A Trial of Research for Genes of Paddy Rice Bearing upon Its Productivity and Resistance against Low Temperature with Special Reference to Types of Diurnal Variation of Rooting Activity in Seedling.

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渋 谷 紀 起：水稲の多収性と耐冷性の遺伝子探求，特に苗発根力の日変化型により求める試みについて

The information as to genetic factors is still lacking, but varietal productivity and varietal resistance against unseasonable low temperature are few doubted upon each existence in rice plant, so that the varieties composed of those two characters have been longed for long years. But according to the facts observed in Tōhoku region of Japan during past years, the productivity has not always associated such a beneficial character as resistance.

Why that has been so and why these characters are heritable ? The answers should be epitomized as simply as possible. Some trials of those are given in the data of this papers, which were obtained by employing various varieties of rice grown in Tsuruoka, Yamagata Pref. and by those rooting activities of seedlings.

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METHODS

Primary efforts were directed to measure the rooting activity of rice seedling. The methods were mostly similar to those reported previously. [To. SHIBUYA (1954)-Bull. Yamagata Univ. (Agr. Sci.) Vol. 1, No. 4] [5].

1) Shortly after random sampling of seedlings by means of picking by hands on seed-bed, the crown roots remained were pruned off ; the seedlings were placed on glass-rings of 1 cm height in the bottoms of beakers, within which the tap water of 2 cm depth were put ; the beakers were entered into a dark thermostat.

2) Total length of newly developed roots per seedling was caught for the indication of rooting activity of the seedling.

OBSERVATIONS AND RESULTS

1. Intervarietal differences in diurnal variations of rooting activities

The fluctuations of rooting activity obtained in detail were shown in Fig. 1.

Undoubtedly in Fig. 1 the rooting activity of rice seedling regularly fluctuates even in day-time. There are important intervarietal differences in the curves : on those belonging to Norin No. 41, the first concave appears at 6.00~7.00 a.m. and

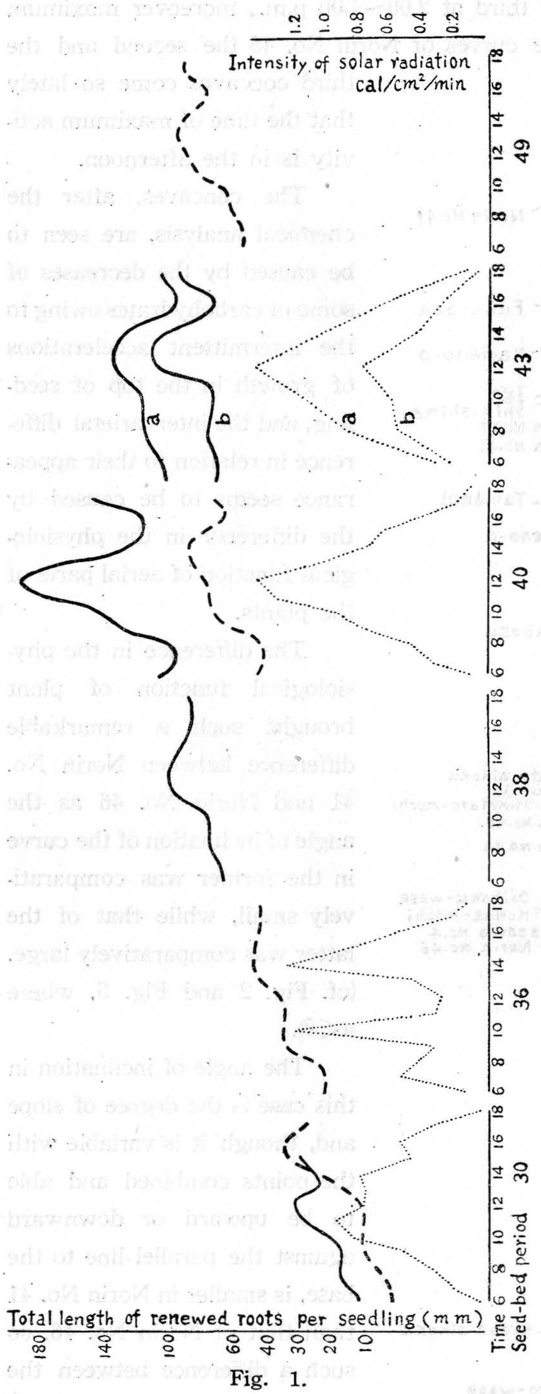

Fig. 1.

{—— Norin No. 41 {a : unshaded
{---- Norin No. 46 {b : shaded

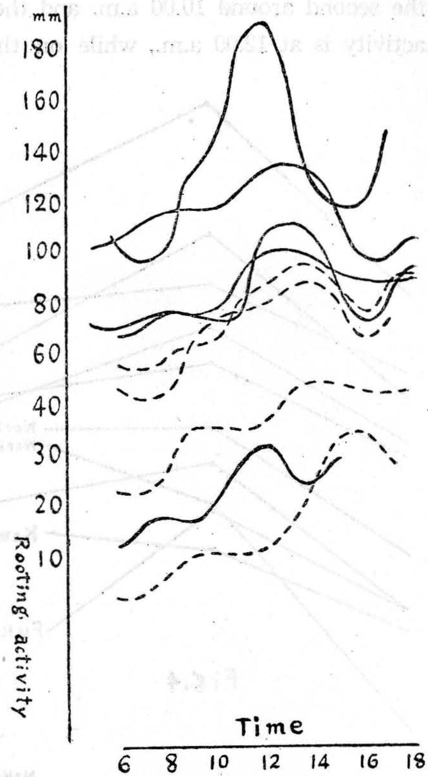

Fig. 2. —— Norin No. 41, ---- Norin No. 46

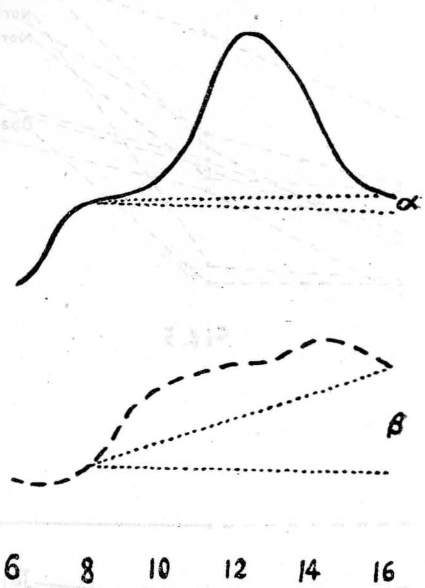

Fig. 3. Angle of inclination of curve.
—— Norin No. 41, ---- Norin No. 46

the second around 10.00 a.m. and the third at 2.00∼4.00 p.m., moreover maximum activity is at 12.00 a.m., while on the curves of Norin No. 46 the second and the third concaves come so lately that the time of maximum activity is in the afternoon.

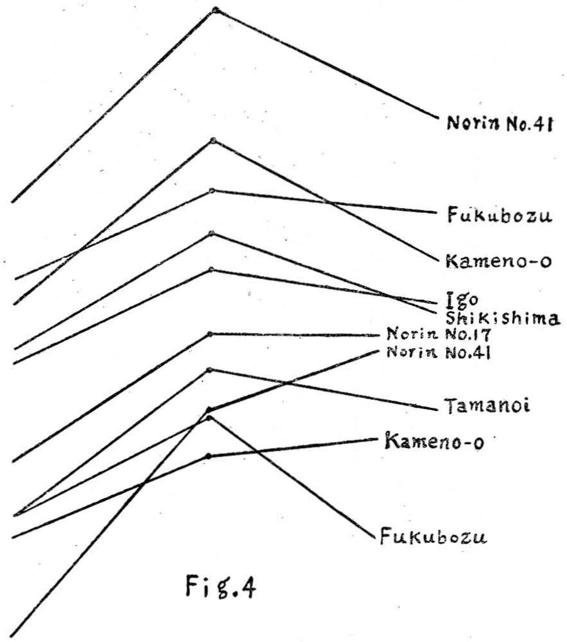

Fig.4

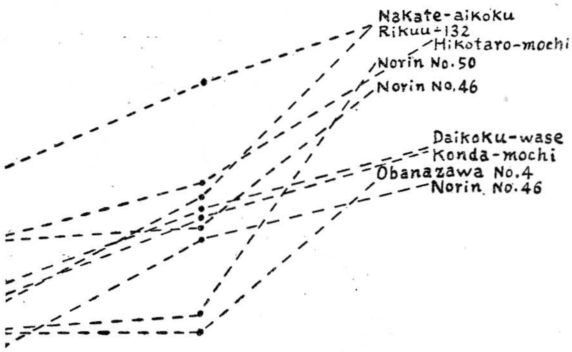

Fig.5

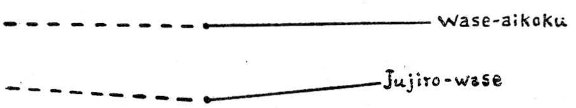

Fig.6

The concaves, after the chemical analysis, are seen to be caused by the decreases of some of carbohydrates owing to the intermittent accelerations of growth in the top of seedling, and the intervarietal difference in relation to their appearance seems to be caused by the difference in the physiological function of aerial parts of the plants.

The difference in the physiological function of plant brought such a remarkable difference between Norin No. 41 and Norin No. 46 as the angle of inclination of the curve in the former was comparatively small, while that of the latter was comparatively large. (cf. Fig. 2 and Fig. 3, where $\alpha < \beta$).

The angle of inclination in this case is the degree of slope and, though it is variable with the points combined and able to be upward or downward against the parallel line to the base, is smaller in Norin No. 41 than that of Norin No. 46, so such a difference between the rooting activity in the morning and that in the evening as EE-MM or (EE-MM)/MM may become small in the former and large in the latter.

EE : seedling picked in the evening and transplanted in the evening
MM : seedling picked in the morning and transplanted in the morning

Each curve in Fig. 3 was given by the mean values of curves in Fig. 2, thereafter the modifications affected upon them in Fig. 2 become zero, for an addition of modifications always conducts to zero. Therefore, each curve in Fig. 3 is showing the varietal phenotype, which exbibits the characteristic type of the variety.

With this standpoint, the angle of inclination as mentioned above can be recognized to be one of the characteristcs of the variety. Also the way combined with lines from 7.30 a.m. to 11.00 a.m. and to 2.00 p.m. (or 3.00 p.m.) in a diurnal variation of rooting activity can show very well the characteristic of varietal phenotype. These combinations with lines were done by this author employing many varieties as seen in Fig. 4, Fig. 5, and Fig. 6.

Fig. 4 shows the first group of varieties, in which the slope of line in the morning is steep and upward, but the slope of line in the afternoon is downward.

Fig. 5 shows the second group of varieties, in which the slope of line in the morning is moderate, but the slope of line in the afternoon is steep and upward.

Fig. 6 shows the third group of varieties, in which the slope of line in the morning is similar to that of the second group, but that in the afternoon is similar to that of the first group.

The present author inquired into the ancestors and offsprings of the varieties employed, and they are shown in Table 1.

Table 1. Ancestors and offsprings. (f) : female (m) : male

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Daihoji-wasé (f)———|
Nakaté-Aikoku (m)——|—Daikoku-wasé
         Yamadera-mochi——→Hikotaro-mochi

              //        (f)————|
Onna-tsuru-mochi (m)———|—Konda-mochi

                              Ban-33 (f)——|
Morita-wasé (f)——|                        |—Norin No. 50
Rikuu-132 (m)————|—Norin No. 1 (m)——|
                          Chuben 121 (f)——|—Norin No. 46

Rikuu-132 (f)————|
Sakai-kaneko (m)——|—Ou-187 (f)————|
                          Wasé-Aikoku (m)—|—Obanazawa No. 4

Igo (m)————————|
Kameno-o (f)———|—Tamanoi
Kameno-o (f)———|
Shikishima (m)——|—Kotobuki (m)——|
                          Nomeri (f)——|—Fukubozu

Fukubozu (f)————|
Morita-wasé (m)——|—Kyonishiki No. 3——→Omiya-nishiki
                       //          (m)——|
              Nomeri × Igo  (f)——|—Shin-nomeri——→Jujiro-wasé

Asahi (f)——————|
Kameno-o (m)————|—Norin No. 17

                  Kariu-shinshu (f)——|
Igo          ——|                     |—Hokuriku No. 14
Shikishima   ——|—Shin-Igo (m)————————|

Kyoto-Asahi No. 1 (f)——|
Hokuriku No. 14 (m)————|—Norin No. 41
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according to Table 1, the grouping based on the type of diurnal variation in rooting activity agrees exactly with the grouping in respect to the genetic affinity except the third group. This agreement may be caused not only by the inheritance but also by the selection. Especially the role of selection must not be neglected.

The data presented above show that Norin No. 41 and Norin No. 46 belong to different group respectively : the former belongs to the first group and the latter belongs to the second group, and this fact is able to be proved by other data as following tables (cf. Table 2. Table 3, Table 4, Table 5). These data of tables were previously reported[5], in which, as a matter of just right, the values of (EE-MM)/MM were always small in Norin No. 41 and large in Norin No. 46, *viz.* the first group<the second group.

Table 2.
Rooring activity in different seed-bed. (Total length of renewed roots per seedling, mm)

Type of seed-bed	Norin No. 46 MM	Norin No. 46 EE	Norin No. 41 MM	Norin No. 41 EE
Flooded bed	27.1	44.7	51.8	62.7
Semi-irrig. warm bed	58.3	172.9	78.7	96.2

Table 3.
Rooting activity on two days after transplanting. (mm)

MM Norin No. 46	MM Norin No. 41	EE Norin No. 46	EE Norin No. 41
32.4	37.2	113.6	86.2

Table 4.
Average length of roots renewed after late manuring by $(NH_4)_2SO_4$, (mm)

Period	Norin No. 46 MM	Norin No. 46 EE	Norin No. 41 MM	Norin No. 41 EE
19/V∼23/V	8.28	38.52	22.65	38.91

Table 5.
Average rooting activity of seedlings in the case of application with α-hormone and 2.4-D

Period	α-hormone				2.4-D			
	Norin No. 46 MM	Norin No. 46 EE	Norin No. 41 MM	Norin No. 41 EE	Norin No. 46 MM	Norin No. 46 EE	Norin No. 41 MM	Norin No. 41 EE
21/V∼25/V	2.46	16.68	9.05	23.04	0.18	1.08	1.49	3.26

2. Genetic factors of rooting activity in rice plant

According to the experimental results as mentioned above, distinctive two kinds of group can be found in rice varieties, which differ each other in the behavior of diurnal fluctuation of rooting activity.

The representative variety of the first group is Norin No. 41, and that of the second group is Norin No. 46.

And after the fact that the rooting activity has always a close connection with CO_2-assimilation by chloroplasts and dissimilation by respiration, the presumption of the plasmagenes and their activities are able to be presented.

C_1 : Activity of a plasmagene which increases the rooting activitv of Norin No.

41 (1st group) in day-time.

C_2 : Activity of a plasmagene which increases the rooting activity of Norin No. 46 (2nd group) in day-time.

B_1^H : Activity of a plasmagene which decreases the rooting activity of Norin No. 41 (1st group) in day-time or in a high temperature.

B_2^H : Activity of a plasmagene which decreases the rooting activity of Norin No. 46 (2nd group) in day-time or in a high temperature.

B_1^L : Activity of B_1 which decreases the rooting activity in the night or in a low temperature.

B_2^L : Activity of B_2 which decreases the rooting activity in the night or in a low temperature.

The first group is C_1B_1-type and the second group is C_2B_2-type. C_1 and C_2 are related to CO_2-assimilating capacities, while B_1 and B_2 are related to dissimilating capacities, in consequence the ones are bearing upon the productivity, while the others are upon the resistance against low temperature (cf. Next section).

The experiments to distinguish the factorial activities of B_1^H, B_2^H, B_1^L and B_2^L were carried out and the results were shown in Table 6.

Table 6.

Rooting activity in accordance with temperature of keeping.
(Length of renewed roots per seedling, mm)

Keeping temp.	High (30°C)		Low (5°C)	
	Norin No. 46	Norin No. 41	Norin No. 46	Norin No. 41
1st exp.	40.6	34.2	79.6	111.8
2nd exp.	78.2	58.0	90.8	95.6
Average	59.4	46.1	85.2	103.7
P	0.1~0.05		0.01~0.001 **	

1st exp. and 2nd exp. were carried out in different date respectively. Intervarietal differences estimated by means of t-test in mixing the data of 1st exp. with those of 2nd exp. were shown with P-values (** : very significant).

According to Table 6, Norin No. 41 loses the rooting activity in high temperature more than Norin No. 46 : $B_1^H > B_2^H$. And Norin No. 41 loses the activity in low temperature less than Norin No. 46 : $B_1^L < B_2^L$.

The comparison of factorial activities of C_1 and C_2 is able to be carried out by means as follows : —

$$\text{Rooting activity in day-time} \begin{cases} \text{1st group } y = \dfrac{C_1 - B_1^H}{(x+1)^2 - x} \\ \text{2nd group } y = \dfrac{C_2 - B_2^H}{(x-1)^2 + x} \end{cases}$$

y : Total length of renewed roots per seedling, (mm).

x : A time, x=0 at 12.00 a.m., x=1 at 1.00 p.m., x= −1 at 11.00 a.m.

Rooting activity after its degression in a night

$$\begin{cases} \text{1st group (Norin No. 41)} \quad y=\dfrac{C_1-B_1^H}{(x+1)^2-x}e^{-B_1^L} \\ \text{2nd group (Norin No. 46)} \quad y=\dfrac{C_2-B_2^H}{(x-1)^2+x}e^{-B_2^L} \end{cases}$$

Therefore, among the values of (EE-MM)/MM,

$$\frac{1-e^{-B_1^L}}{e^{-B_1^L}}\text{(1st group)} < \frac{1-e^{-B_2^L}}{e^{-B_2^L}}\text{(2nd group)}$$

or

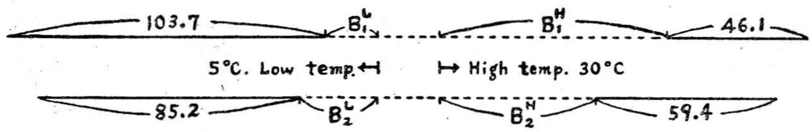
$$\frac{1}{e^{-B_1^L}}\text{(1st group)} < \frac{1}{e^{-B_2^L}}\text{(2nd group)}$$

At the noon [$x=0$, $(x+1)^2-x=1$, $(x-1)^2+x=1$], the rooting activity of the first group was larger than that of the second group : $C_1-B_1^H > C_2-B_2^H$, whereas $B_1^H > B_2^H$, $\therefore\ C_1 \gg C_2$.

3. Genes of resistance against unseasonable low temperature and of productivity

Unseasonable low temperature occurs sometimes in Tōhoku region of Japan and brings the crop failure on the rice. However, there has not yet been found the method to know the resistance against low temperature in the stage of seedling.

The method employed by this author and described in Table 6 will be good for the discovery of varietal resistance in the stage of seedling, moreover of the genes of resistance, for the results in Table 6 provide the facts shown in Fig. 7.



Fig, 7. Temperature necessary for dissimilation

Accrding to Fig. 7 the dissimilation of Norin No. 41 (1st group) is seen to be adaptable to higher temperature, while that of Norin No. 46 (2nd group) is to lower temperaure. This facts indicates that the first needs the higher temperature for its growth, while the second does not always so. Therefore, the second group is more resistant against low temperature than the first group. It is true that the second group includes in itself such varieties as were resistant in the past years, for instance, Rikuu-132, Obanazawa No. 4 and Konda-mochi etc.

Those resistant varieties, if they were grown under favorable fine weather, had not always a high performance in the yield, but others belonged to the first group were contrary. Why those facts occured ? One of the reasons is presumably on the activity of a factor of CO_2-assimilation and on such a fact as $C_1 \gg C_2$.

With this point of view, C_1 or C_2 is a gene of productivity and B_1 or B_2 is a gene of resistance against low temperature. Of course, C_1 is more productive than

C_2, and B_1 is less resistant than B_2 in such a case as $B_1^L < B_2^L$.

If $B_1^L \geqq B_2^L$ in fact, the relative resistance becomes contrary.

DISCUSSION

The curves of diurnal variation about the rooting activity observed by this author were very much resembled those of daily change in CO_2-assimilation under fair weather reported by Dr. NOGUTI, Y. (1938, 1941); the former were seen to be independent upon the earliness or lateness of heading-time and depend on CO_2-assimilating and dissimilating ability, while the latter were seen to be directly dependent upon the time of heading.

If the latter is so as above, the former must indirectly depend upon the time of heading. If the latter does not depend upon the time of heading but upon other heritable character, the former must be completely independent upon the time of heading.

The experiments to estimate the factorial activities of B_1 and B_2 are not enough in the present papers. Pursuing experiments may reverse the relation between them so as to be contrary to the present matter, and then C_1B_1-type may bacome completely superior to C_2B_2-type in the productivity and the resistance.

CONCLUSION

The present author found two distinctive types in the diurnal variations of rooting activity of rice seedling. Both types were recognizable to be phenotypes governed by genotypes.

Two kinds of genotype were shown to be C_1B_1 and C_2B_2. C_1 and C_2 increased the rooting activity in day-time, while B_1 and B_2 decreased it in accordance with temperature. C_1 and C_2 were photosynthetic factors, while B_1 and B_2 were those of dissimilation. Those factorial activities were estimated and decided to be $C_1 > C_2$, $B_1^H > B_2^H$ and $B_1^L < B_2^L$ (B_1^H, B_2^H : factorial activity in day-time or in high temperature, B_1^L, B_2^L : factorial activity at night or in low temperature). In cosequence, those genotypic differences induced the distinctive differences in daily productivity of carbohydrates and in the resistance against low temperature.

If the method by means of measurement of rooting activity in relation to the factorial activity of $C_{1 \text{ or } 2}$ $B_{1 \text{ or } 2}$ is adequate to know in the stage of seedling the productivity and resistance against low temperature, the improvement of rice variety will be achieved more easily.

Another genotypes of another factorial activities may be exist, into which the inquiry is lacking in this papers. If C_1B_2-type is born, it will be productive additionally to the character of resitance. If $C_n B_m$-type is there, the number of genotype will be many. But natural or artificial selections and adaptability of the genotypes must limit the existent number of themselves, so that those as found in the present experiments may be two note-worthy ecotypes.

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摘　　　要

1) 稲苗発根力日変化の型として，相異る2つの型を発見した．これら2つの型は，相異る遺伝子型に基いて発現する相異る表現型であつた．

2) すなわち，発根力の日変化は，日中において発根力を増大させる遺伝子の作用（第1型はC_1，第2型はC_2）と，温度の高低に応じて発根力を減少させる遺伝子の作用（第1型$=B_1^H$，第2型$=B_2^H$，第1型$=B_1^L$，第2型$=B_2^L$）との両者によつて生ずるものとみられた．

3) 高温及び低温に取置きした苗の発根力を尺度として，各型の遺伝子の相対的作用力を算出し，$C_1>C_2$，$B_1^H>B_2^H$，$B_1^L<B_2^L$ であろうとした．

4) C_1B_1型を第1型とし，C_2B_2型を第2型とした．

5) 日中に発根力を増大させる作用をもたらす遺伝子は，炭酸同化作用に関連のある遺伝子であり．他方，発根力に減少作用を及ぼす遺伝子は，異化作用に関連のある遺伝子であつた．

6) C_1B_1型品種は，炭水化物生成に関しては，C_2B_2型品種よりも多収性であると言い得たけれど，耐冷性の点では，C_2B_2型品種よりも小であるとみられた．

7) 交配実験によらなかつたので，上記各遺伝子の遺伝力や連鎖関係を的確には知り得なかつたが，供試品種群（山形県に従来栽培されてきた品種）は，上記両型に従つて，ほぼ2つの類縁群に大別され得ることを知つた．

8) 稲苗発根力の日変化の特異型が，祖先品種にも子孫品種にも見られたことは，遺伝子の存在及びその遺伝力の是認を許すと同時に，栽培地における自然淘汰乃至人為選抜の方向が，ほぼ一定していて2つの方向に集約されていることをものがたるもので，良順年次における多収性品種と不順年次における耐冷性品種といつたぐあいに，上記のごとく存在する2つの型は，2つの生態型でもある．

9) 良順気象下の多収性と，不順気象下の耐冷性とが，必ずしも結びつかなかつたし，現在もなお，充分に結びついていないようであるが，発根力増大遺伝子のうちその作用力の大なるものと，発根力減少遺伝子のうち低温圏作用力の大なるものとを結びつけて，安全多収性の品種をつくることは，必ずしも不可能ではない．

10) 本研究の方法で多収性や耐冷性を検定しようとするには，材料として苗を多数本まとめて使用するので，交配育種の際の初期世代には適用され難い．

11) 遺伝子作用力の測定は，将来，もつと詳しく行われねばならないのであるが，もし本報告の結果と異る結果が生ずるならば，品種ないし機能に関する類型は変更されることとなろう．