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Application of Ratoon to a Test of Agronomic Characters in Rice Breeding. I. Variation in Ratoon Ability and Its Relation to Agronomic Characters of Mother Plant

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30 cultivars of paddy were grown in a randomized block design with 4 replications. The rice plants were cut at 5cm above the ground at 4 different growth stages, i.e. 10, 20, 30 and 40 days after heading. Ratoon weight, ratoon height and percentage of ratoon tillers to that of mother plant, were recorded 40 days after cutting. With respect to the 3 ratoon characteristics a significant decrease was observed to occur when the cutting time was delayed from 10 to 20 days after heading. The increase in the subsequent cutting was less marked. Analysis of variance suggests that ratoon weight, ratoon height and percentage of ratton tillers are heritable. In cuttings made 10 and 20 days after heading, there was a positive and highly significant phenotypic correlation between percentage of ripened grains of mother plant and these ratoon traits. Heritabilities in the broad sense for the ratoon traits became higher in the order, ratoon weight, ratoon height, percentage of ratoon tillers. Moreover, the heritability of percentage of ratoon tillers was nearly equal to that of culm length and panicle length. These facts show that ripening ability of rice plant may be tested by observing the ratoon, especially percentage of ratoon tillers.

Introduction

Ratoon of rice plant, regrowth in a paddy field after harvest, is well known. Ratooning, obtaining a second harvest from a second growth of the main crop, has been practised in many countries, such as India (Gupta and Mira, 1948; Reddy and Pawer, 1959), Japan (Ishikawa, 1964; Yamamoto, 1973), the United States (Evatt and Beachll, 1960; Ebatt, 1966; Mengel and Leonards, 1976), the Philippines (Bahar and Datta, 1977) and Ethiopia (Prasher, 1970a, b). Some of these papers pointed out that prain yields in the ratoon crop differed significantly among cultivars. These experiments were carried out to obtain a more efficient second crop. Plant breeders have not paid much attention to ratoons, and they have not tried to exploit ratoons in the breeding of rice.

The variation in ratoons and their relationship to agronomic characters of mother plant are presented in this study from the viewpoint of providing rice breeder with a new selection measure.

Materials and Methods

30 rice cultivars (*Oryza sativa* L.) listed in Table 1 were used. They were selected from the recommended cultivars throughout Japan except Hokkaido district.

The experiment was conducted at Kagawa in the 1977 season. 36-day-old seedlings were transplanted with a single plant per hill spaced at 30×10cm on June 4. These cultivars were grown in a randomized block design with 4 replications. Each replication comprised 150 plants. The main crop was fertilized with 1.0kg N/a, 0.8kg P_2O_5/a and 1.0kg K_2O/a as basal. No fertilization was applied to the ratoon crop.

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Table 1. Rice cultivars used

	Name		Name		Name
1	Kinmaze	11	Minehikari	21	Mineyutaka
2	Yaeho	12	Harebare	22	Sachikaze
3	Nipponbare	13	Akinishiki	23	Tamayodo
4	Tosan No. 38	14	Kusabue	24	Norin No. 24
5	Akitsuho	15	Tsukubanishiki	25	Hakoda
6	Satominori	16	Norin No. 29	26	Yachikogane
7	Akibare	17	Ginmasari	27	Akibae
8	Yamabiko	18	Koshijiwase	28	Suzukaze
9	Norin No. 44	19	Chiyohikari	29	Sachiwatari
10	Chusei-shinsenbon	20	Azusa	30	Syurei

The 30 cultivars were cut at 5cm above the ground at 4 different growth stages, i.e. 10, 20, 30 and 40 days after heading. Ratoon weight, ratoon height and percentage of ratoon tillers ((number of tillers per ratoon plant/number of tillers per mother plant) × 100) were recorded 40 days after cutting. Furthermore, such agronomic characters of mother plant as culm length, panicle length, number of glumous flowers per panicle, percentage of ripened grains, thousand-kernel-weight, number of tillers per plant and grain yield were recorded.

Results

A wide range of intervarietal variation was observed in agronomic characters of mother plant such as heading date, plant type and culm length. The earliest and latest heading dates were July 28 and August 30, respectively.

The means of ratoon weight, ratoon height and percentage of ratoon tillers of 30 cultivars at different cutting times are shown in Fig. 1. Increase in the delay of the cutting time from 10 to 20 days after heading was accompanied by a significant decrease in the values of these characteristics. But sligt increase was observed in subsequent cuttings. The degree of increase, however, differed with characteristics. A wide range of variation among cultivars was observed in ratoon for each of the cutting times. For the case of cutting at 10 days after heading, ratoon weight varied from 0.1 to 1.8g, ratoon height from 5 to 54cm and percentage of ratoon tillers from 5 to 71%.

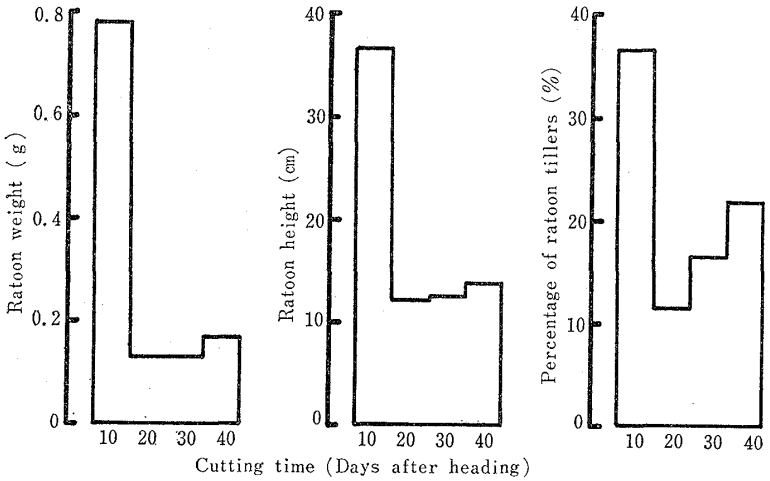

Fig. 1 Weight, height and percentage of tillers in ratoon crop at different cutting times

The results of analysis of variance for ratoon weight, ratoon height and percentage of ratoon tillers are give in Table 2, showing that there were significant differences in the variance due to cultivar, cutting time and cultivar×

Table 2. Analysis of variance of ratoon traits

Trait	Source	d.f.	M.S.
Ratoon weight	Cultivar (C)	29	0.36**
	Cutting time (T)	3	13.16**
	C×T	87	0.24**
	Error	360	0.06
Ratoon height	Cultivar (C)	29	823.58**
	Cutting time (T)	3	17021.03**
	C×T	87	192.99**
	Error	360	66.25
Percentage of ratoon tillers	Cultivar (C)	29	3363.81**
	Cutting time (T)	3	14167.89**
	C×T	87	301.08**
	Error	360	117.67

** : Significant at 1% level

Table 3. Phenotypic correlation coefficients between ratoon traits and agronomic characters of mother plant

	Cutting time (Days after heading)	Culm length	Panicle length	Number of glumous flower per panicle	Percentage of ripened grains	Number of tillers per plant	Thousand -kernel -weight	Grain yield
Ratoon weight	10	−0.35	0.07	0.12	0.43*	0.01	0.23	0.38*
	20	−0.18	−0.23	0.01	0.40*	0.13	−0.14	0.32
	30	−0.33	0.18	0.19	0.15	−0.34	0.10	0.03
	40	−0.04	0.27	0.15	−0.02	−0.34	0.32	−0.07
Ratoon height	10	−0.20	0.15	0.18	0.58**	0.17	0.26	0.36
	20	−0.22	−0.32	−0.03	0.47*	0.13	−0.01	0.34
	30	−0.22	−0.12	0.11	0.15	0.01	−0.15	0.15
	40	−0.25	0.27	0.17	0.09	0.07	0.18	0.08
Percentage of ratoon tillers	10	−0.41*	−0.22	−0.08	0.59**	0.06	0.12	0.35
	20	−0.24	−0.21	−0.11	0.41*	0.15	−0.10	0.18
	30	−0.31	−0.25	0.05	0.20	0.00	−0.15	0.06
	40	−0.21	−0.10	0.17	0.17	−0.07	0.07	0.17

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

cutting time interaction. These results suggest that traits of the ratoon are hereditable and that variations in these traits with delay of the cutting times differed among cultivars, including that these traits, as mentioned above, variated with the cutting times.

The fact that ratoons are heritable is of great interest to plant breeders. The relationship between ratoons and mother plants in agronomic characters is even more important. The phenotypic correlation coefficients between ratoon traits and some agronomic characters in mother plant are given in Table 3. Significant positive correlations were seen in some cases where cutting times were 10 and 20 days after heading. The phenotypic correlation coefficients tended to decrease with delay of the cutting times. It is noteworthy that there were significant positive correlations between the traits of ratoon and percentage of ripened grains in the cuttings of 10 and 20 days after heading. For cutting on 10 days after heading, ratoon weight exhibited a significant positive correlation with grain yield and percentage of ratoon tillers a significant negative correlation with culm length. In cuttings 30 and 40 days after heading, however, ratoon traits were not related to agronomic characters of mother plant. Panicle length, number of glumous flowers per panicle, number of tillers

Table 4. Genotypic correlation coefficients between ratoon traits and agronomic characters of mother plant

	Cutting time (Days after heading)	Culm length	Panicle length	Number of glumous flower per panicle	Percentage of ripened grains	Number of tillers per plant	Thousand-kernel-weight	Grain yield
Ratoon weight	10	−0.38	0.10	0.14	0.90	0.03	0.29	0.65
	20	−0.22	−0.26	−0.00	0.94	0.13	−0.22	0.58
	30	−0.48	0.21	0.23	0.48	−0.53	0.19	0.26
	40	−0.06	0.42	0.19	0.00	−0.54	0.46	−0.01
Ratoon height	10	−0.21	0.17	0.20	0.91	0.23	0.27	0.58
	20	−0.25	−0.35	0.05	0.95	0.14	−0.01	0.57
	30	−0.28	−0.15	0.13	0.36	0.01	−0.18	0.30
	40	−0.29	0.33	0.18	0.12	−0.17	0.20	0.10
Percentage of ratton tillers	10	−0.63	−0.24	−0.09	0.94	0.06	0.10	0.55
	20	−0.26	−0.23	−0.13	0.76	0.18	−0.12	0.29
	30	−0.34	−0.28	0.05	0.38	0.01	−0.18	0.11
	40	−0.23	−0.09	0.19	0.26	−0.07	−0.11	0.22

Table 5. Broad sense heritability of ratoon traits and agronomic characters of mother plant

Trait	Cutting time (Days after heading)	Heritability (%)	Character of mother plant	Heritability (%)
Ratoon weight	10	79.7	Culm length	94.4
	20	69.2	Panicle length	92.4
	30	63.6	Number of glumous flowers per panicle	92.4
	40	67.1	Percentage of ripened grains	34.9
Ratoon height	10	80.9	Number of tillers per plant	61.6
	20	82.4	Thousand-kernel-weigh	78.4
	30	83.4	Grain yield	45.4
	40	82.4		
Percentage of ratoon tillers	10	87.5		
	20	90.9		
	30	91.0		
	40	90.0		

per plant and thousand-kernel-weight, furthermore, did not show any relation to ratoon traits for any of the cuttung times. The genotypic correlation coefficients between ratoon traits and the agronomic characters are shown in Table 4. For cuttings 10 and 20 days after heading, ratoon traits had very high positive correlations with percentages of ripened grains. However, genotypic correlttion coefficients were generally low in other combinations.

Heritability estimates in the broad sense of ratoon traits and the agronomic characters are tabulated in Table 5. The estimates of heritability for ratoon weight varied with the cutting times, but those for ratoon height and percentage of ratoon tillers were essentially constant. Furthermore, the estimates of heritability for percentage of ratoon tillers were higher than those ratoon weight and ratoon height, and were nearly equal to those for

culm length, panicle length and number of glumous flowers per panicle.

Discussion

Ratoon weight, ratoon height and percentage of ratoon tillers decreased markedly with delay of cutting-time from 10 to 20 days after heading and then increased slightly with 30 to 40 days after heding. Soga and Nozaki (1957) pointed out that the culm of rice plant is a very important storage organ and that the carbohydrate content of the culm decreased rapidly during filling period of 10 to 25 days after heading and increased slightly after that time. Therefore, it should be noted that ratoon weight, ratoon height and percentage of ratoon tillers might be related to the carbohydate content of the culm. Ehara et al. (1965a, b, 1966) reported that the regrowth of herbage plants in Gramineae depended on the amount of food reserves accumulated in the stubble and roots of the plants. The present results suggest that the ratoon of rice may also have the same physiological property as the stubble and roots for regrowth of herbage plants in Gramineae.

Grain yield from ratooning, i.e. a second crop, varied among cultivars (Prashar 1970, Yamamoto 1973, Bahar and Datta 1977). The present expriment also showed that ratoon weight, ratoon height and percentage of ratoon tillers were significantly different among cultivars. These ratoon traits, however, showed no correlation with earliness of cultivars, of which heading ranged from July 28 to August 30. Furthermore, it seems that these traits were not related to the plant types. Therefore, these facts show undoubtedlly that ratoon weight, ratoon height and percentage of ratoon tillers are heritable.

Percentage of ripened grains is very important in constituting yields of rice plant. However, plant breeder has not been provided a useful selection measure for higher percentage of ipened grains since its heritability is lower, as was seen in Table 5. From this point of view, it is very useful to learn that the traits closely related to percentage of ripened grains are ratoon weight, ratoon height and percentage of ratoon tillers got by the cuttings of 10 to 20 days heading. Heritability estimates of these traits of the ratoon were very high. It may be possible, therefore, to evaluate the ripening ability of rice cultivars by observing the ratoon.

Mastushima and Wada (1958) reported from their investigation of the ripening machanism in rice that percentage of ripened grains depended on the amount of carbohydrate accumulated after heading rather than that stored before heading. Using the rice plants exposed to $^{14}CO_2$ at different stages, Oshima (1966) concluded that a great part of the starch contained in the grain wa attributable to photosynthesis after heading. In several papers, it has been emphasized that the period after heading is more important for determining the degree of ripening of rice plants. In the present experiment, the traits of the ratoon, which emerged from the dafoliated aerial part of the stubble 10 days after heading, show a significant correlation with percentage of ripened grains. These traits varied greatly among cultivars. Phenotypic correlation coefficients between percentage of ripened grains and both the ratoon height and percentage of ratoon tillers were higher than that between percentage of ripened grains and ratoon weight. Heritability decreased in the following order : percentage of ratoon tillers, ratoon height and ratoon weight. It may be concluded from these facts that percentage of ratoon tillers got by the cutting 10 days after heading should be recorded as a measure of the ripening ability in rice.

Literature Cited

BAHAR, F. A. and S. K. DE DATTA 1977. Prospects of increasing tropical rice production through ratooning. Agron. J. **69** : 536～540.

EHARA, K., T. SASAKI and H. IKEDA 1965. Physiological and ecological studies on the regrowth of herbage plants. I. Effect of food reserves and temperature on the regrowth of orchardgrass and Italian ryegrass. J. Japan. Grssl. Sci. **10** : 214～220.

———, ———, ——— and Y. NATA 1965. ———— II. Effect of changes in food reserves, temperature, light and plant nutrients on the regrowth of orchardgrass and bahiagrass under dark conditions. J. Japan. Grassl. Sci. **10** : 221～225.

———, Y. YAMADA and N. MAENO 1966. ———— IV. The evidence of utilization of food reserves during the early stage of regrowth in bahiagrass (*Paspalum notatum* FLÜGGE) with $^{14}CO_2$. J. Japan. Grassl. Sci. **12** : 1～4.

EVATT, N. S. 1966. High annual yields of rice in Texas through ratoon or double cropping. Rice J. **69** : 10～32.

——— and H. M. BEACHELL 1966. Ratoon cropping of short-season rice varieties in Texas. International Rice Commission Newsl. **9** : 1～4.

GUPTA, P. S. and A. K. MIRA 1948. Possibility of increasing the yield of rice by ratooning in the U. P.. Indian Farming. **9** : 13～15.

ISHIKAWA, T. 1964. Studies on the ratoon of rice plant in early cultivation. Bull. Fac. Agric., Univ. Miyazaki, Japan **10** : 72～78.

MASTUSHIMA, S. and G. WADA 1958. Analysis of developmental factors determining yield and its application to yield prediction and culture improvement of lowland rice. XLVIII. Studies on the mechanism of ripening. (9) Relation of the percentage of ripened grains and the yield of grain to the amount of carbohydrates stored by the time of heading, that of carbohydrates accumulated after heading and the nitrogen content at heading time. Proc. Crop Sci. Soc. Japan **27** : 201～203.

MENGEL, D. B. and W. J. LEONARDS 1976. Effect of water management and rate of nitrogen fertilization on second crop yield and quality. 68th Annual Progress Report, Rice Experiment station, Crowley, Louisiana : 52～55.

OSHIMA, M. 1966. Translocation and redistribution of the assimilated ^{14}C in rice plant. J. Sci. Soil Manure, Japan **37** : 589～593.

PRASHER, C. R. K. 1970a. Paddy ratoons. World Crops **22** : 145～147.

——— 1970b. Some factors governing rice-ratoon yields. Plant and Soil **32** : 540～541.

REDDY, V. R. and M. S. PAWAR 1959. Studies on ratooning in paddy. Andhra Agric. J. **6** : 70～72.

SOGA, Y. and M. NOZAKI 1957. Studies on the relation between seasonal changes of carbohydrates accumulated and the ripening at the stage of generative growth in rice piant. Proc. Crop Sci. Soc. Japan **26** : 105～108.

YAMAMOTO, T. 1973. Double cropping by ratooning of rice. Kenbun-syupan, Japan, p.37～42 (in Japanese)

水稲における再生の育種的利用に関する研究
I. 品種間差異ならびに農業諸形質との関係

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水稲における再生の育種的利用を検討するため，水稲30品種を供試し，出穂後 10，20，30 および40日に地際より 5cm で地上部を剪除し，剪除後 40 日に再生重，再生草丈および再生茎率を調査した。

再生重，再生草丈および再生茎率のいずれもは，剪除時期が出穂後 10 日から 20 日へ移動するに伴い，顕著に減少したが，その後はおおむね増大するようであった。分散分析の結果，再生重，再生草丈および再生茎率が品種固有の遺伝的特性であることを示唆した。また出穂後 10 および 20 日に剪除したときの再生重，再生草丈および再生茎率は登熟歩合と有意な正の表現型相関を示した。遺伝力（広義）も再生重，再生草丈，再生茎率の順に高くなり，とくに再生茎率の遺伝力は稈長，穂長または1穂頴花数のそれに匹敵するほどであった。

以上の結果から，水稲の再生，たとえば出穂後 10 日に地上部を剪除したときにみられる再生茎率を調べることにより登熟歩合を容易に検定できることが示唆された。