Chlorosis of Rice Seedlings in Mechanized Transplanting

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Area for mechanized transplanting, corresponding to only 3% of the total rice area in 1970, has increased rapidly, reaching 47% of rice area in Japan in 1974. For the mechanized transplanting, mass raising of seedlings by the use of joint or cooperative nursery facilities has come to be widely practiced. In this method of raising seedlings, however, chlorotic seedlings showing chlorosis of leaf blade frequently occur. They are poor in quality, giving poor rooting and establishment after transplanting and consequently poor growth and reduced grain yield. In case of severe chlorosis, transplanting can not be done.

In the Chugoku National Agricultural Experiment Station, a study on this disorder was initiated by Kusanagi in 1970 by the use of phytotron just completed, and succeeded by the present author. The study was almost completed in 1975 after about 5 years of experimental research.

The present paper describes briefly results of the study, although a detailed report will be published in the Bulletin of the Station, Series A No. 25.

Factors determining the occurrence of chlorosis

Light and temperature at the stage of seedling emergence after germination and of greening, size of seedlings at the start of greening, and duration of exposure to an inadequate condition during the greening stage are the factors influencing occurrence and degree of chlorosis.

1) Seedlings emerged in darkness at high temperature were liable to develop chlorotic leaves, whereas those emerged under light or at low temperature were not liable (Fig. 1 A).

2) Greening treatment at low temperature

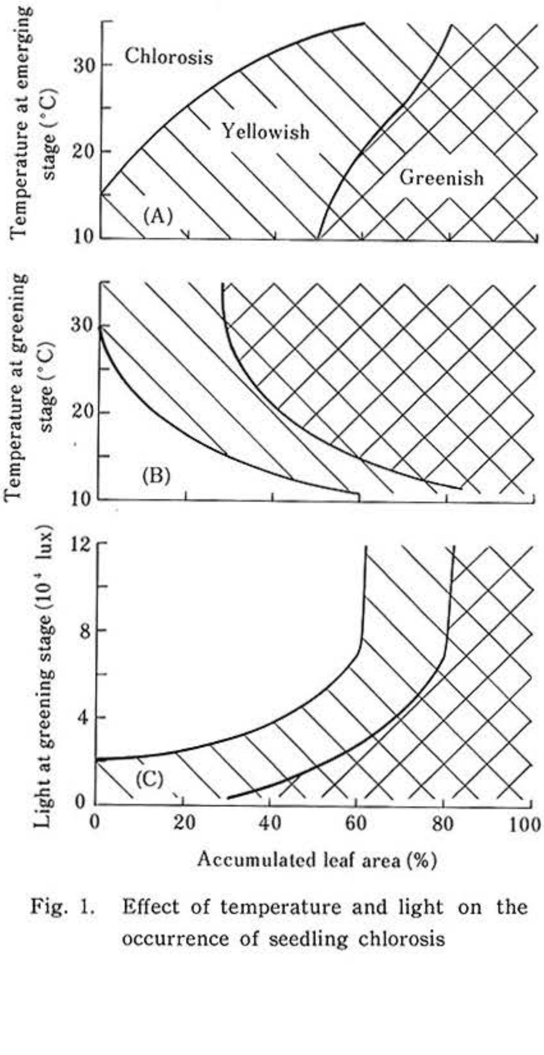

Fig. 1. Effect of temperature and light on the occurrence of seedling chlorosis

Table 1. Critical values of temperature and light intensity that induce chlorosis of seedlings

Temperature at emerging stage	Light intensity at indicated temperature at greening stage					
	10℃	15℃	20℃	25℃	30℃	35℃
35℃	5 klux	10	20	40	80	160
30	10	20	40	80	160	—
25	15	30	60	120	240	—
20	20	40	80	160	—	—
15	25	50	100	200	—	—
10	30	60	120	240	—	—

Table 2. Morphological characteristics and chlorophyll content of chlorotic seedlings

Degree of chlorosis (%)*	Plant height (cm)	Leaf number (number)	Fresh weight (mg)	Dry weight (mg)	Chlorophyl content (mg)**
0 (S)	13.7	2.8	145	23.6	4.4
25	12.1	2.7	138	22.4	3.1
50	11.3	2.4	119	20.0	2.3
75	11.8	2.1	107	18.4	1.1
100	11.4	2.0	98	16.2	0.1

*) : Degree of chlorosis was shown in percentage of chlorotic area to total leaf area.
**) : Chlorophyll content was shown in mg per 1 g of fresh leaf blade.

and high light intensity was apt to develop chlorosis. Lower the temperature and higher the light intensity, the more was the degree of chlorosis (Fig. 1 B and C).

There are close inter-relations between temperature at the stage of emergence and temperature and light intensity at the greening stage in inducing chlorosis. Critical values that induce chlorosis of these three factors are inter-related as expressed by the equation (1) and (2).

$$L=[250(40-T_1)]e^{0.1386T_2} \quad \cdots\cdots\cdots(1)$$
$$L=(10,000-250T_1)\cdot 2^{0.2T_2} \quad \cdots\cdots\cdots(2)$$

where L=Critical light intensity (lux) at the greening stage
T_1=Critical temperature (°C) at the emergence stage in darkness
T_2=Critical temperature (°C) at the greening stage

The actual critical values are listed in Table 1, which shows, for example, that when seedlings, emerged in darkness at 30°C, are exposed to 10°C–10 klux, 20°C–40 klux and 30°C–160 klux during the greening treatment, the chlorosis occurs. But, if the greening treatment is done at a condition with higher temperature and lower light intensity than those shown above, no chlorosis occurs.

3) Occurrence of chlorosis is related to the duration of greening treatment applied at an inadequate condition. The longer the duration, the more is the degree of chlorosis. For example, in case when seedlings, emerged in darkness at 30°C, were subjected to greening treatment at a condition of low temperature and high light intensity such as 10°C–50 klux or 11.5°C–50 klux or 11.5°C–50 klux, chlorosis began to occur at 6–8 hrs of the treatment, and the chlorotic leaf area increased with a prolonged duration of the treatment.

4) Seedlings grown up due to delayed greening treatment are apt to develop chlorosis, whereas the treatment applied at an early stage of seedlings, such as at 2–3 cm of plant height with 0.3–0.5 of leaf number, hardly induces chlorosis.

5) Varietal difference in the occurrence of chlorosis was examined using 12 Japanese and 3 foreign varieties with different growth durations. No definite relation was observed between the occurrence of chlorosis and the length of growth duration, and the varietal difference was not apparent.

Morphological and physiological characteristics of chlorotic seedlings

Chlorotic seedlings are inferior to normal seedlings in many characters, because of lowered carbon assimilation and transpiration due to impeded chlorophyll formation.

1) Number of leaves, fresh weight and dry weight of chlorotic seedlings were smaller than those of normal seedlings. The inferiority became more apparent with higher degree of chlorosis (Table 2).

2) Chlorophyll content of leaf blade was very low. Chlorotic portions of leaf blade contain almost no chlorophyll a and b. Decrease of chlorophyll content was in parallel to the ratio of chlorotic area to the total leaf area (referred to the degree of chlorosis in this paper) determined by naked eyes (Table 2).

3) Amount of carbon assimilation and respiration decreased with the increase of chlorosis. Since the decrease of carbon assimilation was more remarkable than that of respiration, CO_2 balance, ie, carbon assimilation minus respiration, was decreased markedly and became zero at the degree of chrolosis of 60%. Therefore, seedlings with degree of chlorosis more than 60% cease to grow after the exhaustion of nutrients in endosperm (Fig. 2).

4) Evapotranspiration was also decreased linearly with the increase of chlorosis. For every 10% increase of the degree of chlorosis, evapotranspiration as expressed by percentage to that of normal plant decreased by 6%. The decrease was more in daytime than in the night.

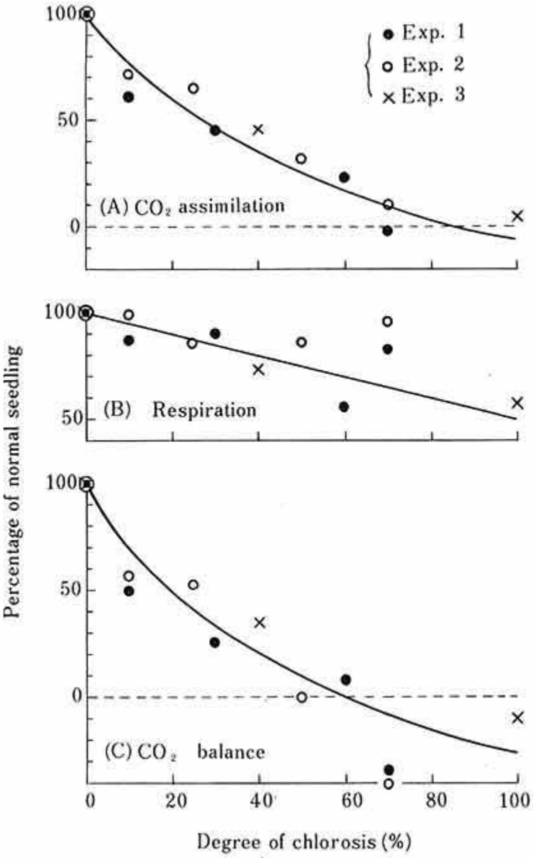

Fig. 2. CO_2 assimilation, respiration and CO_2 balance (assimilation–respiration) of seedlings with different degree of chlorosis

Growth after transplanting and grain yield

Using chlorotic seedlings produced experimentally, seedlings with 0, 25, 50, 75, and 100% of chlorosis were selected and transplanted. Establishment after transplanting, growth and grain yield were examined.

1) Chlorotic seedlings showed poor establishment and slow increase in plant height, fresh weight and dry weight. Some of them died. The higher the degree of chlorosis, this tendency was more remarkable (Table 3).

2) Date of heading and maturity was

Table 3. Establishment and growth after transplanting of chlorotic seedlings*

Degree of chlorosis (%)	Taking root (%)	Plant height (cm)	Leaf age	No. of stems (no/hill)	Fresh weight (mg)	Dry weight (mg)
0 (S)	100	24.5	7.1	12.8	1255	197
25	99	23.4	7.1	12.0	1133	175
50	95	20.9	6.9	10.7	859	141
75	86	20.0	6.7	8.3	706	96
100	23	16.8	6.1	1.2	76	14

*) : Observations were done at 20 days after transplanting

delayed. For example, seedlings with 100% chlorosis showed the delay of heading time and full heading time by a week, and the delay of maturity by 10 days. It was found that accumulated air temperature during a period from transplanting to maturity (Y) has a very high correlation, $r=0.999$, with the degree of chlorosis (x). The relationship is expressed by a simple formula of linear regression as follows:

$$Y(°C)=1.788x\,(\%)+3176 \quad \cdots\cdots(3)$$

3) An estimation was made on changes of growth stage and grain yield by different cropping seasons under the climatic condition of normal year at Fukuyama (site of the Station) when chlorotic seedlings are used for cultivation. Based on the accumulated temperature and grain yield, both actually measured, the estimation was made by utilizing an estimating equation[2] showing grain yields in different cropping seasons of "rice culture with young seedlings".

When chlorotic seedlings are used for cultivation, the growth stage is delayed, particularly in late cropping seasons. Decrease of yield is also more remarkable in later cropping season (Table 4). It suggests that the yield decrease may be more remarkable in cold areas or in cool highlands than in warm districts. Critical degree of chlorosis that is practically permissible is regarded as 50–60% for the optimum cropping season and 30–40% for the latest cropping season.

Table 4. Grain yields* of rice plants grown from chlorotic seedlings

Cropping season (Date of transplanting)		Degree of chlorosis of seedlings 0%	25%	50%	75%	100%
May	1	93	93	94	95	58
May	11	95	95	96	96	59
May	21	97	97	98	98	60
June	1	99	100	100	100	61
June	11	99	99	99	98	60
June	21	99	97	96	95	57
July	1	90	87	83	78	44
July	11	58	47	33	18	0
July	21	0	0	0	0	0

*) : Grain yield as expressed by percentage of the yield of normal plants grown in optimum cropping season

Measures preventing chlorosis

Mode of occurrence of chlorosis indicates that it occurs easily in areas with low temperature such as cold districts and cool highlands. In these areas, re-planting of seedlings is not practicable due to a limited duration of cropping season. Therefore, practical measures preventing chlorosis are needed.

1) In order to avoid the seedling emergence in darkness, an electric light is used, or thick straw-mat as a covering material for nursery apparatus should not be used.

2) Temperature should be controlled not to give too high temperature during the stage of emergence, particularly prior to the greening treatment low temperature below 30°C is desirable.

3) Not to delay the start of greening treatment, the treatment should be made at an early stage with 2–3 cm or less of plant

height.

4) By removing straw-mat covers, the nursery apparatus should be exposed to light, being kept under vinyl covers to keep warm, and then transferred to outdoor when seedlings begin to show green color.

5) Greening is mostly promoted under a light intensity of 500–2000 lux. When the outdoor light is too strong, shading is made by marsh-reed screen, cheese-cloth or colored vinyl film. Difference in effect by different color is relatively small, but transparent vinyl film is less effective, because of less shading.

6) In case when the greening treatment has to be done under low temperature and high light intensity, it is effective to curtail the exposure time during the initial 1–2 days of treatment.

References

1) Statistics & Survey Dept., Ministry of Agriculture & Forestry: Crop Statistics. No. 17, 190 (1975) [In Japanese].

2) Hitaka, N. & Washio, O.: Studies on the cropping season of young seedling culture of paddy rice in Chugoku district. *Bull. Chugoku Agr. Exp. Sta.*, Series A No. 22, 1–20 (1973) [In Japanese with English summary].