<Article>

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

3. Response of Rice to Plant Population and Spacing in the Salty Soil Area

IM, Hyong Bin,* Ung Kyu LIM and Jai Sup SHIM**

(*College of Agriculture, Seoul National University, **Chungbuk College)

3. 干拓地에서 水稻個體群과 栽植密度에 關하여

任絅彬*・林雄圭*・沈在燮**

(*서울大學校 農科大學 **忠北大學)

ABSTRACT

Field studies were conducted with the split plot design of 20 treatments with a combination of 4 levels of 3, 5, 7 and 9 plants per hill and 5 levels of 60, 80, 100, 120 and 140 hills per 3.3m² on non-, low- and high-salty areas. Rice variety, Kusabue was grown under the standard fertilization and cultivating.

Investigation was made on the productive structure of plant population, leaf-area index, light intensity curve by stratum of crop population at the panicle differentiation stage. The competition density effect on the photosynthetic capacity was low as the salt concentration became higher. This seemed to suggest the possibility of an increased yielding capacity by closer planting in the salty areas. The effect of an increased number of hills per unit area was greater than that of an increased number of plants per hill due to the total leaf area and space distribution of the active assimilation parts of rice plants.

The number of panicle per unit area in the salty areas were increased when the number of hills per 3.3m² increased over an increased numbe of plants per hill, and the panicle weight was reduced by close planting in the non-lalty area, while it was not reduced so much in the salty areas. The number of grains per panicle was significantly decreased by close planting in the salty areas as in the non-salty area, and ratio of matured grain was not decreased even by close planting in the salty areas, while it was significantly decreased by close planting in the non-salty area.

An increase in the rice yield was possible by close planting and greatly related to leaf area index in the salty areas but not in the non-salty area. Increasing the number of hills per unit area showed greater effect on the increase of the rice yield than an increased number of plants per hill in the salty areas. Relationships between the growth characteristics and the rice population affected by plant spacing mode for maximum production were discussed.

INTRODUCTION

Crop production means the total productivity of the crop which depends solely upon the photosynthetic

1) This research was performed with the financial assistance of the Trust Fund, MOST, USAID/K,

utilization of field space. The plant spacing needed to obtaine a maximum production for a unit area has been frequently studied by plant ecologists. Boysen-Jensen(1932) attempted for the first time a statistical analysis on crop yields in relation to plant population per unit area.

In the present study the main objective was to examine the effect of plant spacing upon the production of rice grown, vegetation and reproductive growth and ripening of grain on both non-salty and the low-and high-salty areas.

Data on the effects of plant spacing of transplanted rice seedlings on productivity and other factors of growth in reclaimed salty paddy fields in Korea have been rarely reported. According to the report of Crop Experiment Station, Suwon, Korea (1924 a, b), 13 plants per hill with 60 hills per $3.3m^2$ showed the best results while the Honam Crop Experiment Station, Iri, Korea (1966) reported that 5 to 10 plants per hill with 120 hills per $3.3m^2$ produced the best results.

MATERIALS AND METHODS

The experiment was performed with a wide variation of number of plants per hill and also number of hills per unit area in the three experimental areas, the high- and low-salty and the non-salty areas, which were contained 1.0 %, 0.5 % and 0 % of salt, respectively, as of the end of April. The basal dressing consisted of 5kg, 8kg and 8kg of N, P_2O_5 and K_2O, respectively, in each three areas followed by top dressings of 3kg of N for tillering and 2kg before heading stage. The two variable factors, numbers of plants per hill and number of hills per $3.3m^2$ were as follows: (a) Number of plants per hill: 3, 5, 7 and 9. (b) Number of hills per $3.3m^2$: 60, 80, 100, 120 and 140.

The splitplot design consisted of 20 treatments, replicated 3 times. The plots were 4m×3m in size. Seedlings of the Kusabue rice variety were transplanted from the seebed to the experimental plots on June 18. The experimental plots were properly managed in accordance with the standard practices employed in the local rice paddy fields. Light intensity was measured with Toshiba's electrical photometer.

RESULTS

1) Productive Structure of Rice Population

The productive structure of plant population and the vertical distribution of the relative light intensity were nivestigated on, (1) 3, 5, 7, and 9 plants per hill in 100hills per $3.3m^2$ plots and (2) 7 plants per hill on 60, 80, 100, 120 and 140 hills per $3.3m^2$ area plots.

Figure 1 shows the productive structure at each plant spacing with the fixed number of 100 hill per $3.3 m^2$. The left side from the center line is the assimilation part for the photosynthetic system (leaf blade) and the right side is the non-assimilation part.

The upper part of each figure is the relative light intensity indicated in percentage by 5 parts on the rice plant when the atmospheric light intensity is set as 100 at the time of measuremet. The left and right graduations indicate the dry weight in kilogram of the top system per each $3.3m^2 \times 3.6$ plot cut by stratum of 5 divisions of the assimilation part and non-assimilation part at the total space of 20cm from the ground in the non-salty area and of 15 cm in the low-salty areas. The figures of both sides centering the axis of the original point indicate the total quantity of dry matter (kg) of rice top system per $3.3 m^2 \times 3.6$.

Figure 1 shows that there was no structural difference in particular except in the total production of dry matter in each treatment between the same salt concentration in the profile of panicle differentiation stage when the number of hills per 3.3m² was fixed at 100. It shows, therefore, an expanded structure of the central protion of the plants.

In the non-salty area the curve of the relative light intensity shows that the light penetrated to near the ground portion in case of plots with 3 plants per hill while it shows an extremely darkening trend as it goes down to the lower to the lower portion of plant populations of 5, 7 and 9 plants per hill. In short, it reaches the limiting density of space utilization due to the thick growth of leaf and stem. Although the production of dry matter on the part of assimilation and the non-assimilation part was increased up to 3-7 plants per hill was decreased at 9 plants per hill. It may be seen, therefore, that density effect is pronounced in plots having more than 7 plants per hill.

The relative light intensity curve by stratum in the low-salty area shows that the light penetrates abundantly to the ground surface of each plant per hill. The appearance of the curve is similar but the relative light intensity was directly proportional to the stratum in case of 3 plants per hill. As the number of plants per hill increased, it appeared as an exponential curve. The volumes of tissue of the assimilation and non-assimilation parts were also increased from 3 to 7 plants per hill and was decreased to some extent at the density of 9 plants per hill.

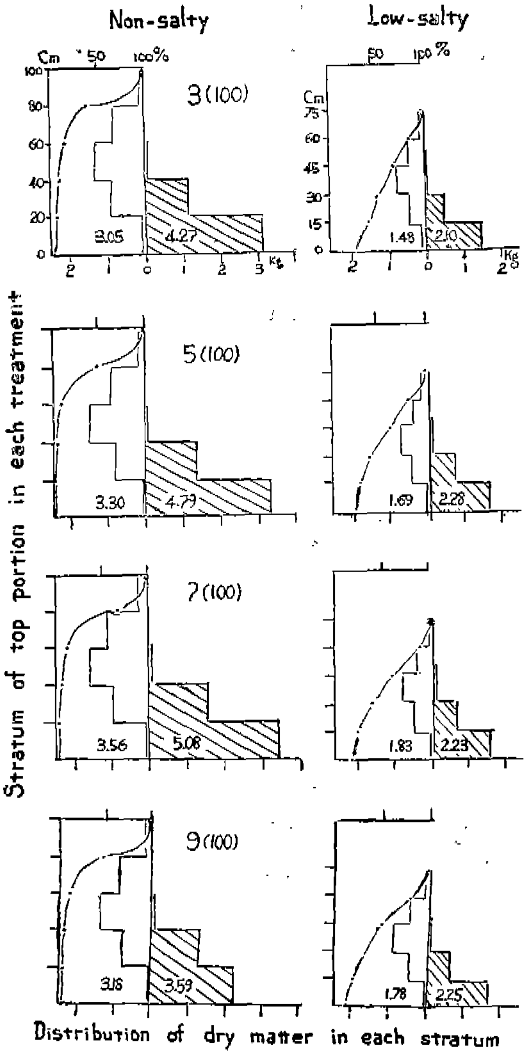

Fig. 1. Productive structure of plant population when the number of hills was fixed at 100 and when the number of plants was changed at the paniclediffer-entiation stage. Figure at the bottom for each treatment shows dry weight of rice in kilograms per 3.3 m²×3.6.

Figure 2 shows the productive structure and the relative light intensity curve by stratsum when the number of plants per hill is fixed at 7 but the number of hills per 3.3 m² is changed. The relative light intensity curve by tratum also shows that the light penetrates abundantly to near the ground portion and much space for growth in the case of the number of hill is changed in low-salty areas comparing to the non-salty area.

Although the total production per unit area was remarkably increased in the plots with 60 to 100 hills per unit area in the non-salty area, the assimilation portion and non-assimilation portion in the plants increased slightly by close plantings(over 100 hills per 3.3 m²). The "law of a constant in final yield" was thereby established.

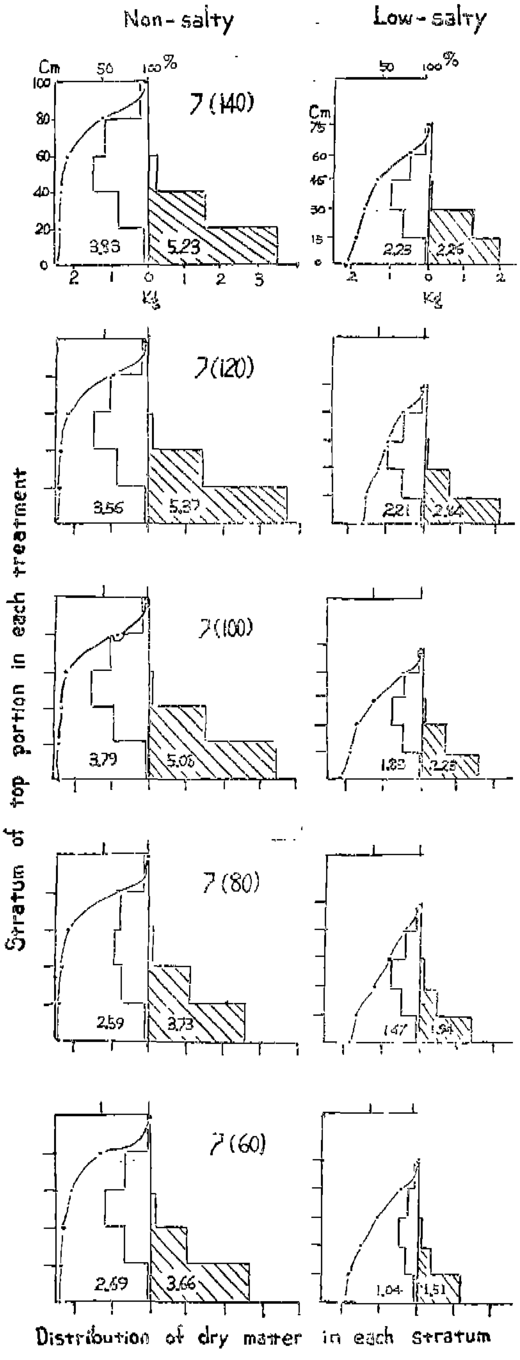

Fig. 2. Productive structure of plant population when the number of plants was fixed at 7 and the number of hills was changed at the panicle differentiation stage. Figures at the bottom for each treatment shows dry weight in Kilogram per 3.3m² × 3.6

In plots of more than 100 hills per 3.3 m², (i.e. 140 hills per 3.3 m²) a pattern of relatively higher production with a dense distribution on the upper stratum of the productive structure was observed which disturbed remarkably the penetration of the light into the vegetative corvering. This is considered to be a disadvantageous structure for the assimilatory production from the light receiving capacity of the plant population.

In low-salty area there was observed a remarkable increase in production from 80 to 120 hills per 3.3 m². The total productions by close planting of over 120 hills per plot were similar. In high-salty area the total production an the productive structure were almost the same except in all plots containing 60 hills per plot.

The variations of productive structure affected by the plant spacings due to the different number of hills per 3.3m² with the fixed number of 7 plants per hill is great in general; e.g., the density effect of the number of hills seemed to be greater than that of the number of plants per hill from view of the productive structure.

Figure 3 shows the relationship between leaf area index (LAI) and rough rice weight produced when the number of plants was increased with the fixed number of hills at 100 per 3.3m² and the number of hills per 3.3m² was changed with the fixed number of plants at 7 per hill in the low-salty areas.

In the former's case, an increased number of plants did not increase greatly the leaf area per unit area. It was reduced in 9 plants per hill as compared with 7 plants per hill in non-salty area. In the low-salty area, the leaf area per unit area showed an increasing trend by 3 to 7 plants per hill, while it was reduced with 9 plants per hill.

In the latter case was observed no differences in particular in the LAI by the transplanting of 100 to 140 hills with 7 plants per hill in the non-salty area while the LAI was remarkably reduced by 60 and 80 hills. However, in the lowsalty area, the LAI was increased as the number of hills per plot increased. In the salty areas, it was observed that the increasing of rough rice yields were greatly related to the increasing of the LAI (Figure. 3).

2) Plant Spacing and Agronomic Plant Characteristics.

There was small differences in the culm length when the number of plants per hill and the number of hills per 3.3m² in the non-salty, the high- and ow-salty areas. However, there was observed a decreasing trend in the panicle length with close planting in each salt concentration area. The spacing effect at this time seemed to be a greater the number of plants per hill increased than when the number of hills per plot increased.

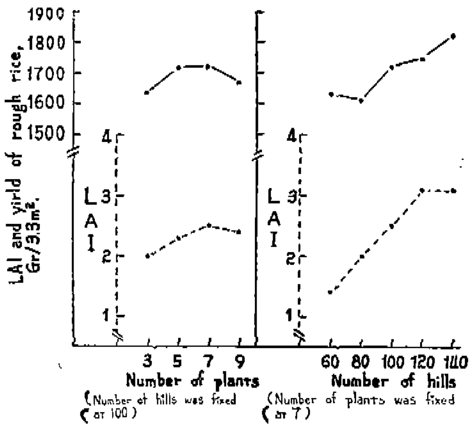

Fig. 3. Relationship between planting density and the rough rice in weight and LAI.

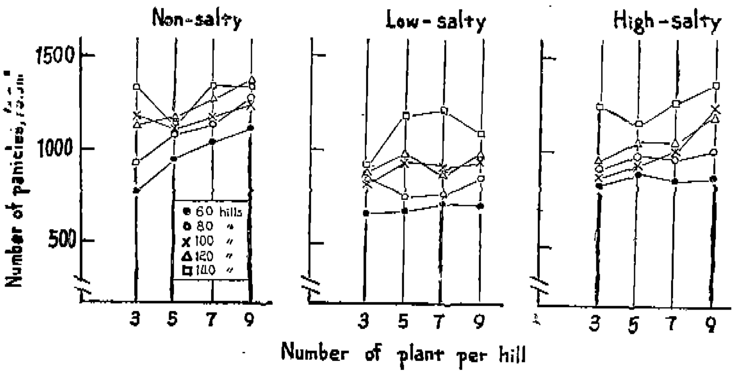

Fig. 4. Relationship between the planting density and number of panicles per 3.3m² area plot.

It was observed that the number of panicles per hill decreased remarkably when the number of hills per 3.3 m² was increased with the fixed number of plants per hill in the non-salty area and both salty areas. The increase in the number of panicles per hill by increasing the number of plants was not markebly greater.

Figure 4 shows that the number of panicles per hill in the plots with 60 hills and 80 hills in the non-salty area was increased remarkably when the number of plants per hill remained fixed (7 plants per hill). Slight increases were observed in other cases in non-salty area and in the both salty areas. The number of panicles per plot of 3.3m² was remarkably increased in each salty areas when the number of hills was changed with the fixed number of plants per hill (7 plants per hill).

The number of panicles of transplanted seedlings per plot were decreased equally in each area according to the increase of the number of plants per hill and the number of hills per 3.3m² but the most intense effect was observed in the increase in the number of hills per plot.

An increase of the number of plants per hill and the number of hills per plot brought about a remarkable decrease in panicle weight in the non-salty area. On the other hand, the panicle weight was decreased by an increase in the number of plants per hill in the high-salty area, while an increase of the number of hill per plot did not affect the panicle weight. Therefore, an increased yield may be expected by increasing the number of hills per unit area.

The plant spacing on the panicle weight was remarkable in the low-salty area similar to that in the non-salty area that is the effect of number of hill was greater than number of plants per hill and the panicles are heavier in weight than that in other experimental areas. It is considered nccessary to study further the mechanism that marked the heavier panicle weight in the low-salty area.

Figure 5 shows the panicle weight per hill in each treatment plot of the respective salty areas. The panicle weight per hill was increased remarkably in 60 hills for area. As the number of plants per hill increased in the non-salty area, there was a considerable decrease in all cases when more than 100 hills per plat were present.

There was observed no effect of an increased number of plants per hill on the rough rice weight per hill in the low-salty area. An increased number of hills per 3.3 m^2 decreased remarkably the total panicle weight per hill.

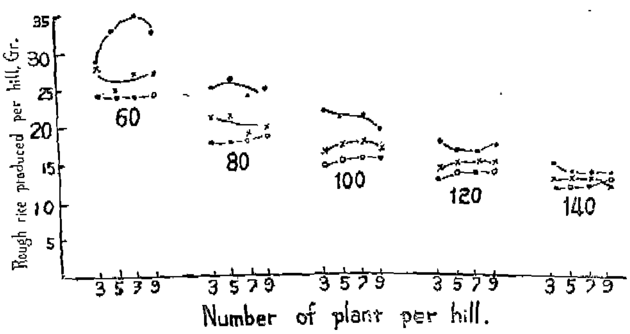

Fig. 5. Planting density and weight of rough rice per hill
●—● : Non-salty area, ×—× : Low-salty area, ○—○ : High-salty area.

In the high-salty area, an increased number of plants per hill seemed to bring about a little increase in the panicle weight per hill. As in the low-salty area, an increase of the number of hills per plot was affected greatly by the density effect. When the number of hills was constant at 140 hills per plot in the non-salty and low- and high-salty areas and the number of plants per hill was increased, the panicle weight per hill was slightly reduced in the non- and low- slty areas while there was no decrease observed by an increased number of plants per hill in the high-salty area.

The panicle weight per hill was sharply decreased by closer plantings with an increased number of hills per plot in the non-salty area. On the other hand decrease in the panicle weight per hill was not significant in the low- and high-salty areas. Therefore, there was almost no difference observed in the panicle weight per hill in the planting of 140 hills between each experimental area. This phenomcnon may suggest that an increased yield will be within the bounds of possibility by closer planting in the salty areas.

The number of grains per panicle was decrease as the number of plants per hill and the number of hills per plot increased in the non-salty and both low- and high-salty areas.

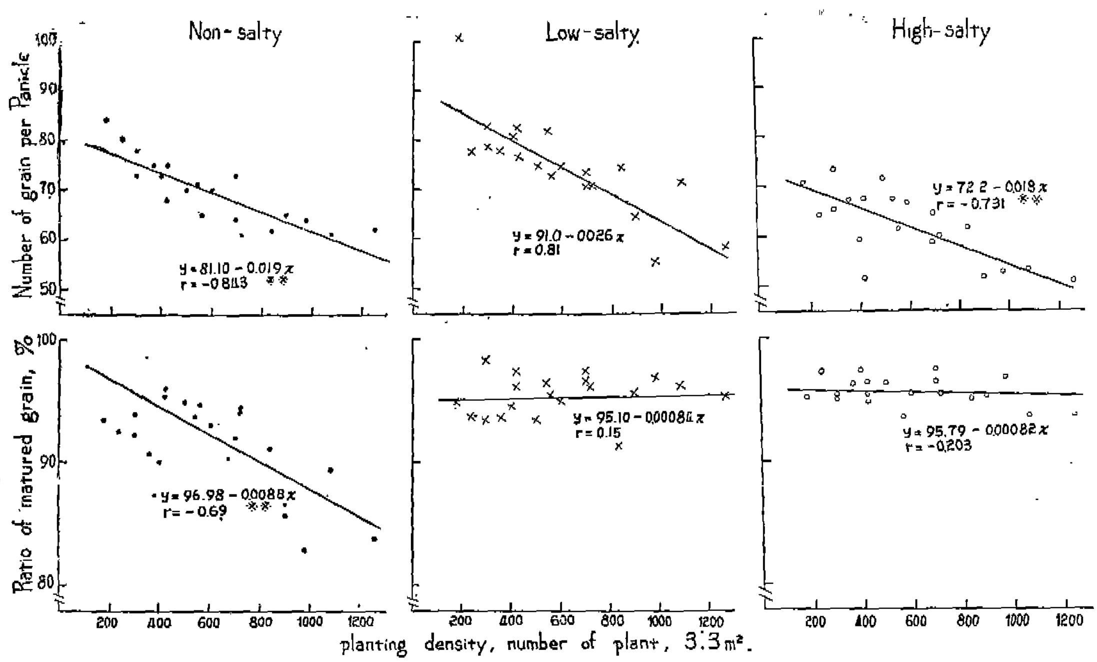

Fig. 6. Relationship between the planting density and grain number per panicle and ratio of matured grains.

The number of matured grains was the highest in the plot in the low-salty area. Figure 6 shows the relationship between the plant spacing and matured grain in 3 experimental areas. The matured grain decreased with closer planting in the non-salty area while the number was not decreased in both salty areas.

There was observed neither variation in the weight of one thousand rough rice grains according to the salt concentration nor closer planting treatment in each experimental area.

The cross sectioned area of the middle part of the first elongated internode of the stem when the number of hills per 3.3m² was fixed at 100 and changed the number of plants the number of plants per hill was also fixed and changed the number of hills at the maturing stage, were investigated in order to know the possibility of lodging by close planting. The results are shown in Figure 7. The stems became thick up to the planting of 5 plants per hill in the both non- and low-salty areas, but became thin in case of more than 5 plants per hill. Figure. 7 shows that the the stems became thin by close planting in the non-salty area when the number of hills per plot are increased with the fixed number of plants per hill at 7 plants while they did not become thin up to the planting of 80 hills in the low-salty area. In case of more than that close planting the stems became remarkably thin. However, in the salty area the stems were thick in all treatment plots as compared with the non-salty area, and also the length of stems was short. The length of stems from the low-salty area was shorter by percent in the planting of hills per 3.3m²(3, 5, 7 and 9 plants per hill on the average) and 18 percent in 7 plants per hlil (60, 80, 100, 120 and 140 hills per 3.3m² on the average) as compared with that of the non-salty area. Although the nature of stem wall structure as mentioned by Hozyo (1965) is also a problem to be taken into account, it was considered that there is little danger of lodging even by close planting in salty area in comparison with the non-salty area.

3) Plant Spacing and Yield of Rough Rice

In the high-salty area an increased yield of rough rice was produced by increasing the number of plants per hill, and such increased yieds were observed more remarkably when the number of hills per plot was increased. This condition suggests that an increase in the number of hills in the high-salty area is the most important factors for inducing increased yields.

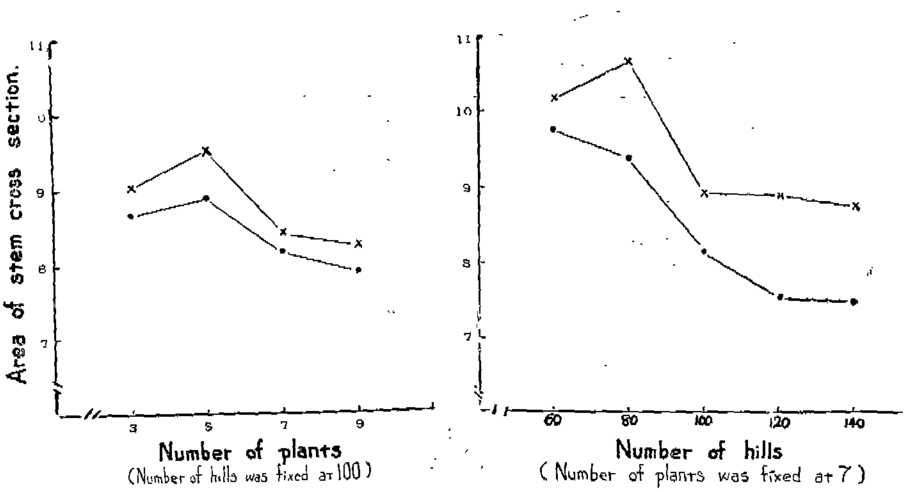

Fig. 7. Planting density and area in cross section of first elongated node. Areas of cross section were indicated with relative value.
● : Non-salty area, × : Low-salty area.

An intermediary state was observed in the low-salty area; as an increased number of plants per hill did not produce an increased rice yield while an increased number of hills produced an increase of rough rice.

The yields produced on each salty area are shown in Figure 8, when the number of plants per hill was constant and the number of hills per plot was increased, the yields on the non-salty area of the 3 plants per hill per plot were increased but decreased when the number of hills was over 100. On the other hand, a continuously increase in yields were observed in the low- and high-salty areas. The planting of 5 plants per hill decraased the yields when over 100 hills per 3.3 m^2 were used in the non-salty area and the increase continued for all plots in both low- and high- salty areas. In the planting of 7 plants per hill a decreasing trend was observed in yields due to closer planting in the non-salty area. Increased yields were brought about by increasing the number of hills per plot in both low- and high-salty areas. In the planting of 9 plants per hill per plot in the non-salty area, the yields decreased. In the low-salty area, however, an increased yield was produced up to 120 hills per plot, but closer planting than 120 hills per plot decreased the yield. In the high-salty area, closer planting produced increased yields and with 9 plants in 140 hillsper plot the maximum yield was produced.

Figure 9 shows the yields per plot increased as the number of transplanted seedlings per plot of the planting density increased. Although the yields increased in case of about 400 to 500 plants per plot (5 plants with 80 hills and 5 plants with 100 hills) in the non-salty area, there was no increased yield

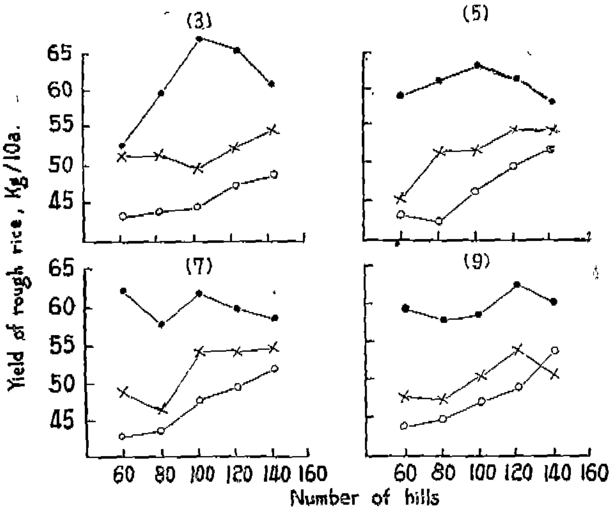

Fig. 8. Relationship between the number of hills and yield of rough rice.
The figures in perenthesis indicate the number of plants per hill.
● : Non-salty, X: Low-salty, O: High salty.

in an increased density over that indicated above but rather a decreasing trend in yields. The yields of rough rice the indicated "a law of constant in final yields" was in operation mantioned previously.

In the high-salty area the rough rice weight was increased when 1260 plants or more over planted per 3.3 m². This suggests that close planting increased the rice yields. This was also shown in the experiment which indicated that the status of relative light intensity curve by stratum, the weight of dry matter at the panidle differentiation stage and also the number and weight of panicles. However, in the low-salty area, the increasing ratio of yield was very low as the planting density per area increased in the plots having 100 to 140 hills per plot. The planting of some 1,000 plants per plot was considered to be the maximum production point for the rice plants..

Table 1. Effectiveness of the Number of Hills and Number of Plants on Rough Rice Yield in Lowsalty are. (Gr/3.3 m)

No. of Plants	Number of Hills					Average
	60	80	100	120	140	
3	5,158	5,160	4,956	5,227	5,481	**1,732**
5	4,527	5,160	5,208	5,487	5,460	**1,732**
7	4,872	4,612	5,206	5,303	5,799	**1,720**
9	4,793	4,738	5,061	5,313	5,212	**1,675**
Average	1,613	1,640	1,703	1,777	1,829	

Table 2. Effectiveness of the Number of Hills and Number of Plants on Rough Rice Yield in High-salty area. (Gr/3.3 m)

No. of Plants	Number of Hills					Average
	60	80	100	120	140	
3	4,326	4,387	4,415	4,747	4,855	1,515
5	4,377	4,261	4,670	4,983	5,173	1,564
7	4,323	4,380	4,719	4,923	5,184	1,569
9	4,395	4,503	4,734	4,932	5,416	1,599
Average	1,452	1,461	1,545	1,632	1,719	

Rough rice produced for each treatment as mentioned above was statistically analyzed. The number of plants per hill and the number of hills per unit area in each treatment did not give a significant difference in the non-salty area.

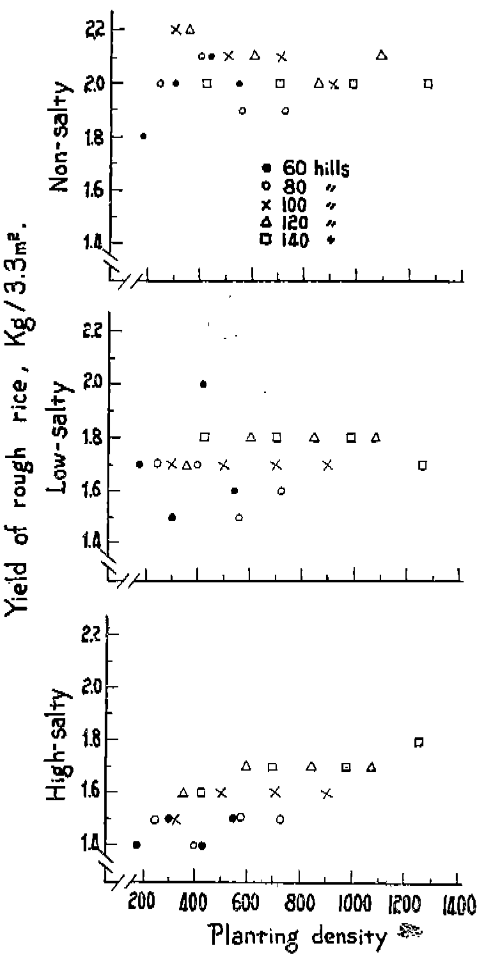

Fig. 9. Relationship between the planting density and yield of rough rice.

In the low-salty area the number of plants per hill to the yield was not statistically significant but the effect of number of hills per plot was shown to be significance at the 5 percent level. Duncan's multiple range test is shown in Table 1. It appeared that the treatment of 100 to 140 hills per plot gave an significant difference in the yield increase. The number of plants per hills did not shows significant differences within treatment. The same effect was observed from 3 to 9 plants per hill in the yield of rough rice. The effectiveness of the number of hills and the number of plants per hill in the table of analysis of variance on the 9 plants plantings were decreased 13.5 kilogram of rough rice per 10 a in yields under that of 7 plants according to these data. The best result of treatment in the low-salty area was 3 to 7 plants with 100 to 140 hills per plot.

The analysis of variance on the effect of plant spacing in the high-salty area is shown in table 2. The effect of number of plants was significant at the 5 percent level, although the number of hills per unit area was significant at the 1 percent level difference, 5 to 9 plants per hill were significantly better than that of the 3 plant plantings. The 120 and 140 hills were better than other treatments and were significant. It is indicated that the 5 to 9 plants per hill with 120 to 140 hills per plot can be recommended for best results in the high-salty area.

DISCUSSION

In order to increase the yields of crops, it is necessary to maximize the effects of photosynthesis. Furthermore, it is also necessary to more effectively utilize growing conditions and to accumulate the synthesized dry matter in the produced grains. The productivity of crops is considered to be regulated by the following three conditions: (1) photosynthetic capacity of the individual leaves of crops, (2) leaf area per unit land area and (3) space distribution of the individual leaves within the crop population.

Watson (1947) reported that the measure of leaf area per unit area is the most important factor in the regulation of the productivity of crops and that there is no significant difference in the photosynthetic capacity of the individual leaves between the crops or varieties. However, it is apparent that there will bedifferences in photosynthetic capacity of the individual leaves between she salt and non-salt soil conditions.

Gauch and Eaton (1942) claimed that the growth of crops in salty areas is interrupted by the inactive utilization of assimilatory products rather than a reduction in the photosynthetic capacity. According to Bernstein and Hayward (1958), the inactive growth of rice in the salty areas attributable to the reduction in photosynthetic capacity per unit area and the in active utilization of assimilatory products. On the other hand, Nieman (1962) reported recently that photosynthetic capacity is not reduced even under salty conditions.

In the present experimeet, the different of photosynthetic capacity among the non-salty, low- and *high-salty areas is of course one* of the problems to be taken into account. However, space distribution of leaves within the rice plant population, (i.e., productive structure of rice popuration and leaf area index per unit area) is regarded as the most important factors between each treatment plot of the present experiment rather than photosynthetic capacity of the individual leaves as claimed by Watson (1947).

Figure 3 shows that an increase in the number of hills per plot controls effectively the increase of the LAI. It seems, therefore, that the LAI at the panicle differentiation stage and the production of rough rice at harvesting time are greatly related.

According to the theory asserted by Donald (1958), each treatment in the low-salty area does not have sufficent leaf area to be suitable for maximum activities, and the production rough rice was increased. On the contrary, there was observed an increasing trend in the LAI and the production rough rice up to 100 hills with 7 plants per hill in the non-salty area but did not increased with more than 100 hills per plot. Consequently, it is considered that there is sufficient leaf area for maximum crop production as asserted by Donald (1958). It may be also considered that an increase of the LAI is an important factor in the production of rough rice in salty areas. Therefore, increased production will possibly result from an enlargement of the LAI in case of close planting.

A comparison of Figure 1 and 2 and Figure 8 show that the LAI in the case of the planting of 3 plants in each 100 hills (300 seedlings) and 9 plants in each 100 hills (900 seedlings) per 3.3 m^2, the planting density was increased 3 times but LAI is increased by about 5 to 6 in the latter than the former case. If the number of hills was changed from $7\times60=420$ to $7\times140=980$, the LAI increased 2.2 times. This indcates that an increased number of hills per 3.3 m^2 has an exorbitant effect on increasing the LAI as compared with an increased number of plants per hill at the unit area when the same number of seedlings were transplanted.

It is considered, therefore, that "diffused distribution method"(multi-planting of hills per unit area) has a great effect on increasing the LAI and an increased production of rough rice as compared with the "concentrated distribution method"(multi-planting as plants per hill). It is further presumed that an increased number of hills per plot increased significatly the production of rough rice while an increased number of plants per hill did not have any effect on an increase in the production of rough rice in salty areas.

The productive structure of the plant population showed a similar pattern without any structural difference following the variations in the number of plants per hill. However, in case of the different number of hills per plot there is some variation in the ratio of the assimilation and non-assimilation parts. The space distribution of assimilation part is relatively thick at the plant height of 40 to 60cm in case of close planting.

Monsi and Saeki (1953) pointed out that the space distribution of the assimilation parts and the relative light intensity curve by layer are closely related. The down part of the plant population is darkened by the light absorption of the upper part leaves. They measured in a grass land the relationship betweenthe light intensity (I) at a certain height within the plant population and the total leaf area above the height. As a result of this measurement, they obtained the following formula:

$$I = I_{0e}^{-KF}$$

Where I is the light intensity above the plant population, K is the light absorption coefficient of leaf and F is the LAI.

The light intensity curve by layer within the plant population makes an exporntial variation and the light intensity diminishes sharply as it goes down to the lower side of the plant population in the non-salty area.

As Figure 2 shows that in case of the close planting of more than 80 hills per $3.3\,m^2$ with 7 plants per hill, the leaves under 40 cm receive less than 5 percent of the light. However, in both salty areas, the leaf layers at 15 to 30 cm in height from the ground receive 30 to 40 percent of the natural light, as a whole; i., 30,000 to 40,000 lux of light penetrates during fine weather. It can be seen, therefore, that the lower part is almost saturated by light. It is presumed that there is almost no reduction in the photosynthesis of the lower leaf due to light deficit in salty area and the dry matter production is proportional to the leaf area per unit area and the production of rough rice also is thereby proportional to the leaf area. (See Figure 3)

There have been not a few reports available concerning the increase in the number of panicles per $3.3m^2$ by close planting. In the present experiment the number of panicles was remarkably increased by close planting in the salty areas. Except in case of sparsely planting in the non-salty plot, there was observed no effect of the increased number of plants per hill for an increase of the number of panicles. In any experimental area the effect of an increase in the number of plants was not significant while the effect of an increase of the number of hills was significant. The number of panicles per area was increased by an increased number of hills in both salty areas. This seems to suggest that the increase in the number of panicles by close planting may result in an increased yield in the salty area.

The panicle weight was greatly decreased by either increasing the number of plants per hill or the number of hills per $3.3m^2$ in the non-salty plot. Consequently the final yield was almost the same. On the contrary, however, the panicle weight was not decreased even by close planting in both salty areas. That is even though the number of panciles is increased, the panicle weight was not decreased. However an increased yield resulted from close planting.

The number of grains per panicle was decreased equally by close planting in the non-salty, low- and high-salty areas. It seemed that the effect of the increase in the number of plants per hill was greater than that of the increase of the number of hills per plot on the decrease of the number of grains by close planting in the salty areas.

The main cause that the panicle weight is not decrease in particular even by close planting in the salty areas can be seen from the higher ratio of maturd grains which do not decrease even by close planting. The ratio of matured grain in close planting greatly decreased in the non-salty area. This was not true in both salty areas.

Although the straw weight per area increased by close planting in the non-salty area, it seemed that an increased number of plants per hill had an effect on the straw weight and that the straw weight was not increased in particular by an increased number of hills per plot in salty areas. Consequently, the ratio of the weight of rough rice to straw weight was not decreased greatly by close planting in the salty areas. This may be attributable to the fact that the plants are short due to the salt effect and the number of stems do not increase even by close planting in salty areas.

Iwaki (1956), Ota et al. (1955) and Choi et al. (1963) reported that the ratio of matured grain to total grain decrease in salty area. However, in the present experiment, the ratio of matured grain on the salty areas was much greater than that of the non-salty area. Environmental conditions during the period from one month before heading until about one month after heading are considered to be the most important factors in the determination of the ratio of matured grain. Therefore, the ratio of matured grain as mentioned above might have resulted by the favorable salt concentration of the reclaimed area which reduced the selt content in paddy field after precipitation in the middle of July this year through the maturing stage of rice plant during early August.

The law of constant in final yielding capacity mentioned by Kira (1961 a,b), Takeda (1961 a,b) and Yamada (1961 a,b) was applied to the present experiment. The yields were uniformed but not increased by the close planting of more than 100 hills per plot with 3 to 5 plants per hill. This was the same as reported by the crop experiment stations in Korea.

Yamada (1961 a,b) reported that the close planting of 600 to 800 plants per hill increases the yield. However, the turning point of the production curve to which the "law of constant in final yield" is applicable will somewhat vary according to environmental factors and varieties of rice rice grown.

There have been some reports about the good results obtained from close planting of small hills in the non-salty area. However, the effect of an increased number of plants per hill in the low-salty area was not significant decrease in the yield. It was apparent that an increase of the number of hills per $3.3m^2$ plots instead of the number of plants per hill as salt concentration rises is one of the most suitable methods, in general, for an increased yield of rice in the salty area.

摘　　要

株當栽植本數를 3, 5, 7, 9의 4水準, $3.3m^2$當 株數를 60, 80, 100, 120, 140의 5水準의 組合인

20處理를 四月末 鹽分濃度가 各各 1.0%, 0.5% 및 0%인 高및 低鹽分區 그리고 熟畓區에 구사부에를 供試하여 適期栽培 熟畓標準法으로 實驗하였던 바 아래와 같은 結果를 얻었다.

1) 幼穗分化期에 作物個體群의 生産構造, 葉面積係數, 個體群의 層別相對照度曲線을 調査하였던 바 光合成 能率에 있어서 鹽分濃度가 높아짐에 따라 密度競爭効果가 낮았다 따라서 密植함이 增收의 可能性이 있음을 나타냈다. 그리고 總葉面積과 同化部의 空間配置에 있어서 株當本數增加보다 株數增加의 効果가 컸다.

2) 鹽分區들에서는 株當本數를 增加시키는 때에 比하여 3.3 m²當 株數를 增加시키는 때 顯著히 單位面積當 穗數가 增加되었다.

3) 熟畓區에서는 密植하므로써 穗重이 顯著히 줄었는데 鹽分區들에서는 密植하드라도 穗重이 크게 줄지 않았다.

4) 鹽分區들에서는 熟畓區에서와 마찬가지로 密植하므로써 穗當粒數가 有意하게 줄었다.

5) 鹽分區들에서는 密植하드라도 稔實率이 減少되지 않았으나 熟畓區에서는 密植하므로써 有意하게 稔實率이 떨어졌다.

6) 鹽分區들에서는 精租生産이 LAI에 比例되었으며 熟畓區에 比하여 稈長과 稈徑이 密植하여도倒伏의 危險이 적을 것으로 보였다.

7) 以上과 같은 여러 點을 綜合하면 鹽分地에서는 密植하므로써 增收가 可能하다. 그리고 鹽分地에서는 株當本數의 增加보다 單位面積當의 株數增加가 增收에 더 効果가 컸다 (가) 熟畓區에서는 3~5 本植의 3.3m²當 100本을 넘는 密植은 結果가 나빴으며 (나) 低鹽分區에서는 3~7本植의 100~140株가 좋았고 (다) 高鹽分區에서는 5~9本植의 120~140株가 좋았다.

LITERATURE CITED

1. Agriculture Experiment Station, Suwon, Korea. 1924. Research Report, Experiment on the plant spacing of rice, on number of plants per hill.
2. ____________. 1924. Research Report, Experiment on the plant spacing on number of hills per unit area.
3. ____________. 1940. Research Report, Experiment on the plant spacing of rice, on the number of plants per hill and number of hills per unit area.
4. Bae, S.H., Y.C. Oh, and K.B. Yeun. 1965. Research Report, Experiment on the late season culture of rice, density experiment. Crop Exp. Stat., Suwon, Korea, 339—353.
5. ____________, K.B. Yeun, and C.D. Song. 1965. Research Report, Experiment on the early season culture of rice, density experiment. Crop Exp. Stat., Suwon, Korea, 264—285.
6. Bernstein, L., and H.E. Hayward. 1958. Physiology of salt tolerance. Ann. Rev. Pl. Physiol. 9, 25—46.
7. Boysen-Jensen, P. 1932. Die Stoffproduktion der Pflanzen. Jena.
8. Choi, H.O. et al. 1963. Research Report, Stock improvement experiment of rice for reclaimed soil area. The pre-test of productivity of the stock varieties for reclaimed soil area. Crop. Exp. Stat. Suwon, Korea, 159—181.
9. ____________, K.B. Yeun, and C.D. Song. 1963. 1963. Research Report. Experiment on early season culture of rice. Plant spacing experiment. Crop Exp. Stat. Suwon, Korea, 394~404.
10. Donald, C.M., and J. N. Black. 1958. The significance of leaf area in pasture growth. Herb. Abstr. 28, 1—6.

11. Gauch, H. G., and F.M. Eaton. 1942. Effect of saline substrate on hourly levels of carbohydreates and inorganic constituents of barley plants. Pl. Physiol. 17, 347—365.
12. Honam Crop Experiment Station, Iri, Korea. 1966. The Research Report. On the plant spacing experiment of rice in reclaimed soil area.
13. Hozyo, Y., and K. Oda. 1965. Studies on the stiffness of culms in barley plants. 7. Relation between the development of nodes and bending moment in nodes. Proc. Crop Sci., Japan. 33 (4), 289—292.
14. Iwaki, S. 1956. Studies on the salt injury in rice plants. Mem. Ehime Univ. Sect. VI. 2(1), 1—156.
15. Kira, D. 1961. The crop yield and plant spacing. (1) On the plant spacing of rice plants. Agr. Hort., Japan. 36(7), 1101—1106.
16. __________. 1961. The crop yield and plant spacing. 3. On the plant spacing of rice plants. Agr. Hort., Japan. 36(9), 1421—1425.
17. Kyongki-do Agricultural Experiment Station. 1930. Research Report, Experiment on the plant spacing of rice, on number of hills per unit area.
18. Kyongbuk-do Agricultural Experiment Station. 1930. Research Report, Experiment on the plant spacing of rice, on relationship between the number of hills per unit area, number of plants per hill and fertilizer applications and varieties.
19. Monsi, M., and T. Saeki. 1953. Uber die lichtfaktor in den Pflanzengesellschaften und seine Bedeutung fur die stoffproduktion. Jour. Bot., Japan. 14, 22—52.
20. Nieman, R.H. 1962. Some effects of sodium chloride on growth, photosynthesis, and respiration of twelve crop plants. Bot. Gaz. 123(4), 279—285.
21. Ota, K., T. Ogo, and K. Sasai 1955. Studies on the saline injury on crops. IX. On the influences of the saline irrigation water upon the shape of rice kernels. Okayama Prefect. Agr. Exp. Stat. Spec. Bull. 51, 21—26.
22. Takeda, T. 1961. The problem of the planting of close density and limitation of yield in rice culture. Agr. Hort., Japan. 36(4), 627—632.
23. __________. 1961. The problem of the planting of close density and limitation of yield in rice culture. (2). Agr. Hort., Japan. 36(5), 791—796.
24. Watson, D.J. 1947. Comparative physiological studies on the growth of field crops. (I). Ann. Bot. N.S. II, 41—89.
25. Yamada, N. 1961. On the plant spacing and yield in rice culture. (1). Agr. Hort., Japan. 36(1), 13—18.
26. __________. 1961. On the plant spacing and yield in rice culture. (2) Agr. Hort., Japan. 36 (2), 311—315.