Effect of Food Reserves on the Ratoon Growth of Rice Plant

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Ratooning of rice plant—obtaining a second harvest from a second growth of the main crop—has been practised in many countries. Ratooning was also applied to the utilization of rice plants as fodder⁵⁾. It has been suggested that ratoon growth might be applied to produce an index which will represent the physiological situation of a rice plant¹⁰⁾. Moreover, ratoon growth are of great interest for testing agronomic characters in rice breeding³⁾. However, ratoon growth will be varied according to internal and external conditions of the stubble and roots of the rice plant. The amount of food reserves, the number of resting buds, the vigor of resting buds and others are comprised in the internal conditions. Temperature, the amount of mineral nutrients within the field, water management and others are comprised in the external conditions.

Ratoon growth was more vigorous under higher temperature conditions⁴⁾. When manuring of nitrogen was given to the main crop in the period between the earlier ripening stage and the harvest, the grain yield of the ratoon crop increased accordingly^{1,6,11)}. The grain yield decreased as the time between the main crop harvest and irrigation for the ratoon crop was shortened¹⁾. However, investigations which are concerned with the internal conditions of ratoon growth of a rice plant have apparently not been published to date.

This paper is investigating the effect of food reserves on ratoon growth of the rice plant.

Materials and Methods

Six rice cultivars, Ginmasari, Sachiwatari, Chiyohikari, Azusa, Satominori and Yacho,

were used. Thirty five-day-old seedlings were transplanted to 1/5000 a Wagner pots with a single plant per pot on June 5. Compound fertilizer (N:15%, P_2O_5 :12%, K_2O :15%) was applied at the rate of 3.5 g per pot as basal. Rice plants were divided into 3 groups in order to regulate artificially the amount of their food reserves during the period from the 4th day before heading to the 10th day after heading. Thereafter, the plants were grown under 3 different environments in the green house: full sunlight, shaded to about 50% sunlight and shaded to 25% sunlight. A black cheese cloth was used for shading. Aerial parts of the plants were cut 5 cm above the ground on the 10th day after heading. Immediately on cutting, the plants were translocated to a dark environment of 25°C temperature. A fertilizer was not applied to the ratoon crop.

Ratoon height and percentage of ratoon tillers were noted on the 5th, 10th, 15th, 20th, 30th and 40th day after cutting. Note on ratoon weight was taken on the 40th day after cutting. Ratoon heights were measured from ground level. Percentage of ratoon tillers was taken to be the number of ratoon-plant tillers times 100 divided by the number of mother-plant tillers. Stem base of mother plants was collected on the day of cutting. Weights of the ratoon plant and of the stem base of the mother plant were measured for dry matter. From the weight of the latter, stem base weight per hill and per stem were determined. The total available carbohydrate (TAC) content of the stem base was analyzed in the manner suggested by MURAYAMA et al.⁹⁾. From this result TAC weight per hill and per stem, and TAC content were determined.

Table 1. Variance analysis for the traits of mother and ratoon plants

Source	d.f.	Mean of Square				
		Stem base weight per hill	TAC content	Percentage of ratoon tillers	Ratoon height	Ratoon weight
Cultivar (C)	5	2.61**	0.091**	1452.2**	2015.4**	0.39**
Shading (S)	2	17.05**	0.123**	7887.4**	6885.8**	3.11**
C×S	10	0.51	0.055	85.8	61.5	0.04
Error	54	0.27	0.022	241.3	86.6	0.03

Source	d.f.	Mean of Square		
		Stem base weight per stem	TAC weight per hill	TAC weight per stem
Cultivar (C)	5	0.0056*	0.442*	0.0029*
Shading (S)	2	0.0220**	3.227**	0.0163**
Error (C×S)	10	0.0010	0.123	0.0007

*, **: Significant at 5 and 1 % level, respectively

Table 2. Five stem base traits at 3 environments

Trait	Full sunlight	50% sunlight	25% sunlight
Stem base weight per hill (g)	4.42	3.21	2.80
Stem base weight per stem (g)	0.303	0.215	0.185
TAC weight per hill (g)	2.69	1.68	1.29
TAC weight per stem (g)	0.185	0.109	0.085
TAC content (mg/g dry wt.)	605	492	456

Results

The range of the heading dates among the 6 cultivars was from August 9 to August 20. The intensities of illuminations for the 3 different environments in the green house: full sunlight, shaded to about 50% and to about 25% sunlight intensity were 83-, 41- and 21- $\times 10^3$ lux, respectively. Variance analysis for the 5 base stem traits of the mother plants on the day of cutting and for the 3 ratoon traits of ratoon plants on the 40th day after cutting is shown in Table 1. Five stem base traits are stem base weight per hill and per stem, TAC weight per hill and per stem, and TAC content. Three ratoon traits are percentage of ratoon tillers, ratoon height and ratoon weight. There were significant differences in the variance due to cultivar and shading. This result suggests that traits of the ratoon and the stem base are hereditary. Furthermore, cultivar $\times$ shading interaction was not found to be significant

in stem base weight per hill, TAC content and the 3 ratoon traits. This fact represents that traits of the various cultivars varied with the extent of shading but there were no detectable differences among cultivars.

The means of 5 stem base traits of 6 cultivars at different environments is given in Table 2. As seen from this table, the values of the 5 stem base traits decreased significantly and linearly with the intensity of shading. However, each of these traits did proportionally not vary to the intensity of shading.

Changes in ratoon heights and in the percentage of ratoon tillers for the 3 different environments are shown in Fig. 1. These parameters increased logistically in the ratoon plants. The maximum value in each of these traits was significantly different among the 3 shading treatments. The maximum values of the percentage of ratoon tillers were 71% in full sunlight, 58% in the 50% and 35% in the 25% sunlight

Fig. 1. Changes in percentage of ratoon tillers and ratoon height for 3 different environments.

●: Full sunlight, ▲: 50% of sunlight,
■: 25% of sunlight.

Fig. 2. Ratoon weight on the 40th day after cutting at 3 environments.

environments. The time required to reach these maximum values was not different among the 3 different environments and was about 15 days. The maximum values for ratoon heights were 64 cm in full sunlight, 48 cm in the 50% sunlight and 30 cm in the 25% sunlight conditions. The times required to reach these maximum values were 30 days for full sunlight, 25 days for the 50% sunlight and 20 days for the 25% sunlight. These times were shorter in the most shaded environment.

Fig. 2 shows ratoon weight for the 3 different environments on the 40th day after cutting. The weight was highest for full sunlight; second for the 50% sunlight and lowest for the 25% sunlight. Furthermore, there were significant differences among the 3 different environments.

A decrease with the intensity of shading was observed in the 5 stem base traits of mother plants and also in the 3 traits of ratoon plants. Therefore, the 3 ratoon traits might be correlative to the 5 stem base traits. Table 3 shows correlation coefficients between the formers and the latters. Every one of the correlation coefficients was significant. The correlation coefficients between the 2 stem base weight traits and the ratoon traits, and that between the 2 TAC weight traits and these ratoon traits were higher than that between TAC content and these ratoon traits. It is suggested, therefore, that the percentage of ratoon tillers, ratoon height and ratoon weight depend largely on the 5 stem base traits, especially in stem base weight per hill and per stem, and TAC weight per hill and per stem. Ratoon weight and the 5 stem base traits were most highly correlated; second were ratoon height and the 5 traits; third were percentage of ratoon tillers and the 5 traits. It might be expected that ratoon weight in the dark environment may be a means of evaluating stem base and

Table 3. Correlation coefficients between stem base and ratoon traits

Trait	Percentage of ratoon tillers	Ratoon height	Ratoon weight
Stem base weight per hill	0.798**	0.806**	0.912**
Stem base weight per stem	0.793**	0.828**	0.902**
TAC weight per hill	0.754**	0.820**	0.879**
TAC weight per stem	0.760**	0.846**	0.900**
TAC content	0.491*	0.636**	0.600**

*, **: Significant at 5 and 1 % level, respectively

Fig. 3. Relation in ratoon weight to stem base weight per stem and TAC weight per stem.

●: Stem base weight per stem,
○: TAC weight per stem.

Vertical and horizontal lines show standard error.

food reserves on the time of cutting.

From the facts that the ratoon growth depends largely on the weights of stem base and TAC, regrowth might not be observed in ratoon plants in cases in which the weights of stem base and TAC were much too light. Relation in ratoon weight to stem base weight per stem and TAC weight per stem is shown in Fig. 3. Stem base and TAC weight per stem instead of those per hill were adopted for reducing the influence of varietal variation for the number of tillers. It is suggested from this figure that the amount less than a certain weight became a limiting factor for ratoon growth, and that defoliated plants would not ratooned under 0.15 g for stem base weight per stem or under 0.05 g for TAC weight per stem.

Weight of stem base and roots correlated to the amount of food reserves in some

Fig. 4. The relationship between stem base weight and TAC weight per stem.

●: Ginmasari, ○: Azusa,
▲: Sachiwatari, △: Satominori,
■: Chiyohikari, □: Yaeho.

herbage plants⁸⁾. Fig. 4 shows the relationships between stem base weight per stem and TAC weight per stem. As seen from this figure, TAC weight had significant and high correlation with stem base weight. Values for each cultivar are located almost on a straight line. Stem base weight, therefore, may have higher correlation with TAC weight. Correlation coefficient between stem base weight per stem and TAC content was 0.477 (significant at 5% level). This coefficient was significant but apparently lower between stem base weight per stem and TAC weight per stem.

Discussion

In the sunlight environment forliage of ratoon plants seems to grow on their own foliage^{2,4)}. In the dark condition regrowth of herbage plants seems to depend on the food reserves contained in stem base and roots, since photosynthesis is not taken place in the foliages of ratoon plants²⁾. Roots of rice plant, however, do not have a role as a storage organ¹²⁾. In this experiment which was artificially made to regulate the amount of food reserves within the stem base, the traits of ratoon such as the percentage of ratoon tillers, ratoon height and ratoon weight exhibited significant and positive correlations with TAC weight per stem and TAC content. Moreover, the correlation coefficients between the traits of ratoon and TAC weight per stem were higher than those between the traits of ratoon and TAC content. Therefore, it is suggested that ratoon growth of rice plant as well as the pattern of regrowth in bahiagrass and orchardgrass depends highly on the amount of food reserves, especially on the TAC weight contained in the stem base.

Ratoon growth in paddy fields was more vigorous than that in the dark environments, since the foliages of ratoon plants carried on the photosynthesis in the sunlight environments⁴⁾. We should be careful in choosing ratoon traits, if we would like to evaluate the food reserves within the stem base by means of the ratoon traits. Ratoon weight, ratoon height and the percentage of ratoon tillers in the dark environment were closely related to the amount of food reserves within the stem base. However, ratoon weight and ratoon height in the sunlight environment were affected by the level of photosynthetic activity in the foliage⁴⁾. The percentage of ratoon tillers may not be as dependent on photosynthesis in the foliage as ratoon weight and ratoon height, since the percentage of ratoon tillers reached a constant value within 20 days after cutting. From these facts, it seems highly probable that the percentage of ratoon tillers is more useful as a

means to evaluate the amount of food reserves than ratoon weight and ratoon height.

Grain yields in ratoon cropping of rice plants are highly contributed by the number of tillers of the ratoon plants. However, this reaches a constant value in the early stage after harvesting of mother plants, as was stated previously. The cultivars which have a large quantity of food reserves in the time of harvesting of the first crops, therefore, may be more advantageous for ratoon cropping.

Summary

This paper is investigating the effect of food reserves on ratoon growth of rice plant. In order to regulate artificially the amount of the food reserves of rice plants, they were grown for 2 weeks before cutting under 3 different environments, which were full sunlight, shaded to about 50% sunlight and shaded to about 25% sunlight. Aerial part of the plant was cut 5 cm above the ground on the 10th day after heading. Weight and TAC amount in the stem base of the mother plant were measured on the day of cutting. Immediately on cutting, the plants were translocated to a dark environment of 25°C temperature. Ratoon height and percentage of ratoon tillers were noted for 40 days after cutting. Note on ratoon weight was taken on the 40th day after cutting.

Percentage of ratoon tillers, ratoon height and ratoon weight were highest for full sunlight; second for the 50% sunlight and lowest for the 25% sunlight. Furthermore, there were significant differences among the 3 different environments. The time required to reach the maximum value was about 15 days for the percentage of ratoon tillers, and was from 20 to 30 days for ratoon height. Weight and TAC amount in the stem base of the mother plant decreased significantly and linearly with the intensity of shading. It is assumed from these results that the ratoon traits might be correlative to the stem base traits. Correlation coefficients between the formers and the latters were highly significant, as was expected. Furthermore, relations of the ra-

toon traits to stem base weight and TAC weight were more closely those of the ratoon traits to TAC content. It is suggested, therefore, that the percentage of ratoon tillers, ratoon height and ratoon weight depend largely on the weights of stem base and TAC. The weights of stem base and TAC may become a limiting factor for ratoon growth in cases in which the weights were much too light.

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〔和 文 摘 要〕

水稻の再生に及ぼす貯蔵養分量の影響

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水稻の飼料化栽培，再生を利用した二期作栽培および農業形質の間接選抜手段としての利用において，再生は重要な特性である。しかしながら水稻の再生に関する基礎的知見は少なく，再生に及ぼす貯蔵養分量の影響についても明らかにされていない。そこで本報告では，稲体の貯蔵養分量を人為的に調節し，貯蔵養分量が再生に及ぼす影響について検討した。

水稻 6 品種を供試し，1/5000 a ポットで栽培した。出穂前 4 日から出穂後 10 日まで 3 条件下，すなわち自然光区，50% 自然光区および 25% 自然光区へ移動し，稲体の貯蔵養分量を調節した。出穂後 10 日に地上 5 cm で地上部を刈取り，ただちに 25℃ 暗黒下へ移動し，その後の再生茎率および再生草丈，ならびに刈取り後 40 日の再生重を調査した。また地上部刈取り時に稈基を採取し，稈基重および全炭水化物 (TAC) 量を調べた。なお株および茎当たりの乾物重により稈基重を，株および茎当たりの TAC 重ならびに乾物重当たりの TAC 重により TAC 量をそれぞれ評価した。

再生茎率，再生草丈および再生重のいずれもは，自然光区 > 50% 自然光区 > 25% 自然光区の順であった。再生茎率は遮光強度にかかわらず刈取り後 10～15 日に最大となった。また再生草丈が最大になるまでの日数は 25% 自然光区ではほぼ 20 日，自然光区ではほぼ 30 日であった。すなわち遮光強度が弱くなるほど再生草丈は長期間にわたって伸長した。一方稈基重および稈基に含まれる TAC 量は，自然光区 > 50% 自然光区 > 25% 自然光区の順であり，遮光強度が強くなるにともなってほぼ直線的に減少した。再生に関する特性と稈基に関する特性との間に有意な正の相関が認められ，とくに株および茎当たりの稈基重ならびに TAC 重と再生に関する特性との相関係数は乾物重当たりの TAC 重と再生に関する特性とのそれより顕著に高かった。それゆえ再生茎率，再生草丈および再生重のいずれもは稈基の貯蔵養分量に大いに依存するであろう。さらに稈基重および TAC 重の減少にともなって再生重も減少することから，稈基の貯蔵養分量が一定量以下になれば再生しないであろう。