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INHERITANCE OF RATOONING ABILITY IN A CROSS IR 19657 x IR 56 OF RICE

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ABSTRACT

The parental, F_2, F_3 and F_4 generations of a rice cross, IR 19657-34-2-2-3-3 A x IR 56, were evaluated for ratooning ability. Additive and dominant gene effects were significant. The dominance of genes for lower parental value predominantly controlled the inheritance of ratooning ability in this cross. Broad-sense heritability estimate was moderate, whereas narrow sense heritability values were low in F_2 and F_3, indicating the contribution of nonadditive gene action to the expression of this character. Selection schemes utilizing additive and nonadditive gene actions should, therefore, be adopted for the improvement of rice ratooning ability.

Key words: Genetics, ratoon cropping, *Oryza sativa* L.

Because of low production cost, short growth duration, low water requirement and high water use efficiency, ratoon cropping of rice has been considered profitable as the second rice crop to increase production in areas where irrigation facilities are inadequate or a short growth duration does not permit planting of a full season rice crop [1, 2]. Among the several factors that would determine the success of ratoon cropping, the inherent ratooning ability of a cultivar is the most important. Therefore, efforts should be made to breed varieties with good ratooning ability. As information on the mode of inheritance of ratooning ability is limited [3, 4], an attempt has been made to study the inheritance of ratooning ability and its association with other agronomic traits in rice.

MATERIALS AND METHODS

The experiments were conducted at the International Rice Research Institute, Los Baños, Laguna, Philippines. The parents and F_2 populations of an indica rice (*Oryza sativa* L.) cross

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IR 19657-34-2-2-3-3A x IR 56 were grown during the 1983 wet season and 100 F_2 plants were taken at random to raise F_3 generation during the 1984 dry season. The F_2, F_3 and F_4 generations along with the parent strains were raised in compact family block design during the wet season of 1984. Fertilizer was applied one day before transplantation at the rate of 30N : 13P : 25K (kg/ha). Nineteen-day-old seedlings were transplanted with a single plant per hill at a distance of 20 cm between plants in a row. The rows were 4.4 m long and spaced 25 cm apart. Each replication had 4 rows of the parents, 10 rows of each F_2, 1 row of each F_3 and F_4 family. Three replications were made. Thirty kg N/ha was top dressed 30 days after transplantation. Plant protection measures were followed when needed. The agronomic practices for both 1983 and 1984 wet seasons were similar. Ten competent plants from each parent, 90 plants from F_2, and 5 plants each from the F_3 and F_4 families per replication were taken at random. The plants were ratooned by cutting the stalks at maturity 15 cm above the ground. The ratoon tillers were recorded 28 days after cutting. The ratio of ratoon tillers to the first crop tillers was used as an index of ratooning ability, because this ratio had positive and significant correlation with the grain yield of ratoon crop and could be measured at an early stage of ratoon growth, thus facilitating early and rapid mass screening of genotypes. Various genetic parameters were calculated using different generation means and variances. Adequacy of the additive–dominance model was tested using the scale given of [5]. The following equation was used to test the scale effect:

$$\hat{D} = 4\,\bar{F}_3 - 2\,\bar{F}_2 - \bar{P}_1 - \bar{P}_2,$$

where $\hat{D}$ is the test for scale effect, $\bar{P}_1$, $\bar{P}_2$, $\bar{F}_3$ and $\bar{F}_2$ are the means of the respective populations. Variance of D was calculated as $V_D = 16\,V(\bar{F}_3) + 4\,V(\bar{F}_2) + V(\bar{P}_1) + V(\bar{P}_2)$, where $V(\bar{P}_1)$, $V(\bar{P}_2)$, $V(\bar{F}_2)$ and $V(\bar{F}_3)$ are the variances of sample means of respective populations. Standard error (SE) of D was given by $(V_D)^{1/2}$ and the t value was computed as $t_D = D/\,SE_{(D)}$. The calculated t value greater than 1.96 indicates the inadequacy of the additive–dominance model.

The joint scaling test of Cavalli [6] was also performed using the weighted least square technique to obtain the expectations of gene effects: m (mean), d (additive effects) and h (dominance effects). The expectations of different generation means were used to compute [m], [d], [h]:

$$\bar{P}_1 = m + d$$
$$\bar{P}_2 = m - d$$
$$\bar{F}_2 = m + 1/2\,h$$
$$\bar{F}_3 = m + 1/4\,h$$

The significance of the difference between observed and expected generation means was tested using χ^2 test.

The broad sense heritability ($h^2_{(B)}$) was estimated following the method of [7]:

$$h^2_{(B)} = V F_2 - \frac{\sqrt{V P_1 \times V P_2}}{V F_2}$$

The parent–offspring regression was used to compute narrow sense heritability in the F_2 and F_3 generations. The genetic advance under 5% selection intensity and simple correlation coefficients of ratooning ability with other characters were also computed, i.e., first crop plant height, tillers/plant, panicles/plant (in F_2); panicles/plant and grain yield/plant (in F_3 and F_4), following the methods of [8, 9].

RESULTS AND DISCUSSION

The analysis of variance revealed a considerable amount of genetic variability among the experimental populations. The characteristic features of the parents of the cross IR 19657-34-2-2-3-3A x IR 56 are presented in Table 1. IR 56 is a dwarf, early maturing variety with good tillering but poor in ratooning ability, whereas IR 19657-34A is a tall, mid-maturing elite culture with excellent ratooning ability. The mean ratooning ability of the experimental populations is presented in Table 2. The two parents involved in the cross differ significantly from each other. The $\bar{F}_2$, $\bar{F}_3$ and $\bar{F}_4$ means were within the parental range. IR 19657-34-2-2-3-3A had the highest ratooning ability. The $\bar{F}_2$ did not differ from $\bar{P}_2$, $\bar{F}_3$ and $\bar{F}_4$ did not differ significantly but these were significantly higher than $\bar{F}_2$ (Table 2). The F_2 frequency distribution was highly skewed in favour of low

Table 1. Salient features of the parents of the cross

Character	IR 19657-34	IR 56
Plant height (cm)	113.4	88.6
50% flowering (days)	105	85
Tillers/plant	17.2	21.4
Panicles/plant	16.5	20.7
Ratooning ability	0.87	0.37

Table 2. Mean performance for ratooning ability of segregating and nonsegregating generations of the cross IR 19657-34 A x IR 56

Generation	Range	Mean $\pm$ SE
IR 19657-34-2-2-3-3A	0.45–1.1	0.87 ± 0.02^a
IR 56	0.10–0.6	0.37 ± 0.01^c
F_2	0–1.7	0.39 ± 0.03^c
F_3	0.1–1.6	0.57 ± 0.02^b
F_4	0–1.6	0.58 ± 0.02^b

a, b, c—the mean values marked by different letters are significantly different at 5% level.

ratooning ability (Fig. 1), indicating the dominance of low ratooning ability in this cross. The range of variation in F_2 as compared with the parental range showed transgressive segregation towards both higher and lower values (Fig. 1).

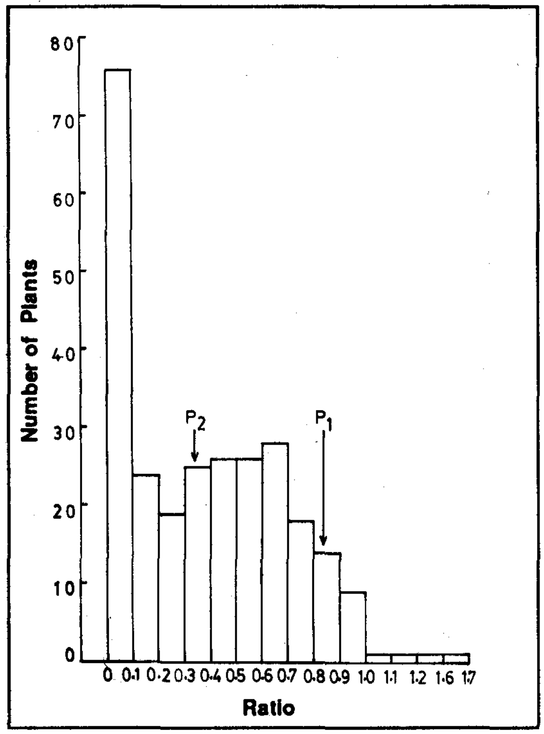

Fig. 1. Frequency distribution of plants for ratio of ratoon tillers to main crop tillers in F_2 population of the cross IR 19657-34-2-2-3-3A x IR 56 (IRRI, 1984).

SCALING TEST AND GENE EFFECTS

The variation in ratooning ability among generation means could not be explained by the additive–dominance model. The inadequacy of the additive–dominance model as shown by the significant scaling test D (0.289 ± 0.09) indicates the existence of nonallelic interactions in the inheritance of ratooning ability in this cross. The results of the scaling test were also supported by χ^2 value based on 3-parameter model ([m], [d], [h]), testing their goodness of fit based on the joint scaling test. The differences between expected generation means based on adequacy of additive–dominance model and observed generation means were significant as the χ^2 value was very high (Table 3). The estimates of [d] and [h] were significant. But the dominant gene effects towards the lower parental mean predominantly governed the inheritance of this character. An earlier study [4] reported additive effects along with additive x additive interaction to be important in the inheritance of this character.

Table 3. Estimates of scaling test and gene effects for ratooning ability in the cross IR 19657-34 A x IR 56

Parameter	Estimate
Mean of F_2 [m]	$0.63 \pm 0.01^{**}$
Additive effects [d]	$0.25 \pm 0.01^{**}$
Dominance effects [h]	$-0.39 \pm 0.06^{**}$
χ^2	19.4^{**}
D scale	$0.29 \pm 0.09^{**}$

**Significant at 1% level.

HERITABILITY AND GENETIC ADVANCE

Information on heritability and genetic advance are useful in predicting the gain expected from selection. Ratooning ability had a low broad sense heritability and genetic advance in the F_2, but showed higher heritability and genetic advance in the F_3 (Table 4).

Table 4. Heritability and genetic advance for ratooning ability in the cross IR 19657-34 A x IR 56

Heritability		Genetic advance (% of mean)
Broad sense:		
F_2 0.44		16.5
F_3 0.66		53.8
Narrow sense:		
F_3/F_2 0.08 (n = 80,	r = 0.174)	2.13
F_4/F_3 0.36** (n = 80,	r = 0.33**)	8.72

Low to moderate heritability estimates have been reported earlier [3, 4], but Ichii and Kuwada [10] reported high heritability for this trait. The varying estimates of ratooning ability could be due to differences in the genetic background of the crosses. The results of the present study and earlier ones suggest that this trait is highly influenced by environmental factors.

The narrow sense heritability, which is based on fixable component of genetic variance, is a better parameter to predict response to selection than broadsense heritability. Regression of F_3 progeny on F_2 and that of F_4 on F_3 (parent–offspring regression) represent the realized heritabilities, which indicate the narrow-sense heritabilities. When the dominance effect is low, both these regressions reflect additive genetic variance, but when dominance is high, regression of F_4 on F_3 gives a better estimate than that of F_3 on F_2 [11].

The F_3 on F_2 regression gave a lower heritability value than the F_4 on F_3 regression (Table 4). This difference may be attributed to environmental effects, as F_2 and F_3 were grown in different years but the F_4 and F_3 plants were grown the same year. The results suggest that the contribution of nonadditive gene action is quite high in the expression of this trait in this cross.

Table 5. Correlation coefficients (r) of ratooning ability with some agronomic traits of the main crop in different generations

Character	values in different generations T		
	F_2	F_3	F_4
Plant height	0.125	—	—
Tillers/plant	–0.076	—	—
Panicles/plant	0.011	0.092	0.056
Grain yield/plant	—	0.068	0.167

In this experiment, selection of F_2 plants was not effective. This was also reflected by the nonsignificant correlation between F_2 and F_3 line means (r=0.174). Predominance of nonadditive gene action in this cross suggests that simple selection in a segregating generation would not be effective. Therefore, breeding methods exploiting additive and nonadditive gene actions, such as, reciprocal recurrent selection and diallel selective mating, might prove useful for the improvement of ratooning ability.

CORRELATIONS

Cuevas-Perez [3] emphasized that while selecting lines for high ratooning ability in a breeding programme, care must be taken not to sacrifice the main crop yield to the extent that the advantage of the ratoon crop yield is neutralized. Therefore, it is pertinent to analyse the association of ratooning ability and other agronomic characters. Ratooning ability in F_2 generation showed positive but nonsignificant associations with plant height and panicles/plant (Table 5). Correlation coefficient between tillers/plant and ratooning ability was negative but nonsignificant. Similarly, in F_3 and F_4 generations, grain yield and panicles/plant were not associated with ratooning ability. These results suggest the possibility of combining high ratooning ability with high main crop yield.

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