kg per 10 a, 80 and 100 plants per hill showed almost the same pattern; i. e., predominant distribution of assimilation leaves at the height of 45—60 cm above the ground. 120 and 140 hills also showed similar pattern, the central part expanded more intensely than the former at the height of 45—60 cm and a many of the leaves were also distributed over 60—75cm stratum. It is appeared that light shortage may occur under 45cm. The productive structure of close planting was observed in case of more than 120 hills per 3.3m², and the total dry matter of the assimilation part was not increased by 140 hills compared with 120 hill per 3.3m².

There was no structural difference in particular between the non-assimilation part of 80 and

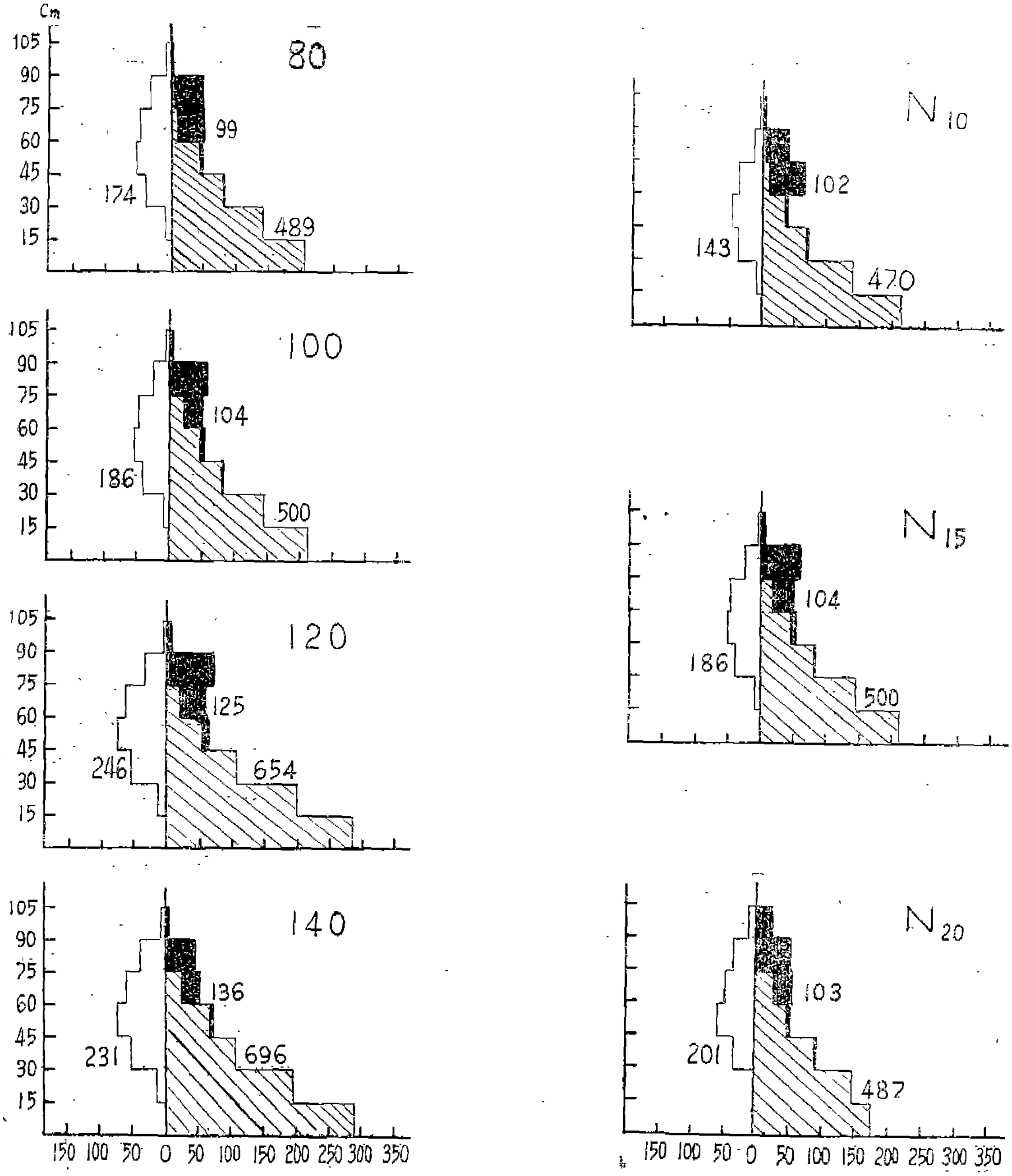

Fig. 1. Productive structure of plant population when the application N was fixed with 15 kg/10 a and the number of hills per 3.3m² was changed (left), when the number of hills was fixed at 100 and changed the application of N levels (right) at the heading stage. Figures for each treatment show dry weight of rice in grams per m².

100 hills per 3.3m^2 while 120 and 140 hills showed almost the same pattern with well developed.

The dry weight of the panicle part at heading stage became heavier by close planting. It seemed that the dry weight of panicle was closely related at this time to the number of panicles.

The productive structure of heading stage was presented by expansion of the assimilation part at the same density treatment (N 15 kg) in comparison with the structure of the panicle differentiation stage and the non-assimilation part was greatly developed by the elongation of the culms in its top portion.

In the comparison of the productive structure when N fertilization was changed with the number of hills fixed at 100, 15 kg and 20 kg of N fertilization showed almost similar effect on the assimilation parts and appeared with intense developmental pattern when compared with 10 kg treatment. The leaf distribution at the height of 45—60 cm above the ground was not intensely expanded. It is apparent, therefore, that the effect of increased N fertilization was not apparent in severe light deficiency of the lower leaves. The weight of the non-assimilation part was little or not changed by the increase of N fertilization, and also no change was observed in the weight of the panicle parts at heading stage in each treatment.

The productive structure of plant population at heading stage and that of the panicle differentiation stage were compared. The non-assimilation part developed rapidly in case of the lower N fertilization plots, while the assimilation parts were not expanded particularly in each treatment. It has been known from the results of the first year's experiment (1967) that the increase leaf area is correlated high significantly to the rough rice yield. However, the expansion of leaf area by close planting within the unit area causes naturally mutual cover and the increase of assimilation amount becomes blunt. The proportion of assmilatory capacity of population/respiration activity decreases as the weight of the non-assimilation part becomes heavier by close planting and then the material consumption follows by respiration.

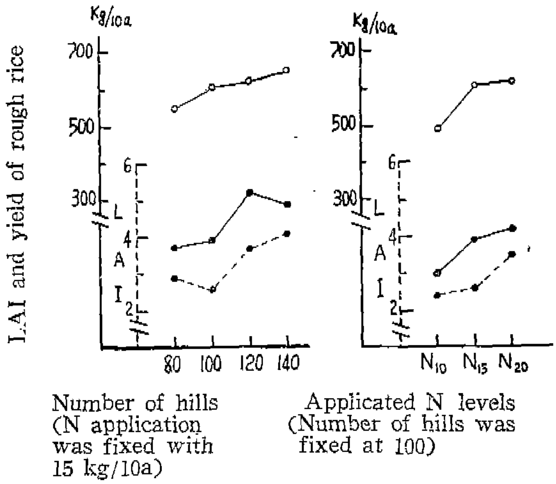

Fig. 2. Relationship between the planting density and applicated N levels and the rough rice yield and LAI.
●—● : Heading stage
●……● : Panicle differentiation stage
○—○ : Rough rice yield

It may be seen, therefore, that the expansion of leaf area by close planting reduces light receiving efficiency in its productive structure compared with increased N fertilization. As shown in the productive structure of 120 to 140 plants per hill, the excessive expansion of the middle part by overgrowth resulted in the reduction of assimilatory efficiency due to light deficiency of the lower leaves and increased respiratory consumption. It is apparent, therefore, that the production of dry matter as the balance between the photosynthetic capacity and respiratory consumption is not great.

The development of the non-assimilation and assimilation parts is illustrated in Table 2.

Table 2. *C/F of Top System at the Panicle Differentiation Stage and Heading Stage (Dry weight, gr/m²)

Treatment (Number of hills/3.3m², N levels)	Panicle differentiation stage			Heading Stage		
	Assimilation part	Non-assimilation part	C/F	Assimilation part	Non-assimilation part	C/F
80	174	318	1.83	174	588	3.38
100	153	283	1.56	186	604	3.25
120	217	390	1.80	246	779	3.17
140	242	445	1.84	231	832	3.60
N_{10}	142	297	2.09	143	572	4.00
N_{15}	153	283	1.85	186	604	3.25
N_{20}	206	352	1.71	201	590	2.94

*C/F: Non-assimilation part/assimilation part.

When the planting density is changed, the density effect appears in almost similar trend at the assimilation and non-assimilation parts at both panicle differentiation and heading stages. The C/F is not affected by the planting density accordingly.

However, when the N application level is varied, the C/F decreases in its numerical value at both panicle differentiation and heading stages as the N application increases. This suggests that the assimilation part develops more than the non-assimilation part.

Fig. 2 shows the comparison of LAI and rough rice yields when the number of hills per 3.3m² is changed with 15 kg/10 a of N is fixed and when the level of N fertilization is varied with 100 hills fixed at panicle differentiation stage and heading stage, respectively.

LAI was increased rapidly by the planting of 120 and 140 hills per 3.3m² while rough rice yield was not greatly increased. As described above, the planting of 100 hills per 3.3m² showed a relatively proper productive structure and the assimilatory capacity per LAI seemed to high.

LAI of heading stage with varied N fertilization showed highly positive correlation to rough rice yields. The expansion of leaf area by the increased N fertilization also accelerated markedly the increase of the number of tillers and leaf length as shown in Fig. 3. The increase of LAI by close planting resulted in an increase of the number of tillers, and leaf length diminishes in the case of more than 100 hills per 3.3m² plot.

As described above, the increase of LAI by close planting showed quite a different pattern from that by the increased N fertilization in its productive structure, ratio of non-assimilation part/assimilation part, space distribution of the assimilation parts and elongation of the upper leaves.

3) Effects of increased N fertilization and planting density on both the culm and panicle length;

The effect of increased N fertilization on culm length was remarkable. In the present experiments with Kusabue variety, the culm length was longer by about 10cm with 20 kg of N fertilization per 10 a compared with 10 kg. The culm length was somewhat reduced by close planting.

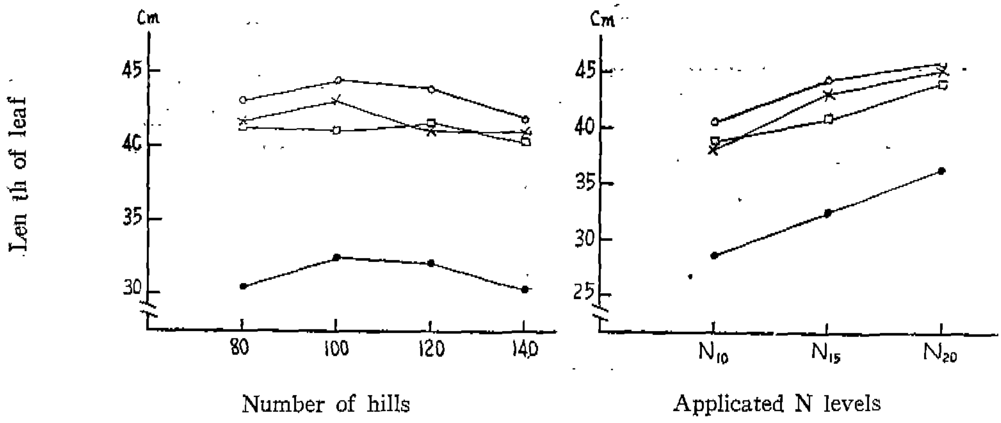

Fig. 3. Length of flag leaf, 2nd, 3rd and 4th leaves in maturing stage.
● : flag leaf, × : 2nd leaf, ○ : 3rd leaf, □ : 4th leaf.

Although the planting density did not affect markedly the culm length as a whole, it was observed that the tendency of increased lengthened development as the N fertilization level increased (Fig. 4).

Fig. 5 illustrates the effects of close planting and increased N fertilization on the cross sectioned area of the first elongated internodes. As obtained from the first year's experiment (1967), the planting of 80 hills per 3.3 m^2 plot produced the largest diameter culms and became smaller as the planting was more closely spaced. The change followed by the varied levels of N fertilization produced the thicker diameter culms at N 15 kg/10 a next in thickness at 20 kg and the thickest at 10 kg.

The increase in planting density produced shorter panicle length in the case of 20 kg of N per 10 a. Other N treatments were not so obvious. Although panicle length was apparently enhanced as N fertilization increased with thin planting increased N fertilization affected very little an increase in panicle length with close plantings. The effects of planting density and increased N fertilization on panicle length were almost similar to the effects on culm length.

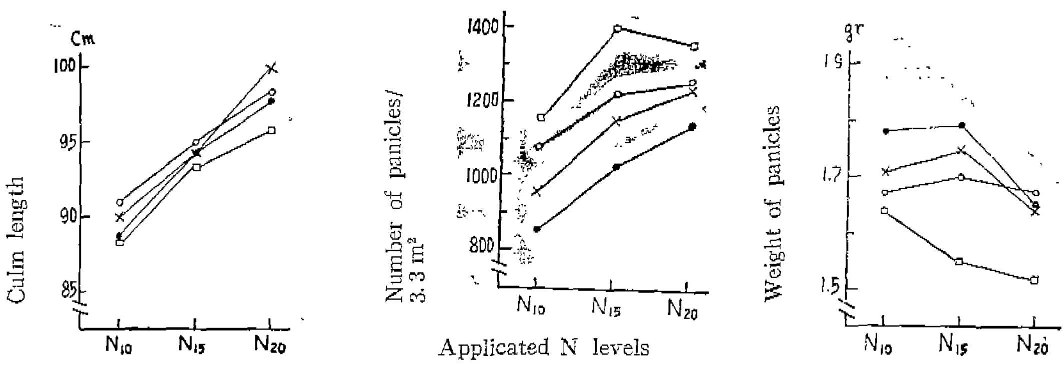

Fig. 4. Relationship between the planting density and applicated N levels and the culm length, number of panicles and weight of panicles.
● : 80 hills, × : 100 hills, ○ : 120 hills, □ : 140 hills per 3.3 m^2 respectively.

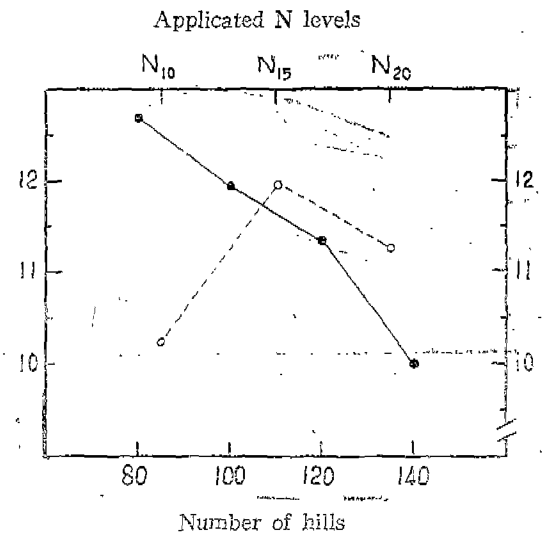

Fig. 5. Relationship between the planting density and applicated N levels and the area in cross section of first elongated node. Areas of cross section were indicated with relative value.
●——● : planting density,
○……○ : applicated N levels.

4) **Plant spacing and agronomic plant characteristics;**

As shown in Fig. 4, the effective close planting was apparent in the remarkable increase of the number of panicles in at the various N fertilization level. The effect of increased N fertilization on the increased number of panicles was more pronounced in sparse plantings than in close plantings. There was no diffrence in the number of panicles between 15 kg and 20 kg of N per 10 a in close plantings of more than 120 hills per 3.3 m^2.

There was no particular difference in panicle weight, as shown in Fig. 4, at any level of planting density except on the 140 hills per 3.3 m^2 plot between 10 kg and 15 kg N treated plots. However, a somewhat heavier trend was observed in the 15 kg N plot and the panicle weight was decreased markedly at any planting density in 20 kg of N fertilization. Panicle weight became light apparently by close plantings at any N level.

The planting density effect on the weight of 1,000 grains was not seemingly as apparent at any N fertilization level as experienced in the first year's experiment (1967). Fig. 6 shows that an increased N fertilization reduced the weight of 1,000 grains markedly, especially in the 20 kg N plot.

The planting density effect on the number of grains per panicle was apparent and reduced the number of grains per panicle as the planting density was heavier. Increased N fertilization did not affect the number of grains per panicle as illustrated in Fig 6.

Matured grains production in this experiment was not decreased by close planting as the 1967 experiments. However, it was reduced apparently by planting of 140 hills per 3.3 m^2 with 20 kg of N per 10 a as the N applications were reduced. In general, the ratio of matured grains were 93.2%, 91.3 % and 88.5 % (on the average), respectively, at 10 kg, 15 kg and 20 kg of N fertilization per 10 a.

5) **Yield of rough rice;**

In the present experiments with the split plot design, the results of analysis of variance on the yield of rough rice showed a 1 % significance between the main plot treated with increased N application and the sub-plot of planting density treatment.

The effects of increased N applications and planting density on the yield of rough rice are shown in Fig. 7 and Table 3, respectively. Yields were increased as the planting density was increased in case of the lowest N application. The effects of close planting were minor as the

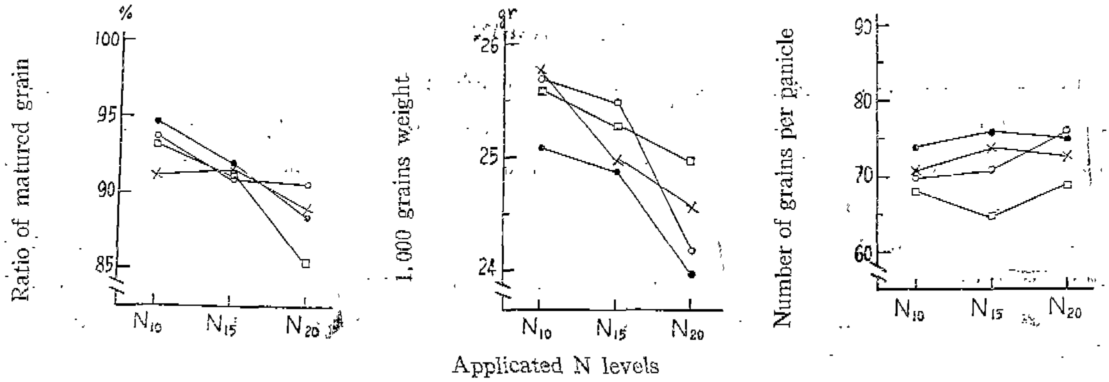

Fig. 6. Effects of the increment of N fertilization and density on the ratio of matured grain, 1,000 grains weight and number of grains per panicle.
● : 80 hills, × : 100 hills, ○ : 120 hills, □ : 140 hills per 3.3m², respectively.

N applications increased. Practically the same yields of rough rice were obtained in the plantings of 100—140 hills per 3.3 m² with 20 kg of N per 10 a.

The average yield of rough rice at 10 kg N per 10 a was 509 kg per 10 a and at 15 kg N and 20 kg the rough rice yields were 609 kg. Therefore, the optimum N fertilization is 15 kg per 10 a. As shown in Table 4 the results of the Duncan's Range Test showed no significant differences among 100, 120 and 140 hills per 3.3 m² plot. It is felt, therefore, that the planting of more than 100 hills with 15 kg of N per 10 a is the most effective spacing for rice in salty areas.

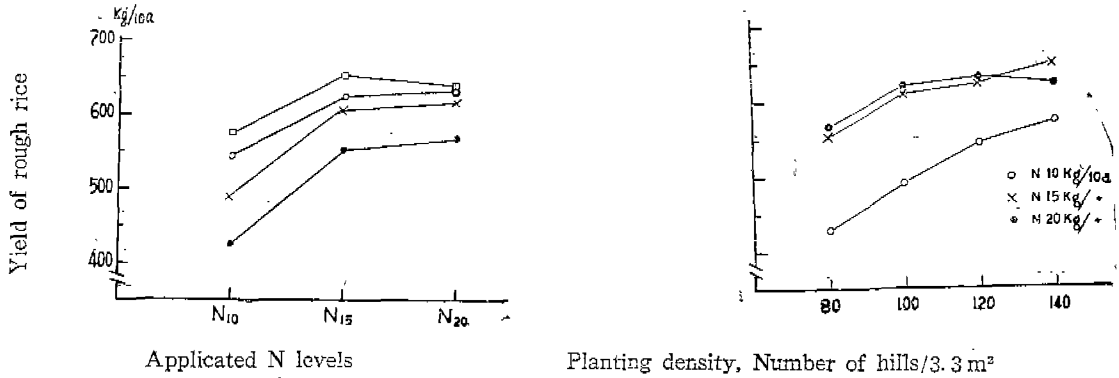

Fig. 7. Effects of the increments of N fertilization and planting density on rough rice yields.
● : 80 hills, × : 100 hills ○ : 120 hills, □ : 140 hills per 3.3 m², resectively.

Table 3. Effects of the N Dressing Increment and Plant Spacing

	N, kg/10 a			
	10	15	20	Average
D₁	428	554	568	517
D₂	492	609	619	573
D₃	545	625	630	600
D₄	573	650	621	614
Average	**509**	**609**	**609**	

DISCUSSION

In the present research project experiments were conducted continuously as in the first year project (Im *et al.*, 1967) to investigate the effects of planting densities and N fertilization levels, when varied on morphological and agronomic characteristics of rice plant populations in the reclaimed salty area.

The planting density effect was apparent by an increase in the number of tillers at the maximum tillering stage in spacings treatment plots within the scope of the present experiments. The number of tillers increased in proportion to the increase of the number of hills per 3.3 m^2 area. This tendency was not affected greatly by the increased appplication of N fertilizer. The effect of increased N fertilization was also remarkably minor in comparison with that of increased planting denstiy on the increasing tiller numbers. For instance, the number of tillers increased in 470, on the average, on the planting or 140 hill plot compared with 80 hillsp er 3.3 m^2 plots while it was increased in 100, on the average, by double fertilization of N 10 kg per 10 a. Therefore, the most effective method to increase the number of tillers per unit area is close planting which is considered to be the most important factor affecting the productivity of plant population in its early growth.

The elongation of plant height (maximum tillering stage) by competition between individual plant in the rice plant population was scarcely observed, while it was evidently affected by the increased N fertilizer application.

It has become known recently that the increased average lightness or enhancement of light receiving efficiency within rice plant population is greatly related to the productivity. Matsuo (1966) stated that such morphological characteristics of rice plant population, as leaf area, number of tillers, plant height, angle between stem and leaf and the leaf thickness are closely related to light utilization receiving efficiency.

The increase of the number of tillers by close plantings of multiple plants per hill within the unit area brings about concentrated distribution, which reduces apparently the light receiving efficiency of the lower part of the plants due to mutual cover this decreases the productivity of the whole plant population (Matsushima *et al.*, 1963, 1965 and 1968).

On the contrary, the increased application of N enhance plant height, which will makes the lower leaves receive light more effectively. Matsuo(1966) claimed that light receiving efficiency is closely correlated to $A\sqrt{h}$ (A: leaf area, h: plant height). It is felt, therefore, that the importance of optimum planting density and effective N utilization were apparently important in determining the morphological characteristics of the plant population after the tillering stage.

Fig. 1 shows the vertical space distribution of leaf within plant population at the panicle differentiation and heading stages. The light receiving forms of the assimilation part appeared in productive structure of the fertilized plots are remarkably different when the number of hills is increased to 120 or 140 hills per 3.3 m^2 with 15 kg N fixed and when N is increased to 20 kg per 10 a with the number of hills per 3.3 m^2 fixed at 100. The former shows the distribution of over grown leaves at the height of 40 to 60 cm reduces the light receiving efficiency of the whole plant population. It has been already known that the penetrated light of plant population declines exponentially as the upper leaf area increases. The developmental variation of the non-assimilation parts by the increased application of N fertilizer was not noticeable contrary to the increase of the non-assimilation part by close planting after the heading stage.

The leaf area increases remarkably by the increased applications of N fertilizer and close plantings. As shown in Table 2, the C/F ratio(non-assimilation parts/assimilation parts) at the panicle differentiation stage and heading stage was not affected by planting densities while it was decreased apparently by the increased applications of N fertilizer.

It is felt, therefore, that the increased application of N fertilizer resulted in higher yield ratios as seen from the comparison of the increase curve of LAI and yield curve of rough rice by increasing the ratio of assimilatory capacity/respiratory capacity of the plant population.

Matsushima *et al.* (1964) reported that the increase of assimilatory production after heading is the important factor in raising rice yields. for which it is important to 1) promote the assimilatory capacity per unit leaf area by increasing the N content of the leaf blade after heading and 2) enhance light receiving efficiency by keeping proper productive structure of population after heading. Matsuo (1966) indicated that light receiving efficiency is affected primarily by leaf area and its growth for which he gives the following formula:

$$P_1 = AfP_0$$

where, P_1 : Assimilatory capacity of plant population, A : Leaf area, f : Declining light due to shading in plant population, P_0 : Assimilatory capacity per leaf area representing plant population.

At this time f is usually influenced by the productive structures of plant population. Horie *et al.* (1966 a, b) stated that the productive structure varies according to planting density and application level of N fertilizer. f (positive number less than 1) being presented as a shading effect by overgrowth is a phenomenon occurring generally due to excessive LAI. Watson(1947) claimed that LAI is the regulating factor of crop productivity. This is identical to the theory of optimum leaf area for maximum crop yield as stated by Donald (1958).

Kanda and Sato (1963) reported that the dry matter production of rice plant reaches the maximum at 3.5—4.0 of LAI and becomes zero at 7—8. Matsushima *et al.* (1964) and Matsuo (1966) stated that the maximum production is at 6.0 and 5.8, respectively. In the present experiments, it was at not more than 5 with 120—140 hills per 3.3 m^2 area of 15 kg of N per 10 a and 4.2 with 20 kg application with 100 hills per 3.3m^2.

Takeda (1961) reported that the optimum LAI varies due to the effects of growth stage, sunlight and other limiting factors of rice plant. In the salty area plant height is usually low and an excessive close planting to expand leaf area results in the enhancement of non-assimilation parts, as discussed above, in addition to apparently unfavorable effect on the soil dimension occupied by the root system compared with the effect of the increased application of N fertilizer.

According to Miyasaka and Ishikura (1964) and De Dotta (1968), the increase of NAR (net assimilation rate) and RGR (relative growth rate) at maturing stage is closely correlated to yields. They further reported that the increase of these factors also depends upon the increase of N content in the leaf and the leaf area as well as the prevention of leaf withering of the lower parts of the plants. The increase N content in the leaf (Im *et al.*, 1967) was observed in the salty area as in the last year's results, but the withering of the lower leaves due to salt damage is a very difficult problem to be solved in rice culture in the salty area. It is felt that the effect of the increased application of N fertilizer on crop yields is particularly significant as it increases N content in leaf, leaf area, prevents leaf withering effectively and not increased the non-assimilation plant parts.

In the present experiments, the RGR of the heading stage was great as the planting density became high due to the enlargement of the non-assimilation parts. The increased applications of N fertilizer did not increase the RGR remarkably. In the latter's case there was no difference observed in the RGR between the N treatments. This might be due to non-increase of the non-assimilation parts, as shown in Table 2, by the increased application of N fertilizer. In the highest planting density of 140 hills per 3.3 m^2 area with the application of 20 kg of N, the leaf area declined at the heading stage. It was felt that the NAR of this period was not correlated to the yield and that the decreasing phenomenon of leaf area and NAR after heading would be affected by the treatment of increased planting density and N fertilizer application.

Although the culm length was shortened by close planting under the condition of multiple N applications, the increased N applications enhanced the culm length in either case. It is considered that lengthy culm affects greatly the uniform light penetration in vertical direction of plant population by lessening the dip angles of the upper leaves and enhancing the height of the plants in the total leaf area(Hayashi and Hiroshi, 1962).

As the results obtained from the first year's experiment(1967), the first elongated stem was reduced in diameter by close planting while it was increased by the application of 15 kg of N per 10 a in comparison with 10 kg per 10 a and slightly larger by 20 kg of N per 10 a. Consequently, it is felt that no lodging will occur within the scope of the increased N treatments of the present experiment.

The number of panicles was increased markedly (Im *et al.*, 1967; Kawada, 1956) by both close plantings and increased N applications. The ratio of productive stem was 96% at the planting density of 80 hills per 3.3 m^2 and 86% at 140 hills, respectively. This indicates a remarkable decreasing tendency, in general, by close plantings. On the other hand, however, the ratio of productive stem was increased by the increased N application; i. e., 84 % at 10 kg of N per 10 a, 93 % at 15 kg and 98 % at 20 kg. The latter growth is usually more active than the early growth in the reclaimed soil areas in Korea. Therefore, it may be considered that the tillers with a weak by N supply at this time is probably grown to productive stem and that productive tillering stage is likely retarded as the growth is delayed generally in the salty area.

The panicle weight was reduced (in 1968) by close planting as in the first year's experiments (1967). The average weight of one panicle at the applications of 10 kg of N per 10 a and 15 kg were the same, but the weight was decreased remarkably at 20 kg.

The number of grains per panicle was greatly affected by planting densities; the l planting density the lesser the number of grains produced in the first year's experi However, it was not affected by the increased applications of N fertilizer(Akamatsu, 1968 a-wada, 1956).

Although the spacing effect on the weight of 1,000 grains was slight the increased N a ica-tions (Atkins *et al.*, 1968) reduced the weight per 1,000 grains. The ratio of matured gra in the salty areas showed a somewhat decreasing tendency by close plantings only in case of i er level of N applications. The weight of 1,000 grains and the ratio of matured grains may be decreased by close plantings in the non-salty areas. This phenomenon was not appeared in the experiments on planting space of the salty areas in the last and present research project. It is felt, therefore, that this is probably due to the declined salt concentration at the maturing stage and the favorable physiological activity of rice plant at the latter growth when the salt tolerance becomes stronger.

The rough rice yield curve of the increased N applications shows that the law of diminishing return is functioning in each space treatment as illustrated in Fig. 7. There was a certain degree of difference in either sparse plantings or close plantings with the increased fertilization exceeding the turning point of 15 kg of N per 10 a, but the law of diminishing returns was clearly apparent.

The condition of multiple N applications vigorized the formation of organs such as the number of stems and of the leaf area, thereby resulting in mutual cover of leaves on the productive structures of plant population making the light receiving system unfavorable and thus reducing the production of dry matter-sugar and starch at the maturing stage. It is obvious, therefore, that the diminishing returns occurred by the decrease of their accumulation in the panicles. This phenomenon was apparent by the decrease in the weight of 1,000 grains.

The increased N application did not increase the number of grains per panicle in the salty area but reduced the function of the floral organs. It also resulted in the inability of pollination or early hibernalism of the material accumulation processes, decreasing the ratio of matured grains by which the diminishing returns probably occurred. It is considered that the decrease in the panicle weight by these two conditions seemed to appear in the diminishing return of rough rice yields beyond the increase of the number of panicles by the increased N applications.

Accorbing to Matsuo (1956), in the rice plant the total of dry matter production plus dry matter consumption and the intensity of the solar radiation by assimilatory capacity of the plant population maintains always a high positive correlation which is expressed in the following formula:

$$\triangle W + Rw \propto L.\ S.\ P_0.\ C$$

hence, $\triangle W = K.\ L.\ S.\ P_0.\ P - Rw$ (K is a constant)

The dry matter production ($\triangle W$) is produced by taking the consumption by respiration from the product of leaf area (S)· unit assimilation (Po)· light receiving coefficient (P)· solar radiation(L).

Although close planting increased the number of stems and even the leaf area at early growth stage, it reduced not only the light receiving efficiency due to mutual cover as illustrated in

Fig. 1 but enlarged rapidly the non-assimilation parts in the latter-growth stage. Consequently, light deficit leaves of the lower part of the plant population and the respiration of non-assimilation parts increased and thereby the dry matter production decreased in the latter growth.

In the salty area, close planting increased actually the number of panicles but decreased the number of grains per panicle and the panicle weight. As illustrated in Fig. 7, the law of spacing effect was applied at 10 kg of N per 10 a. The yield was increased by close planting but the law of constant in final yield was applied substantially in close plantings of more than the turning point of 100 hills per 3.3 m^2 area in the N treatment exceeding 10 kg of N per 10 a.

摘　　要

水稻生育期間中 平均 監分濃度 0.48 %(4月末 0.67 %)의 鹽分干拓地에서 두사부에를 供試하여 N施肥를 反當 10 kg, 15 kg 및 20 kg의 3水準, 3.3 m^2當 栽植株數를 80, 100, 120 및 140의 4水準의 組合인 12處理를 하여 水稻個體群, 收量要因 및 收量등에 미친 N增肥效果와 密度效果와 그의 相互作用을 보았던 바 그 結果를 要約하면 아래와 같다.

1. 最高分蘖期까지의 莖數增加는 어떤 N施肥 水準에서도 密度效果의 法則이 나타났다. 即 栽植株數增加에 比例하여 莖數가 增加하였다. 그리고 N 15 kg/10 a 以上의 施肥에서는 莖數增加에 對한 N增肥效果가 없었다. 草長에 對한 N增肥效果는 顯著하였으나 密度效果는 없었다.

2. 幼穗分化期와 出穗期의 個體群 生産構造에 있어서 密植은 그들의 相互遮蔽를 가져오는 同化部의 空間配置로 因하여 個體群 受光能率이 N增肥의 影響에 比하여 크게 低減되는 것으로 보였다.

3. 그뿐만 아니라 密植에 依한 同化部의 增加는 同時에 非同化部의 增加를 크게 가져오나 N增肥效果는 非同化部의 增加를 隨伴치 않았다. 그러므로 C/F 比에 對한 密度效果는 없으나 N增肥는 그것을 顯著히 적게 하였다. 따라서 個體群 同化力/呼吸力 比로 보아 N增肥效果는 密植效果에 比하여 成熟期의 乾物生産을 크게할 것이 分明하였다.

4. LAI에 對한 精租收量은 N增肥效果가 密度效果보다 더 컸다.

5. N增肥는 稈長을 增加시켰으며 第一伸長節間徑을 比較的 크게 하였으나 密植은 N施肥가 많을 때에 稈長을 짧게 하였으며 密植함에 比例하여 第一伸長節間徑을 적게하였다.

6. 密植과 N增肥에 依한 穗數의 增加는 다같이 顯著하였으나 栽植密度가 높음에 따라 有效莖比率이 크게 떨어졌으며 N增肥는 어느 境過에서도 有效莖比率을 顯著히 增加시켰다.

7. 穗重에 對한 密度效果는 顯著하였으나 N 10 kg/10 a와 15 kg施肥에서는 穗重이 같았으며 20 kg/10 a에서는 떨어졌다.

8. N增肥는 千粒重과 稔實率을 낮게하였으나 穗當粒數에서는 影響하지 않않다. 密度增加는 千粒重과 稔實率에는 影響하지 않았으나 穗當粒數를 크게 떨어뜨렸다.

9. 以上과 같이 N增肥效果와 密度의 效果는 生産構造와 收量要因들에 相異한 影響을 미치므로 密度와 N施肥水準은 恒常 2要因을 聯關的으로 다루어야 할 것으로 생각되었다. 그리고 이와 같은 結果로 精租生産에 對한 N增肥曲線은 15 kg/10 a를 變曲點으로 하는 報酬漸減의 現象이 나타났고 또한 N 10 kg/10 a를 除外한 두 N施肥水準에서는 3.3 m^2當 100株植을 變曲點으로 最終收量一定의 現象이 나타났다.

따라서 鹽分干拓地에서는 N 15 kg/10 a와 3.3 m^2當 100株를 심는 것이 좋다.

LITERATURES CITED

1. Akamatsu, S., 1968. Studies of direct-sowing culture by broadcasting seeds on a submerged

paddy field. No. 6. Effects of seeding density and amount of fertilizer on the growth and yield of rice. Proc. Crop Sci. Japan, 37(1), 17—20.

2. Atkins, R. E., V. H. Reich, and J. J. Kern, 1968. Performance of short stature grain sorghum hybrids at different row and plant spacings. Agron. Jour., 60 (5), 515—518.

3. Buller, R. E., J. S. Bubar, R. H. Fortmann, and H. L. Carnahan, 1955. Effects of nitrogen fertilization and rate and method of seeding on grass seed yields in Pennsylvania. Agron. Jour., 47, 559—563.

4. Canode, C. L., 1968. Influence of row spacing and nitrogen fertilization on grass seed production. Agron. Jour., 60(3), 263—267.

5. Carlson, L. T., 1964. Effects of row spacing and fertilizer treatment on seed yield and related traits of 'Sterling' orchardgrass. Agron. Jour., 56, 565—569.

6. Colville, W. L., 1968. Influence of plant spacing and population on aspects of the microclimate within corn ecosystems. Agron. Jour., 60(1), 65—67.

7. De Datta, S. K., A. C. Tauro, and S. N. Balaoing, 1968. Effect of plant type and nitrogen level on the growth characteristics and grain yield of indica rice in the tropics. Agron. Jour., 60(6), 643—647.

8. Donald, C. M. and J. N. Black, 1958. The significance of leaf area in pasture growth. Herb. Abstr., 28, 1—6.

9. Gritton, E. T. and J. A. Eastin, 1968. Response of peas (*Psium sativum* L.) to plant population and spacing. Agron. Jour., 60(5), 482—485.

10. Hayashi, K. and I. Hiroshi, 1962. Studies on the form of plant in rice varieties with particular reference to efficiency in utilizing sunlight. I. The significance of extinction coefficient in rice plant communities. Proc. Crop Sci. Japan, 30(4), 329—333.

11. Hoag, B. K., J. C. Zubriski, and G. N. Geiszler, 1968. Effect of fertilizer treatment and row spacing on yield, quality and physiological of safflower. Agron. Jour., 60(2), 198—200.

12. Horie, M., I. Yamura, and T. Hosoyama, 1967. Statistical studies on various characteristics of crop plant. IV. Varietal differences of a morphological characteristic of rice plants when three plant-spacing at various levels of nitrogen fertilizer put together. Proc. Crop Sci. Soc. Japan, 36(2), 173—178.

13. ______, ______, and ______, 1967. Statistical studies on various characteristics of crop plants. V. Varietal difference of a morphological characteristic of rice plants when three plant-spacings and three nitrogen levels put together. Proc. Crop Sci. V Soc. Japan, 36(2), 179—184.

14. Im, H. B. *et al.*, 1967. Study on the salt tolerance of rice and other corps in reclaimed soil areas. MOST-USAID Rept. Code N. 66—27. 1—140.

15. Kanda, M. and F. Sato, 1963. Studies on the spacing density of rice plants. Part 4. On the relationship between leaf area index and population growth. Bull. Inst. Agr. Res. Tohoku Univ. Japan, 15(1), 37—52.

16. ______, and T. Nishiyawa, 1967. An analysis of rice population growth in relation to density and mode of planting. Bull. Inst. Agr. Res. Tohoku Univ. Japan, 18(2), 215—240.

17. Kawada, S., 1956. Studies on the root formation in crops. Part 3. Relationship between the initiation of primary root in crown root and the formation of lysigenous aerenchyma, especially conference to the oxidative-reductive electrical potential of soil. Proc. Crop Sci. Soc. Japan, 24, 232—236.

18. Matsuo, D., 1966. Morphology and function of rice plants. Assoc. Agr. Tech.

19. Matsushima, S., G. Wada, T. Tanaka, and T. Hoshino, 1963. Analysis of yield-determining process and its application to yield prediction and culture improvement of lowland rice. LXVII. Studies on the principles for maximizing yield and their demonstration (1). Proc. Crop Sci. Soc. Japan, 32(1), 44—47.

20. ______, ______, and ______, 1964. Analysis of yield-determining process and its application to yield-prediction and culture improvement of low land rice. LXVIII. On the relation between morphological characteristics and photosynthetic efficiency (1). Proc. Crop Sci. Soc. Japan, 33(1), 44—48.

21. ______, ______, and ______, 1965. Analysis of yield determining process and its application to yield-prediction and culture improvement of lowland rice. LXXIII. On the relation between morphological characteristics in receiving light and the percentage of ripened grains. Proc. Crop Sci. Soc. Japan, 34(1), 25—29.

22. ______, ______, and ______, 1968. Analysis of yield determining process and its application to yield-prediction and culture improvement of lowland rice. LXXXIII. Relation between the plant types after heading and the varieties differing in the maturation period Proc. Crop Sci. Soc. Japan, 37(2), 182—186.

23. Miller, R. J., G. W. Landgdale, and D. L. Myhre, 1967. Leaf area and nitrogen uptake of Flue-Cured Todacco as affected by plant density and nitrogen rate. Agron. Jour., 59(5), 409—412.

24. Miyasaka, A. and N. Ishikura, 1964. Effects of some cultural conditions on the development in later growth stage of rice plant in the ill-drained paddy field. Proc. Crop Sci. Soc. Japan, 33(2), 107—110.

25. Monsi, M. und Saeki, 1953. Über die Lichtfaktor in den Pflanzengesellschaften und seine Bedeutung für die Stoffproduktion. Jour. Bot. Japan, 14, 22—52.

26. Takeda, T., 1961. The problem of the planting of close density and limitation of yield in rice culture. (1). Agr. Hort. Japan, 36(4), 627—632.

27. UNDP (SF) soil fertility programme, 1965. Results of fertilizer field experiment in Republic of Korea. Tech. Rept., No. 3.

28. Wada, G., S. Matsushima, and A. Matsuzaki, 1968. Analysis of yield-determining process and its application to yield-prediction and culture improvement of lowland rice. LXXXVI. Relation between the nitrogenous nutrition and the constituting factors of the number of spikelets per unit area. Proc. Crop Sci. Soc. Japan, 37(3), 417—423.