Studies on Diurnal Variation of Rooting Activity in Rice Seedlings and Its Practical Application

Toshioki SHIBUYA

(Laboratory of Crop Science and Plant Breeding, Faculty of Agriculture)

渋 谷 紀 起：稲苗発根力の日変化及びその利用に関する研究

(I) INTRODUCTION

Among several favorable conditions for the transplantation of seedlings in paddy field, it is important that the growth of new crown roots occurs rapidly and much on the seedlings, for the crown roots which hasten to grow long in paddy soil can seat the seedlings vividly to the soil.

Regarding what character of the seedlings is favorable for rooting, SATO's experiments (Kenkiti SATO, 1941 and 1946) pointed out markedly the growth stage of themselves which had a close connection with as well these elapsed days in seed-bed from sowing to picking (seed-bed period) as the rate of sown density.

Other factors that affect upon rooting, for instance, the photosynthesis and the respiration in day-time or night which variate in accordance with the time of picking and that of transplantation and the weather of those interval, should be investigated with considerable attention.

The present papers have a purpose to report about the studies of rice seedlings on their diurnal fluctuation of rooting activity which accords with the light or the temperature, and on the results of experimental culture done as an application of the activity, moreover others concerned.

The works are not yet completed, but once here the informations up to the present are reported.

(II) MATERIALS AND METHODS

1. Measurement of rooting activity

i) Shortly after random sampling of seedlings by means of picking from seed-bed, the crown roots remained were pruned off, the seedlings were put into beakers with the tap water of 2 cm depth. They were placed on the glass-rings in the beakers and entered into a thermostat of dark and 28～30°C.

ii) Instead of the beakers, the seed-bed was brought in use, where the irrigated water was flooded.

iii) Total length of the newly developed roots per seedling was caught for the indication of rooting activity, and thickness of them (cf. Fig. 1) was neglected, for the accurate measurement of it on many roots in a short time was impossible.

2. Keeping of seedlings

The places and the methods of keeping during hours from picking to transplantation were as follows:—

i) The seedlings were kept in a seed-bed maintaining old crown roots in the flooded water.

ii) They were put in the beakers with water of nursery; and at night, the beakers were entered into the dark thermostats of high (28~30°C) or low (5~7°C) temperature.

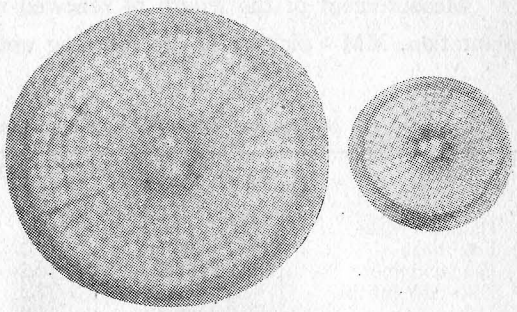

Fig. 1 Different thickness of root.
Left and right are in a similar magnification

3. Measurement of weight and technigue of chemical analysis

i) Fresh weight of the seedlings was measured afterwards the pruning of old roots, of old traces of seed, and the giving a good wash.

ii) To weigh the dry matter, the seedlings removing the old roots or hulls, were put in a drying thermostat of 65°~70°C until the weight came to constant.

iii) Total sugar involved in the seedlings was analysed by means of Bertrand's technique.

4. Experimental cultivation in paddy field

There were so combined the time of picking with the time of transplantation according to "Latin square arrangement", that four kinds of plots were made per variety, i.e. as follws:—

MM : picking in the morning and transplantation in the morning.

ME : picking in the morning and transplantation in the evening.

EE : picking in the evening and transplantation in the evening.

EM : picking in the evening and transplantation in the morning.

On the other hand, with the purpose to study the effect of rooting activity on interplant competition or individual competition, the mixed planting was done in both MM and EE.

(III) ROOTING ACTIVITY AND ITS DIURNAL VARIATION

1. Diurnal fluctuation of rooting activity in rice varieties

In this experiment, the comparison about the rooting activity between the seedlings picked off in the morning and those in the afternoon was dealt with.

Rice varieties employed were 14 of *japonica* type that privately bred in SHŌNAI district, and one diploid *indica* type (2x of Kōnan-tō), one autotetraploid *indica* type (4x of Kōnan-tō).

Picking of seedlings was done at 7.30 a.m. of April 28 and 29, and at 16.30 p.m. of April 27 and 28, when the seed-bed period was 25~27 days.

Just at picking, residual old roots were pruned off, seedlings were transplanted in the beakers with thin tap water, entered into a dark thermostat of 30°C.

Measurement of the length of renewed roots was done on 48 hours after transplantation. MM : picking in the morning and transplantation in the morning. EE : picking in the evening and transplantation in the evening.

Table 1.
Total length of renewed roots per seedling, mm

Name of variety	MM	EE	(EE-MM)/MM (%)
Daikoku-wase	39.0	64.4	65.1
Fukubōzu	74.2	86.7	17.2
Hiedachi-ine	32.7	36.7	12.2
Hikotarō-mochi	47.2	83.7	77.3
Igō	59.0	70.7	11.0
Kameno-o	69.2	78.8	13.8
Konda-mochi	36.0	64.5	79.2
Ōmiya-nishiki	43.6	70.2	61.0
Shikishima	61.3	69.8	13.8
Shōwa-nigō	54.6	69.4	27.1
Tamanoi	32.1	52.4	63.2
Toyokuni	46.0	80.3	74.5
Udoshi-wase	43.8	71.8	63.9
Wase-aikoku	59.5	57.5	-3.3
Kōnan-to (2x)	45.0	60.2	33.8
Konan-to (4x)	3.0	58.1	1836.6

According to Table 1, all varieties except one showed that the activity of the seedlings picked in the afternoon were superior to that of those in the morning. Varietal superiority calculated, that was (EE-MM)/MM, reached in *japonica* type above 60% or below 30%, while in *indica* type 2x reached just 33.8% and 4x which had larger cells in a tissue reached 1836.6%.

2. Diurnal fluctuation of rooting activity of seedlings which were grown up under various types of seed-bed and various habitats

The methods to determine the rooting activity were mostly like as the above experiment except the maintenance of picked seedlings for about 6 hours in the dark vessels, in which the temperature resembled that of air.

The varieties and the developmental stages of seedlings were shown in Table 2. Semi-irrigated warm bed written in the table is an intermediate type of land-bed and flooded-bed, and is protected from cold temperature with paper or film in the primary stage of seedlings.

Table 2 Developmental stages of seedlings shown as "Leaf stage" of main stem

Habitat	Coastal plain				Basin			
Type of bed	Semi-irrig. warm bed		Flooded bed		Semi-irrig. warm bed		Flooded bed	
Vars. name	M(M)	E(E)	M(M)	E(E)	M(M)	E(E)	M(M)	E(E)
Norin No. 46	6.80	6.60	—	—	5.72	5.76	—	—
Norin No. 41	—	—	—	—	6.70	6.12	5.76	5.62
Obanazawa No. 1	7.00	6.70	—	—	6.00	6.00	5.10	5.54
Fukubozu	—	—	—	—	6.20	6.04	5.10	5.16

Note : 1. Coastal plain and Basin lie in Yamagata Pref. Japan
2. ( ) signifies the pre-arrangement of transplantation

The experimental results carried out with the materials shown in Tab. 2, are described in Table 3.

By means of "EE-MM" or (EE-MM)/MM, the increased activity of rooting of EE can be calculated as next table.

Table 3 Rooting activity in accordance with habitat of seedlings and with type of seed-bed. (Total length of renewed roots per seedling, mm)

Habitat	Coastal plain				Basin			
Type of bed	Semi-irrig. warm bed		Flooded bed		Semi-irrig. warm bed		Flooded bed	
Vars. name	MM	EE	MM	EE	MM	EE	MM	EE
Norin No. 46	61.1	58.8	27.1	44.7	58.3	172.9	—	—
Norin No. 41	—	—	51.8	62.7	78.7	96.2	23.0	69.7
Obanazawa No. 1	55.8	61.8	44.7	49.5	92.0	219.3	17.2	80.4
Fukubozu	—	—	59.0	86.2	90.2	193.3	23.0	70.9
Mean	58.5	60.3	45.7	60.8	79.8	170.5	21.1	73.7
Hours in thermostat	83h		128h		75h		55h	

Table 4 Increased activity of EE-seedling

Habitat	Coastal plain				Basin			
Type of bed	Semi-irrig. warm bed		Flooded bed		Semi-irrig. warm bed		Flooded bed	
Difference / Vars. name	Differ. (mm)	Percent. (%)	Differ. (mm)	Percent. (%)	Differ. (mm)	Percent. (%)	Differ. (mm)	Percent. (%)
Norin No. 46	−2.3	−3.7	17.6	64.9	114.6	196.6	—	—
Norin No. 41	—	—	10.9	21.0	17.5	22.3	46.7	203.0
Obanazawa No. 1	6.0	10.7	4.8	10.7	127.3	138.3	63.2	367.4
Fukubozu	—	—	27.2	46.1	103.1	114.3	47.9	208.2
Mean	1.8	3.5	15.1	35.7	90.7	117.9	52.6	259.5

According to Table 4, the seedlings grown up in a basin can have greater difference between MM and EE, than those grown up in a coastal plain of the same latitude.

This fact is presumed, having relation to the amount of substances based on photosynthesis in the seedlings, to be resulted from the characteristics of the basin weather.

In Table 4, comparing mean percentages of four columns each other, the seedlings bred in the flooded bed exceeded seemingly those bred in the semi-irrigated warm bed.

3. Rooting activity in accordance with various temperatures of night

The diurnal fluctuation of rooting activity seen in a dark place as mentioned above are consisted of the inferiority of the "Morning picking" and the superiority of the "Evening picking". One of the reasons why the seedlings belonging to the former are inferior to those belonging to the latter must be the dissimilation by respiration in the night preceding to picking.

The temperature of seed-bed at night will affect on the degree of respiration of the seedlings, consequently on the residuals of it at next morning when the picking is done.

The experiment was carried out by next means: — the irrigated water was drawed

in two beakers, in which the seedlings were put being picked in the evening with the residual crown roots remaining. One beaker was entered into higher temperature (28～30°C), the other was entered into lower temperature (5～7°C). Next morning, those were brought in experiment by means readily mentioned.

The rice varieties employed were Norin No. 46 and Norin No. 41 and Kyōden-mochi.

The results by the measurement on 50 hours after transplantation in beakers were shown in Table 5 and Table 6.

Table 5 Night temp. and rooting activity (Length per seedling, mm)

Night temp.	Norin No. 46		Norin No. 41	
	High (30°C)	Low (5°C)	High (30°C)	Low (5°C)
1st Exp. (June 1)	40.6	79.6	34.2	111.8
2nd Exp. (June 2)	78.2	98.8	58.0	95.6
Mean	59.4	85.2	46.1	103.7

Table 6
Rooting activity of Kyoden-mochi in accordance with night temperature (Length per seedling, mm)

Night temp.	High temp. (28～30°C)	Lowtemp. (5～7°C)
Length of renewed roots	63.0	94.0

Table 7 (Low-High)/High, %

Norin No. 46	43.4
Norin No. 41	124.9
Kyoden-mochi	49.2

With Table 5 and Table 6, such rate as (Low-High)/High can be calculated as shown in Table 7.

According to above three tables, the low temperature in the night lets the seedlings remain these rooting activity, but on the contrary the high temperature is consumptive for it.

The outside view of these seedlings was in the former dry by dehydration, in the latter soft by hydration.

Varietal differences in rooting activity are able to be seen, for instance, Norin No. 41 loses most in all the activity in the high temperature of the night. This type should adapt to the coastal region where the temperature of night is warm.

There should be a correspondence between the diminution of activity in warm night and the remainder of it in cold night.

4. Rooting activity of seedlings which were kept in seed-bed

In both cases of picking in morning for transplantation in evening (ME) and of picking in evening for transplantation in next morning (EM), the picked seedlings are ordinarily kept in the seed-bed with those roots bathing the flooded-water. Consequently the keeping is done in the day or in the night.

Present experiment aimed to determine the effects of keeping of the seedlings on the rooting activity of themselves.

"Morning and morning" (MM): pick at 5.30 a.m., prune off the roots, wash and immediately transplant in a beaker in the morning. "Morning and Evening" (ME): pick at 5.30 a.m., keep in seed-bed, prune off the roots and wash at 17.30 p.m., and immediately transplant in a beaker in the evening. "Evening and Evening" (EE): pick at 17.30 p.m., prune off the roots, wash, and immediately transplant in a beaker in the evening. "Evening and Morning" (EM): pick at 17.30 p.m., keep in seed-bed

throughout the night, prune off the roots and wash at 5.30 a.m., and immediately transplant in a beaker in the morning.

Table 8 Rooting activity of MM, ME, EE and EM. (Total length per seedling, mm, in two days)

	MM		ME		EE		EM	
	Norin No. 46	Norin No. 41	Norin No. 46	Norin No. 41	Norin No. 46	Norin No. 41	Norin No. 46	Norin No. 41
1st exp. (cloudy)	30.0	21.2	102.6	103.8	78.5	78.3	38.5	24.6
2nd exp. (fine)	32.4	37.2	137.8	140.6	113.6	86.2	42.3	38.4
Mean	30.2		121.2		89.2		35.9	

In the leaf stage of a main stem in 1st exp. Norin No. 46 and Norin No. 41 were mostly same, while in 2nd exp. Norin No. 46 was senior to Norlin No. 41.

The results in Table 8 show that ME had the most vigorous rooting, and the sequence from superiority to inferiority was ME>EE>EM>MM (cf. Fig. 2), moreover the fine weather brought more rooting ability on the seedlings than the cloudy weather.

The greatest activity appeared in ME would be related with a wound-hormone produced in the day-time during its keeping period.

When it is fine and cold in the night, the dissimilation may be so retarded that the carbohydrates produced in the fine day-time can remain toward morning, but if it is cloudy and warm, the matter may become contrary.

The greater activity of EE is due to its contents, especially to the carbohydrates produced by photosynthesis till its picking-time.

The rooting activity of EM may solely depend upon the residuals of dissimilation in the night, while that of MM will depend upon both residuals of dissimilation and of growth in the night; thus having no relation to the weather, MM should be inferior to EM in the rooting as seen in the experiment.

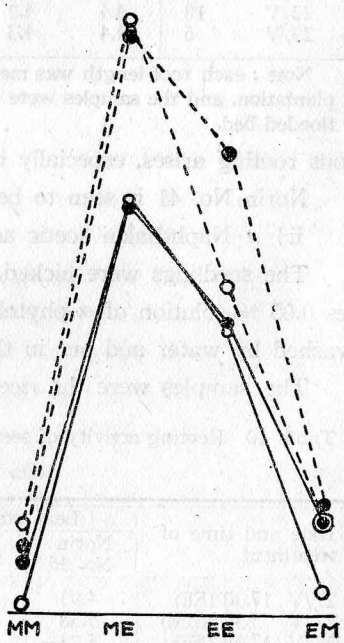

Fig. 2 Rooting activity
● : Norin No. 46
○ : Norin No. 41
—— cloudy
- - - fine

According to the difference between EE and EM or EE and MM under cloudy night, Norin No. 41 losed the rooting activity during the night more than Norin No. 46.

5. Effects of chemical substances on diurnal fluctuation of rooting activity in rice seedlings

Chemical substances used here were Ammonium-sulfate, α-Naphthalene acetic acid and 2·4-D.

i) Ammonium-sulfate

It belongs to a common matter that this manure is supplementally given to the seedlings in rice nursery.

This supplement was experimetally given at 10.00 a.m. in a day to the flooded bed 15 gm per "Tsubo", and then the seedlings were successionally picked at followed every evening and every morning.

Table 9
Rooting followed late manuring by $(NH_4)_2SO_4$ for supplement

Date and time of picking and transplantation	Leaf stage		Root length		Sign
	Norin No. 46	Norin No. 41	Norin No. 46 (mm)	Norin No. 41 (mm)	
19/V 18	4.0	4.0	2.398	13.312	E E
20/V 6	4.1	4.0	3.400	15.695	M M
20/V 18	4.1	4.0	23.200	26.980	E E
21/V 6	4.1	4.0	6.300	11.086	M M
21/V 18	4.2	4.1	43.200	37.752	E E
22/V 6	4.3	4.1	10.222	31.320	M M
22/V 18	4.4	4.2	85.272	77.580	E E
23/V 6	4.4	4.3	13.200	32.512	M M

Note : each root length was measured on 72 hours after transplantation, and the samples were the seedlings grown up in the flooded bed.

According to Table 9, $(NH_4)_2SO_4$ supplementally given to the seed-bed inhibits the rooting for a few days and shortens the difference between MM and EE, but with the lapse of the day the inhibition disappears and the vigorous rooting arises, especially in EE.

Norin No. 41 is seen to be more insensitive to the manure than Norin No. 46.

ii) α-Naphthalen acetic acid and 2•4-D

The seedlings were picked, root-chipped, and washed, then absorbed for 20 minutes 0.05 % solution of α-phytohormone or of 2•4-D. The treated seedlings were again washed by water and put in the beakers, entered into a thermostat of 28°C.

The samples were the rice seedlings grown up in a semi-irrigated warm bed.

Table 10 Rooting activity of seedlings in the case of application with α-hormone and 2•4-D
(On 72 hours after transplantation)

Date and time of treatment	Leaf stage		Norin No. 46		Norin No. 41	
	Norin No. 46	Norin No. 41	α-hormone (mm)	2•4-D (mm)	α-hormone (mm)	2•4-D (mm)
21/V 17.30 (EE)	4.93	5.31	11.75	1.80	16.10	3.35
22/V 5.30 (MM)	5.38	5.51	2.95	0.40	13.60	2.15
22/V 17.30 (EE)	5.23	5.66	31.70	1.10	30.55	5.90
23/V 5.30 (MM)	5.32	5.72	0.30	0.00	8.40	2.50
23/V 17.30 (EE)	5.43	5.70	13.10	0.40	24.65	2.75
24/V 5.30 (MM)	5.66	5.89	2.55	0.00	4.60	0.30
24/V 17.30 (EE)	5.75	5.98	10.15	1.00	20.85	1.05
25/V 5.30 (MM)	6.16	5.97	4.03	0.30	9.60	1.00
Mean EE			16.68	1.08	23.04	3.26
Mean MM			2.46	0.18	9.05	1.49

According to Table 10, the diurnal fluctuation of rooting activity is remarkable in each variety and in α-phytohormone treatment, but not in 2•4-D. 2•4-D injures as worse the seedlings picked in the morning as those picked in the evening.

In the present results in Table 10, Norin No. 41 was so superior in rooting activity to Norin No. 46 throughout the evening and the morning, that the former variety

was seen to have more amount of carbohydrates in the plant than the latter.

6. Renewed root in seed-bed soil

The rooting of rice seedlings is able to take place as well in the seed-bed as in the beaker. The seed-bed is light by sunshine during the day, while the beaker is constantly dark by the shut thermostat.

The place for transplantation in this experiment was the seed-bed soil, and there was no wind on it.

The transplantation in MM of this case so resembles the keeping in ME, that under sunshine the seedlings can enlarge the rooting. But on the contrary, MM in a shade could not increase so much activity as MM exposed to sunshine.

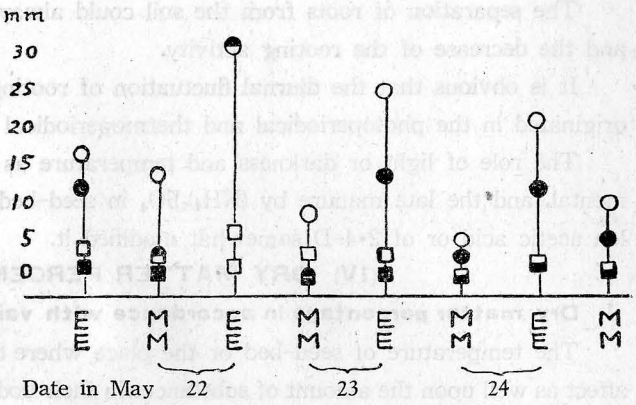

Fig. 3 Diunal fluctuation of rooting activity
○□ : Norin No. 41 ●■ : Norin No. 46
○● : α-hormone treatment □■ : 2·4-D treatment
mm : Total length of renewed roots per seedling

Table 11
Renewed roots of seedlings returned back to seed-bed without old roots. (Total length per seedling, mm., in two days)

Condition on bed \ Name of variety, time of picking and transplantation	Norin No. 46 MM	Norin No. 46 EE	Norin No. 41 MM	Norin No. 41 EE
Sunshine	51.6	35.3	56.2	41.4
Artificial shade	36.0	38.4	41.1	43.7

The fact as above suggests the birth of wound-hormone under sunshine in the day-time, and shows that MM (morning picking and morning transplantation) that showed the inferiority in a dark thermostat, can raise the rooting activity in such a condition as the sunlight shines on the transplanted seedlings and as the wind does not make them wither.

7. Summary

The rooting activity and its diurnal fluctuation was studied with the samples of rice seedlings grown up and treated in several kinds of conditions, and the itemized data were shown in Table 1~11.

Throughout the data obtained, the rooting activity was conformable with the diurnal darkness and the temperature before and behind picking and transplantation.

In every case of the present experiments the darkness was apt to let the rooting activity to decrease, but the light was contrary, and the temperature of somewhat high played to promote the decrease under darkness and the increase under light.

Moreover, there was found such a factor as affected on the rooting activity, and as appeared in accordance with the picking in the morning and with the keeping during a day-time under sunshine.

The separation of roots from the soil could always prevent the growth of plant and the decrease of the rooting activity.

It is obvious that the diurnal fluctuation of rooting activity in rice seedlings is originated in the photoperiodical and thermoperiodical range in a day.

The role of light or darkness and temperature as mentioned above was fundamental, and the late manure by $(NH_4)_2SO_4$ in seed-bed, the absorption of α-Naphthalen acetic acid or of 2·4-D somewhat modified it.

(IV) DRY MATTER PERCENTAGE

1. Dry matter percentage in accordance with various temperatures of night

The temperature of seed-bed or the place where the rice seedlings are kept must affect as well upon the amount of substances in their bodies as on the rooting activities.

The relation between the temperature in the night when the seedlings were kept in beakers and the dry matter percentage of the plants was investigated and shown in Table 12.

Table 12 Night temperature and dry matter percentage.
(Var.: Kyoden-mochi)

Nigth temp.	Outdoor in seed-bed	High temp. (30°C)	Low temp. (5°~7°C)
Of 50 seedlings			
Fresh wt. gm.	16.0	18.2	14.0
Dry wt. gm.	3.1	3.0	3.2
Dry matter percent.	19.37	16.48	22.85

According to Table 12, the seedlings past a high temperature in the night consumed the dry matter more than those past a low temperature. This fact has a close relationship to the superior rooting of the seedlings which were kept under low temperature in the night, cf. Table 5 and Table 6.

2. Dry matter percentage of seedlings which were kept in seed-bed accompanying no transplantation

MM, ME, EE and EM signify almost the same to those of Table 8. The dry matter percentages of those seedlings were obtained as next table.

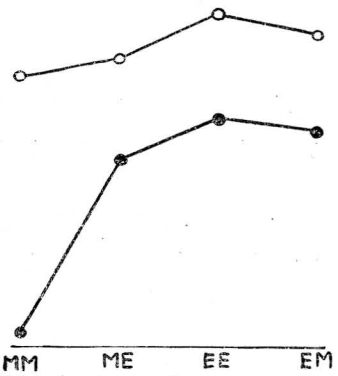

Fig. 4 Dry matter percentage
● : Norin No. 46
○ : Norin No. 41

Table 13 Dry matter percent. of MM, ME, EE and EM

Variety \ Sample	MM (%)	ME (%)	EE (%)	EM (%)
Norin No. 46	12.30	15.82	16.67	16.39
Norin No. 41	17.51	17.90	18.81	18.00
Mean	14.91	16.86	17.74	17.20

Accoding to Table 13 and Fig. 4 the sequence is EE>EM>ME>MM in every variety.

This sequence does not completety agree with that of rooting activity in Table 8.

The fact that EM (seedlings picked in the evening, being kept throughout a night, dried on next morning) was less than EE (seedlings picked in the evening and dried on that

evening) shows the keeping throughout a night always brings a decrease of the dry matters in the plant, because, presumably, of the dissimilation at night.

MM (seedlings picked in the morning and dried on that morning) decreased far more than EM because, perhaps, of the consumption for the growth of roots in the soil.

ME (seedlings picked in the morning, being kept during a day-time, dried on that evening) could aquire the dry matter exceedingly over MM because, perhaps, of a receipt of sunlight during a day-time, but could not increase it over EE.

Throughout the samples, Norin No. 41 was superior to Norin No. 46 in this case.

3. Summary

Temperature of the night during which keeping of seedlings was done influenced significantly upon the dry matter percentage of them, for instance, the high temperature let the percentage to decrease, but the low temperature not always did.

The seedlings picked in the morning and kept in seed-bed during a day-time had an increase of the dry matter percentage over those treated in the morning accompanying no keeping.

The seedlings picked in the evening and kept during a dark night had a decrease of the dry matter percentage under those treated in the evening accompanying no keeping.

Dry matter percentage had as well photo- and thermo-sensitiveness as the rooting activity, but did not agree with the rooting activity in the degree of sensitiveness.

The rooting activity of the seedlings which were kept in seed-bed after picking of morning could predominate exceedingly (cf. Table 8), but the dry matter percentage of those showed to be little, because of, seemingly, absense of wound-hormone to the dry matter and the presense of it to the rooting.

(V) SUGAR CONTENTS IN RICE SEEDLINGS

Total sugar percentage was derived from the dry matter by means of Bertrand's method.

1. Diurnal range of total sugar percentage

At 5.30 a.m., 10.00 a.m., 14.00 p.m., and 18.00 p.m. in a semi-fine day, the seedlings were taken by picking from seed-bed, washed by water removing the old roots and hulls, and dried in a thermostat of 70°C, and milled, then dried to extreme in 100°C, to know the moisture content. The meal of each sample being consisted of 50 individuals carried into the analytic device.

According to the results in Table 14, diurnal range of total sugar percentage in a day is remarkable. Resembling the air temperature, the

Table 14

Diurnal range of total sugar percentage (At 10 % of water content)

Time of picking \ Name of variety	Norin No. 46 (%)	Norin No. 41 (%)
5.30	18.4	15.9
10.00	19.1	16.2
14.00	19.7	21.2
18.00	19.5	16.0

sugar content in rice seedlings reached a maximum around 14.00 p.m. and a minimum in the early morning, and came down evidently toward the evening.

In Table 14, there can be found a difference between two varieties as that the diurnal range of Norin No. 41 is more steep than that of Norin No. 46.

2. Variation of total sugar percentage in accordance with time of picking and with keeping

The samples in this experiment were as follows: —

MM: picked in the morning (6.00 a.m.) and dried on that morning.

ME: picked in the morning, kept in seed-bed during the day-time and dried on the evening (18.00 p.m.).

EE: picked in the evening (18.00 p.m.) and dried on that evening.

EM: picked in the evening, kept in seed-bed during the night and dried on the next morning (6.00 a.m.).

Table 15 Percentage of total sugar in MM, ME, EE, EM. (At 10 % of water content)

Variety \ Sample	MM (%)	ME (%)	EE (%)	EM (%)
Norin No. 46 (grown up in coastal plain)	18.9	18.7	22.3	21.0
〃 (grown up in basin)	17.1	19.6	21.8	19.6
Norin No. 41 (grown up in coastal plain)	17.3	17.5	23.0	22.5
Mean	17.8	18.6	22.4	21.0

Each value in relation to the percentage of total sugar in Table 15 behaved mostly simiarly to that of dry matter percentage in Table 13.

Next, the effect of the temperature of a night, throughout which the seedlings were kept, upon the percentage of total sugar in EM (evening picking for morning dry) was investigated, and the result was shown in Table 16. In this investigation, the control was EE (evening picking for evening dry). The seedlings of EM were devided into two parts, the one was entered into the high temperature throughout a night and the other was entered into the low temperature.

Table 16
Night temp. and total sugar percent. (Var. Kyoden-mochi. At 10 % of watar content)

EE (%)	28~30°C (%)	5~7°C (%)
30.9	25.0	30.3

According to the figures shown in Table 16, the keeping throughout a night made the percentage of total sugar to decrease, to a large degree in a high temperature and to a small degree in a low temperatute.

3. Summary

After the similar sequence of values in relation to the total sugar percentage to that of dry matter percentage, it is concluded that the total sugar in rice seedlings is most effective on the dry matter.

The total sugar percentage had not a close correlation with the rooting activity, for instance, the sequence of the values of total sugar percentage was EE>EM>ME>MM, while that of rooting activity was ME>EE>EM>MM.

The figures in Table 14, which showed a diurnal range of total sugar percentage, behaved to agree with that of air temperature.

The temperature of a night throughout which the keeping of seedlings were done affected upon the percentage of total sugar in them; a high temperature let the percentage to decrease heavily and a low temperature let it to decrease lightly.

Herein is additionally shown the relationship of sugar contents to the dry matter and the rooting activity with a test-figure (Fig. 5).

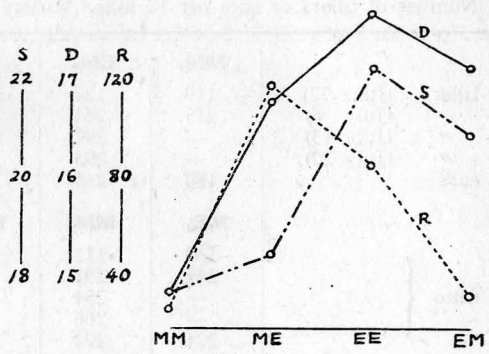

Fig. 5
S: Total sugar percentage
D: Dry matter percentage
R: Total length of roots per seedling (mm)

(VI) GROWTH IN PADDY FIELD

1. Preliminary experiment

The plots were MM and EE, (MM: picking at 8.30~9.00 a.m. and transplantation at 9.00~10.00 a.m., EE: picking at 14.30~15.00 p.m. and transplantation at 15.00~16.00 p.m.).

The transplanting density of each plot was 3 individuals a hill in 23×24 cm^2.

Table 17 Changing phases of number of tillers per hill. (Variety: Norin No. 46)

Plot \ Date	June 20	June 30	July 10	July 20	July 30	August 10	August 20
MM	7.5	16.1	23.4	22.4	20.7	17.5	16.2
EE	10.9	20.2	26.2	25.6	24.3	20.8	19.3

According to Table 17, MM was inferior to EE already in the beginning of tillering, and this transmitted to the last.

The number of ears per hill was shown in Table 18, with which the mean length of stems and ears, and the mean value of yield per 10 a. were written.

Table 18 Growth quantity
(Variety: Norin No. 46)

Item \ Plot	MM	E E
Number of ears	15.9	19.0
Length of stem (cm)	81.03	81.39
Length of ear (cm)	15.43	15.54
Grain yield (Koku of rough rice per 10 a.)	3.076	3.246

The inferiority of MM in the number of tillers was so successively kept on the number of ears and on the yield as to reduce.

It is presumably concluded that the seedlings belonged to MM had small activity of rooting and stood so lately in paddy field, while those of EE had large activity and stood so early there, that the growth quantity of the former at the goal was inferior to that of the latter.

2. Result in Latin Square System on the number of tillers

The kinds of plot in paddy field laid in accordance with "Lattin Sguare System"

were as follows: —

MM_1～MM_4: morning picking (at 5.30～7.30 a.m.) for morning transplantation

ME_1～ME_4: morning picking for evening transplantation (at 17.00～19.00 p.m.)

EE_1～EE_4: evening picking (at 17.00～19.00 p.m.) for evening transplantation

EM_1～EM_4: evening picking for morning transplantation.

Table 19

Number of tillers or ears per 10 hills. (Variety : Norin No. 41)

		MM_1	EM_2	EE_3	ME_4
tillers	(June 22)	119	127	153	145
〃	(July 6)	215	264	299	272
〃	(July 13)	—	297	—	—
〃	(July 20)	—	295	—	—
ears		180	215	225	216
		ME_1	MM_2	EM_3	EE_4
ditto		130	112	149	155
		244	231	280	268
		—	254	—	—
		—	266	—	—
		204	202	228	195
		EE_1	ME_2	MM_3	EM_4
ditto		137	149	119	130
		254	277	247	249
		—	298	—	—
		—	301	—	—
		203	222	194	213
		EM_1	EE_2	ME_3	MM_4
ditto		116	130	126	92
		259	249	255	213
		—	280	—	—
		—	280	—	—
		237	196	233	191

Note : planting density is 3 individuals a hill in 23×24 cm^2

The results of measurement in relation to the number of tillers and to the number of ears from the biginning of growth to the maturity are shown in Table 19.

With the data on June 22 in Table 19, the analysis of variance was carried out as next table.

According to Table 20, the differences among plots were remarkably significant. Then the real differences are able to be esti-

Table 20 Analysis of variance in relation to the number of growing tillers on June 22

Item		Sum of square (S.S.)	Degree of freedom (N)	Variance (S.S./N)	Variance ratio (F)	Probability (P)
Main effect	Row	1148.19	3	382.73	4.89	almost 0.05
	Columnn	260.19	3	86.73	1.10	>0.20
	Kind of plot	2498.19	3	832.73	10.64	0.01～0.001
(Interaction) Error		469.37	6	78.23		
Total		4375.94	15			

mated as seen in Table 21.

In Table 21, the sequence from superiority to inferiority was determined distinctly to be EE>ME>EM>MM. This agrees with EE>MM in Table 17 and the sequence between EE and MM of rooting adtivity.

With the data measured on July 6, the real differences among four kinds of plot were estimated as written in Table 22.

In this case also, the sequence from superiority to inferiority was EE>EM>

ME>MM, and MM was remarkably less than others, while there was found less significant difference among four kinds of plot than the case of June 22.

Table 21
Differences among plots in relation to the number of tillers measured on June 22

	MM	ME	EE	EM
	92	145	155	130
	119	126	153	149
	112	149	130	127
	119	130	137	116
Sum	442	550	575	522

Table 22
Differences among plots in relation to the number of tillers measured on July 6

	MM	ME	EE	EM
	213	272	268	249
	247	255	299	280
	231	277	249	264
	215	244	254	259
Sum	906	1048	1070	1052

3. Rooting activity affecting on competition

The rooting activities of the seedlings shown in Table 10 by Norin No. 41 (variety name) were superior to those by Norin No. 46 (variety name) in both cases of EE and MM (EE: picked in the evening and transplanted in the evening in a beaker; MM: picked in the morning and transplanted in the morning in a beaker).

Those seedlings, without pruning the roots and without treatment by chemical substances, were transplanted in paddy field according to next manner.

MM and EE
- solely planted No. 41 ··· two individuals of Norin No. 41 were transplanted at a same hill. (Varietal separation with Norin No. 41)
- solely planted No. 46 ··· ditto except the variety
- mixed ····· (No. 41+No. 46): each one of two verieties was transplanted at a same hill. (Varietal mixture with Norin No. 41 and Norin No. 46)

At harvest for sampling, the hills were pulled off, and these subsoil parts were washed with water, and separated to each individual for investigation.

Table 23 Number of ears per individual

Sample	MM				EE			
	Solely planted No. 41	Mixed		Solely planted No. 46	Solely planted No. 41	Mixed		Solely planted No. 46
		No. 41	No. 46			No. 41	No. 46	
Number of ears	9.55	12.00	8.22	8.80	9.80	10.40	8.80	11.65
Signifcance level of difference (t-test)		0.02 ≀ 0.01	0.01 ≀ 0.001	0.7 ≀ 0.6		0.2 ≀ 0.1	0.2 ≀ 0.1	0.05 ≀ 0.01

According to Table 23, the number of ears of Norin No. 41 increased remarkably in mixed planting of MM, and those of Norin No. 46 decreased remarkably in mixed planting of EE. Moreover, Norin No. 46 was surely weak in the competition regarding to the ear produdtion in both cases of MM mixture and EE mixture.

This fact is presumably caused by a difference in relation to the rooting activity at the time of transplantation.

4. Tillers and yield

Early and vigorous rooting of the transplanted seedlings in paddy field brings on rice plant so early the development of tillers that these number in the hills becomes many (cf. Table 17, 19, 20, 21, 22, 23), but all of them can not always emerge the ears.

The number of earless uneffective tillers born in the period of maximum-tiller stage may usually respond to several conditions, and the number of uneffective tillers has not always a relationship with total number of tillers. A case as shown in Table 17 and Table 18 as that the number of tillers in the beginning of tillering transmitted to the last and to the number of ears, is a special case in a very favorable condition.

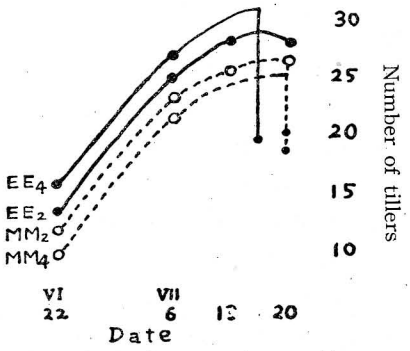

Fig. 6 Variety : Norin No. 41
Vertical lines : uneffective tillers with failure of heading.
Number is per hill ; each hill is consisted of 3 individuals

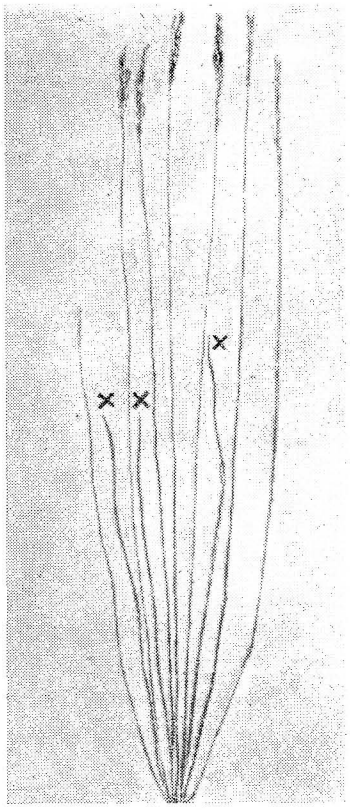

Fig 7
× : Earless uneffective tillers of high order or of high position in an EE plant.

Generally the number of tillers is seen to be independent to the number of ears.

Under such an unfavorable condition as it was cool in temperature and rare in shining, the rice plants of each experimental plot (= MM, ME, EE, EM) had an characteristical process respectively in uneffective tillering. MM that was most inferior in tiller formation (cf. Table 21) had a few uneffective tillers, while EE that was most superior in tiller formation had many uneffective tillers : Fig 6.

In the yield at last, EE was considerably superior to MM, as shown in Table 24 and Table 25.

The results written as above show that the rice hill which could have a great deal of tillers in the tillering stage of growth brought a great deal of uneffective tillers and in return the much yield of grain in the last.

The crop-physiological reason of these results is presumably based on the survival of the vigorous tillers of low order or of low position which grow in the early

Table 24
Grain yield (Janese sho per Japanese Tsubo)

MM_1 0.941	EM_2 1.011	EE_3 0.912	ME_4 0.976
ME_1 1.091	MM_2 0.879	EM_3 0.918	EE_4 0.984
EE_1 1.003	ME_2 0.888	MM_3 0.947	EM_4 0.955
EM_1 0.894	EE_2 1.076	ME_3 0.915	MM_4 0.950

Table 25 Grain yield

	MM	ME	EE	EM
	941	1091	1003	894
	879	888	1076	1011
	947	915	912	918
	950	976	984	955
Sum	3717	3870	3975	3778
Koku per 10 a.	2.788	2.902	2.981	2.834

stage, for they become so effective as to be many in the number of spikelets. But on the contrary, the rice hill consisted of tillers of miscellaneous vigorousity, even though all of them are of low order or of low position, is never uniform in the size of panicle, and must be small in the yield.

5. Summary

The plot-experiments were carried out in paddy field, where MM (morning picking and morning transplantation) was always inferior to EE (evening picking and evening transplantation) in the point of tillers' number, especially of their primary number in the growth. And this was apt to be successively kept on the later stage of the growth under favorable weather, for instance, in preliminary experiment, on the number of ears and on the yield.

Under cool and cloudy condition, the superiority of EE to MM in the number of tillers at the stage of growth was not always kept on the later of it, but made many tillers of high order and of high position to be uneffectively earless, then made the yield consisted of survived effective tillers in EE, in return, be predominant to that in MM, for because MM-hill producing few uneffective tillers included many small ears in itself.

In both cases of MM and EE, the seedling which had superiority in rooting activity at the time of mixed planting overpowered the other so apparently that had much ears at harvest than the other.

(VII) DISCUSSION

In 1941 and 1946, kenkiti SATO pointed out in his experiments that the rooting activity was responsible to the cultural circumstances, for instance, to the sown date, the seed-bed period, the rate of sown density and so on.

The experiments carried out by Takane MATSUO and OTHER (1949) showed the amount of N. and C. in the leaves of rice seedlings were affected not only by the rate of sown density and the sown date but also by continuous shade or continuous light in the seed-bed period.

Such rooting activity and containing substances as mentioned above did not mean the diurnal variation at all.

The experimental results in this papers shown by the present author points out

the diurnal variation of the rooting activity which responds not only to the artificial cultural circumstances, for instance the type of seed-bed, but also the diurnal variation of micro-clima in the seed-bed; the seedlings of the present papers showed apparent diurnal variation in rooting activity independently to the kind of habitat, whether it was basin or coastal plain.

As one of characters of rice plant that varied diurnally, Yakiti NOGUTI (1941) pointed out its assimilating activity of CO_2. WILSON, BOGGESS, and KRAMER (1953) studied on the diurnal fluctuations in the moisture content of some herbaceous plants. The results shown by the present author also varied diurnally in the total sugar percentage which rose to be maximum at the time of 14.00 in a day conformably to the NOGUTI's data.

According to present studies, the rooting activity of seedlings was affected mainly by the dry matter or the total sugar content, and in part by a minor factor, for which such instance as follows provides a substantiation. When a seedling being contained comparatively low amount of sugar at the time of picking in the morning could increase it somewhat in the process of keeping in day-time by sunlight, though it was less than that picked in the evening, the rooting activity becomes so large as to pass remarkably over that of seedling picked in the evening.

This suggests that the rooting activity is influenced mainly by the amount of sugar content and to a little by others, for instance, perhaps, a kind of wound-phytohormones.

Yoshio OHTANI (1950) reported about the effects of stamping upon the rooting of wheat and barley, where the stamping or a wound on an aerial part of plant brought the evident elongation of roots in the soil. Wounds by stamping on wheat seedlings resemble exactly those by picking for rice seedlings. And in the present experiment, the picking by hands done in the morning made the rooting accelerate.

So far as there concerns the wound to the rooting activity outside of the sugar, the percentage of total sugar in the seedlings is not always parallel with the degree of rooting activity, as seen in the present papers.

The effects of wound in this case is assumable to belong to such seedlings as are kept during the day-time after the picking in the flooded seed-bed. Therefore the wound-phytohormone, if it is, will have a close connection with the sunlight and abundant water supply.

The pruning the leaves in the report by K. SATO (1942) promorted the rooting of rice seedlings. But in his report was not mentioned at all about what time in a day the pruning was done. According to the results of present papers, the optimum time of pruning for the formation of wound-phytohormone must be a time in a morning.

The diurnal variation of rooting activity studied by the present author signifies the diurnal variation of latent ability to root. The latent ability can be known in the

appearance of renewed roots. The methods employed to know the latent rooting ability of rice seedlings was suggested by the experiment carried out by Kengo YAMAMOTO (1951).

The discussion has to go in the results in the field where the seedlings were transplanted. There has been no report concerning the role of transplanting time in a day except the present papers.

According to the present papers, the enforcement of rooting activity with the application of optimum time for picking or transplantation accelerated the developement of tillers and consequently increased the number of tillers. But by the enfeeblement of rooting activity, the development of tillers was retarded and consequently the number of tillers was decreased.

In such a favorable year as most of tillers could emerge the ears, the increase of the number of tillers induced the increase of the number of ears and of the yield, but in the cool and cloudy condition the acceleration of the development of tillers brought an abundant earless uneffective tillers in rice hill. But in the latter case, grain yield consisted of the remained vigorous effective tillers grown in early time was comparatively much.

S. MATSUSHIMA and OTHER (1953) reported that the uneffective tillers appeared in the maximum-tiller stage ceasing the elongation of leaf blade, especially in the fertilized condition with nitrogen and in the dense planting. Also in this experimental case by the present author, a similar condition was seen: the cool and cloudy condition brought on rice plant in paddy field the effect of surplus nitrogen, and the acceleration of the development of tillers brought on it the effect of dense planting, so that the uneffective tillers might increase.

Recently the mechanism of competition among different genotypic individuals has been studied and discussed (Toyokazu YAMADA and OTHER 1953, Kan-Ichi SAKAI 1951 and 1952), and according to the present papers, the differences of rooting activities in the seedlings at the time of mixed transplantation were found to become one of the factors affecting on competition. i.e. under mixed-planting, the seedling of vigorous rooting activity acquired the dominance in the number of ears far over the other of weak rooting activity.

(VIII) CONCLUSION

In the process of present experiment it was exhibited that the rooting activity of rice seedlings was a response to the external environmental conditions especially to sunlight or temperature at the time of taking by picking on seed-bed or transplantation, and the performance of paddy depended as well upon the total sugar contents or the dry matter of the seedlings as upon their rooting activity. With this instance, it is a plausible explanation that the performance of paddy depends fundamentally upon the sunlight and the temperature around the time of picking or transplantation, and physiologically upon the CO_2- assimilation at that time.

Thus, the useful seedlings which elevate the performance in grain yield must contain great amount of sugar contents or abundant dry matter in leaves, whereas have large activity of rooting at the time of picking or of transplantation. Such usefull seedlings as above should be gain in the seed-bed in the afternoon, for the sunlight and temperature may be supplied till that time; but if they were kept in flooded seed-bed throughout a dark night, they diminish the contents by dissimilation.

The seedlings taken by picking early in the morning and kept in seed-bed throughout a fine day-time, are associated with a special root-promoting substance during the keeping period, but can not so much elevate the yield as are expected due to their low content of sugar.

These functional characters of rice seedlings variable with the time of picking and of transplantation influence upon the interplant competition in the field, into which the present papers inquired somewhat, and subsequently the studies on it have to be undergone.

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摘　　要

1) 稲苗発根力の日変化が，暗黒恒温の下で検定された．此の日変化は，数多の品種において認め得るほどに普遍的なものであつた．4 x 稲では，早朝，発根力減少を顕著に示した．

2) 盆地で育つた稲苗は，海岸平野で育つた稲苗よりも，発根力及びその日変化が大きく，また，水苗代で育つた苗は，保温折衷苗代で育つた苗よりも，発根力及びその日変化が大であつた．

3) 夕取朝植苗は夜間苗代に取置かれるのであるが，夜間の温度が低い場合には，発根力の減少や炭水化物の消耗が少なくて済むが，夜間温度が高ければ，減少や消耗が著しい．

4) 日中取置苗は，日中の浴光により，炭水化物を体内に増加し得るが，この増加の割合を遙かに超えて，発根力を増大させる．これは多分，日中取置時間内に発根促進ホルモンが体内に造成されるからであろう．

5) 追肥物質や特殊物質の吸収によつて，稲苗発根力の日変化は，拡大されたり縮小されたりする．

6) 無風日射下での苗代における発根力検定は，苗代への日中取置操作後の発根力検定と相似た結果をもたらした．

7) 稲苗発根力と，苗全糖歩合または苗乾物率とは平行的関係を示した．そしてここに発根促進ホルモンが関与して，此の平行関係を破つた．

8) 全糖含量歩合が高く，乾物率が大で，その上，発根力も大なる苗が，収量を高め得る苗で，これは，夕取夕植によつて得られた．

9) 発根力の大なる夕取苗から成る稲株は，然らざる稲株よりも，分蘖開始が早く且つ分蘖量も大であつた．夕取夕植の稲株は，良順気象の下で株当穂数を多くさせて収量を大にしたが，寡照低温気象の下では高位分蘖及び高次分蘖を多数無効化した．

10) 発根力の異る2つの苗を接近混植したが，此の間の競合の結果が明らかに穂数に現われ，発根力において勝るほうが，穂数を多数ならしめた．

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