PERFORMANCE OF VEGETATIVELY PROPAGATED F_1 PLANTS IN RICE[1]

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I. INTRODUCTION

Although heterosis in grain yield of rice has been observed as early as 1926 (Jones), it is still not feasible at the present time to commercially utilize hybrid vigor in the F_1 generation of rice because of the difficulties involved in the economical production of F_1 seeds. Recently, however observation made at the Chiayi Agricultural Experiment Station tends to indicate that the degree of reduction in the hybrid vigor of F_1 varies with individual cross combinations, suggesting that there can be substantial amount of residual heterosis in F_2 or even F_3 generation of certain rice crosses. This observation has prompted speculation concerning the possible utilization of hybrid vigor in the F_2 or F_3 generation of rice. The idea of utilizing hybrid vigor in the F_2 or F_3 generation of particularly productive small grain crosses was suggested by Anderson in as early as 1919 and Griffee (1921) also indicated that this method might have promise under intensive farming. In view of the limited advantage obtainable from the newly developed pureline varieties in yield over the existing commercial ones (Kariya, 1966), it appears highly likely that greater increase in yield can be expected from growing F_2 or F_3 population instead of planting conventional rice varieties.

It is anticipated that the cost of F_2 or F_3 seeds can be more expensive than that of the ordinary rice seeds inasmuch as only limited amount of F_1 seeds is usually produced by available techniques. For the commercial utilization of heterosis in F_2 or F_3 to become a reality way has to be found for a rapid increase of these seeds so that the cost of seed production can be lowered to an acceptable level. Vegetative propagation of F_1 plants appears to be a logical solution to this problem. This experiment was designed to provide information on the possibility of raising F_1 plants from the cuttings or the division of tillers and the performance of these vegetatively propagated F_1 rice plants in terms of grain yield and other related agronomical characters.

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MATERIASL AND METHODS

Field experiments were conducted in the first and second crops of 1970 at wan-tien-li Farm of the Chiayi Agricultural Experiment Station. Three F_1 crosses namely Taichung 180 xTaichung 186 of early maturing japonica group, C 236 x Tainan 4 of late maturing japonica group, and C 235 x IR 9-60 of indica group, their respective parents, and standard commercial check varieties were employed in the first crop. In the second crop, however, Taichung 180 x Line 54233 was used to replace early maturing japonica group, Taichung 180 x Taichung 186 whereas the other two groups remained unchanged. Taichung 180, Tainan 5, and Taichung native 1 were used as check varieties for early maturing japonica, late maturing japonica, and indica groups respectively. Line 54233, C 236, and C 235 were new lines selected at this Station whereas IR 9-60 was introduced from the International Rice Research Institute (IRRI).

Rice seedlings raised from seeds and cuttings were used for F_1 but only seeds were used to raise seedlings for parental and check varieties. Rice cuttings of F_1 were taken from stubbles of F_1 plants grown in the previous crop. Rice stubbles were digged out, washed, separated into individual tillers, and carefully cut into short pieces. Each cutting consisted of at least one node with one viable bud. Rice cuttings were then planted in the shallow lead flat to provide a nursery for the growth of rice seedling. Rice seedlings raised from cuttings were transplanted into paddy field in the same way as those raised from seeds. Forty to sixty rice plants were planted for each population at the spacing of 25 x 20 cm with one seedling be transplanted at each hill. Rice seedlings were transplanted on February 2 in the first crop and on July 29 in the second crop.

At 35 and 25 days after transplanting in the first and second crops respectively when rice plants had already produced more than 5 tillers, division method was employed to help these tillers become independent plants. About 10 to 20 rice plants were carefully pulled out from each population and each plant was separated into individual tillers for replanting. Tillers from the same individual plants were planted in a row in the order of their respective size from the mother tiller to the smallest one. Rice plants not pulled out for replanting were used as check for making comparison. Standard cultural practices were followed for the management of the experimental plots.

Heading date, plant height, number of panicles per plant, and grain yield per plant were recorded for each population. Total grain yield produced from rice plants derived from a given rice seedling was calculated. Heterosis expressed in rice plants raised from rice seeds and rice cuttings was also compared.

RESULTS AND DISCUSSION

Percentage of Germination in Rice Cuttings

The percentage of germination in rice cuttings is shown in Table 1. It was observed that as much as 70% of rice cuttings germinated in F_1 hybrids of all three crosses in the first crop. In the second crop, however, the percentage of germination in rice cuttings was very low. No germination of rice cuttings was detected in the early maturing japonica group whereas only 2.1 and 12.1% of rice cuttings germinated in late maturing japonica and indica groups respectively. The exact reason for this difference in the germination percentage of rice cuttings between the first and second crops is not presently clear. Further investigation appears necessary to stabilize the germination of rice cuttings. Nevertheless, the percentage of rice cuttings observed in the first crop may be considered high enough to justify the feasibility of increasing F_2 seed production through planting of rice cuttings. It was of interest to note that rice cuttings of indica cross were usually associated with higher percentage of germination in both crop seasons when compared with those of japonica crosses, indicating that F_1 hybrids between indica rice varieties may be more suitable for propagation through cuttings due probably to their superior ability in regeneration.

Table 1. Percentage of germination in rice cuttings of F_1 hybrids.

Group	First crop, 1970			Second crop, 1970		
	No. of cuttings planted	No. of cuttings germinated	Percent of germination (%)	No. of cuttings planted	No. of cuttings germinated	Percent of germination (%)
Japonica (early maturing)	104	74	71.2	131	0	0
Japonica (late maturing)	118	84	71.2	141	3	2.1
Indica	122	93	76.2	282	37	12.1
Total	344	251	73.0	554	40	7.2

Percentage of Survival in Replanted Tillers.

Division method was employed during the tillering period to separate young rice tillers for replanting. It was observed that more than 90% of these replanted tillers survived to become fully matured rice plants (Table 2). There was no significant difference in the percentage of survival among F_1 hybrids of three groups, although the percentage of survival in the second crop of rice were slightly higher than those of the first crop. Rice tillers separated from F_1 plants raised from rice seeds appeared to survive equally well as those from F_1 plants grown from rice cuttings. Since the percentage of survival for replanted tillers was higher and more stable than the percentage of germination for rice cuttings, the increase of F_2 seed production through division of tillers may be more practical than the use of rice cuttings.

Table 2. Percentage of survival with division of F_1 hybrids.

Source of F_1 hybrid	Group	First crop, 1970			Second crop, 1970		
		No. of tillers planted	No. of tillers survived	Percent of survival (%)	No. of tillers planted	No. of tillers survived	Percent of survival (%)
F_1 from seeds	Japonica (early maturing)	39	36	92.3	119	118	99.2
	Japonica (late maturing)	57	55	96.5	147	144	98.0
	Indica	20	19	95.0	135	133	98.5

	Total	116	110	95.0	401	395	98.5
F_1 from cuttings	Japonica (early maturing)	154	140	90.9	—	—	—
	Japonica (late maturing)	206	193	93.7	33	33	100
	Indica	153	145	94.8	118	118	100
	Total	513	478	93.2	151	151	100

The Growth of Rice Plants.

The growth of vegetatively propagated F_1 rice plants in the first and second crops of 1970 is presented in Table 3. It was observed that F_1 plants raised from rice cuttings headed similarly but grew taller and produced more tillers than F_1 plants grown from rice seeds in the first crop for early maturing japonica group, showing that vegetatively propagated F_1 plants can grow better than conventional seed grown F_1 plants of early maturing japonica cross in the first crop. Normal rice growth was also available for F_1 plants from cuttings of late maturing japonica cross in the first crop, although they produced slightly less panicles per hill in comparison with that of seed grown F_1 plants. F_1 plants from rice cuttings of indica group tended to head earlier, grew shorter, and produced less panicles per hill than F_1 plants from rice seeds in both crops, especially in the first crop, indicating that the growth of vegetatively propagated F_1 plants of indica cross appeared normal, although it was slightly inferior to that of seed grown F_1 plants. The poor growth of vegetatively propagated F_1 plants of indica cross may be due largely to their early maturity, but the reason for this situation is not yet well understood at this moment.

Table 3. The growth of vegetatively propagated F_1 hybrids.

Group	Popu-* lation	First crop, 1970						Second crop, 1970					
		Heading date (days)		Plant height (cm)		Panicles per hill		Heading date date (days)		Plant height (cm)		Panicles per hill	
		Without division	With division	Without division	With division	Without division	With division	Without division	With division	Without division	With division	Without division	With division
Japonica (early maturing)	P_1(ck)	95.3	—	102.3	—	8.6	—	48.0	—	96.9	—	13.5	—
	P_2	93.8	—	104.0	—	11.1	—	52.1	—	110.0	—	9.1	—
	F_1S	94.1	64.3 (99.8)	105.0	108.7	12.9	13.9	46.2	39.3 (64.3)	97.3	74.9	10.8	8.4
	F_1C	94.3	63.6 (98.8)	107.0	111.5	13.4	14.1	—	—	—	—	—	—
	CK	104.6	—	107.0	—	11.8	—	60.3	—	110.0	—	10.6	—
	P_1	97.9	—	97.8	—	16.6	—	57.9	—	101.6	—	10.2	—

Japonica (late maturing)	P_2	100.1	—	103.8	—	14.8	—	56.9	—	109.2	—	12.3	—
	F_1 S	97.9	68.4 (103.4)	104.1	103.7	18.0	15.1	59.2	51.8 (76.8)	103.3	94.7	9.1	10.0
	F_1C	98.7	70.0 (105.5)	104.0	104.7	15.0	12.4	—	47.9 (72.9)	—	93.3	—	8.7
Indica	CK	105.1	—	79.0	—	12.1	—	60.8	—	84.3	—	13.2	—
	P_1	102.6	—	85.1	—	16.9	—	61.8	—	95.9	—	11.7	—
	P_2	107.7	—	81.6	—	18.6	—	69.3	—	84.2	—	14.8	—
	F_1 S	101.8	70.1 (105.1)	85.6	86.2	19.4	17.0	61.2	54.4 (79.4)	95.5	84.8	14.0	11.1
	F_1C	90.9	65.4 (100.4)	82.1	87.4	16.5	15.6	57.8	52.0 (77.0)	95.4	86.0	12.4	14.7

*CK, P_1, P_2=Check and parental varieties, respectively.

P_1S, C=F_1 plants raised from seeds and cuttings, respectively.

F_1 plants developed from rice tillers divided for replanting during the maximum tillering period were found to head 5 to 10 days and 17 to 20 days later than F_1 plants without division treatment in the first and second crop respectively, although their growing days reduced nearly 30 and 7 days in the first and second crops, respectively. F_1 plants with division was taller in the first crop but shorter in the second one when compared with those without division. F_1 plants with division generally produced less panicles than F_1 plants without division especially in the second crop with the exception of early maturing japonica group in the first crop where F_1 plants with division produced as much panicles per hill as F_1 plants without division. The results of this experiment clearly indicated that F_1 plants raised from rice tillers divided for replanting during the tillering period canbe grown at least as well as F_1 plants without division treatment in the first crop. In the second crop, however, the growth of F_1 plants with division is likely to be affected because of gradual decline in temperature after replanting.

The Production of Grain Yield.

The grain yield production of vegetatively propagated F_1 rice plants is given in Table 4. It was observed that grain yield of F_1 plants from cuttings was similar to that of F_1 plants from seeds for early maturing japonica cross whereas F_1 plants from cuttings gave slightly higher yield than F_1 plants from seeds for late maturing japonica cross in the first crop. The grain yield of F_1 plants from cuttings for indica cross was slightly lower in the first crop but was slightly higher in the second one when compared with that of F_1 plants grown from rice seeds. The lower yield production of vegetatively propagated F_1 plants of indica cross in the first crop may be largely attributable to their poor growth as reflected by shorter plant height and less panicles per hill.

F_1 plants raised from division of tillers generally yielded better in the first crop but poorer in the second one when compared with F_1 plants without division. This situation was more pronounced in the early maturing japonica cross where grain yield production of F_1 plants with division increased almost 30% in the first crop but decreased nearly 63% in the second one when compared with F_1 plants without division. It appears therefore not practical to increase F_2 seed production by means of division of tillers for early maturing F_1 hybrids in the second crop. The low yield production of F_1 plants with division may be due largely to the reduced plant growth and poor maturity of rice grains caused probably by the long delay in heading.

The number of plants increased from one F_1 seed and cutting through division of tillers was 4.3 and 6.2 respectively in the first crop whereas in the second crop, 12.7 and 9.7 plants could be increased from one F_1 seed and cutting, respectively. The smaller number of plants increased from each F_1 seed or cutting in the first crop can be explained by the fact that only few tillers were available for division at 35 days after transplanting because of unusually low temperature prevailing during the tillering stage of this crop. The total yield produced from rice plants increased through division of tillers from one F_1 seed or cutting was 159.1 and 220.0g respectively in the first crop while 221.9 and 203.1 g of F_2 seeds were produced by each F_1 seed and cutting respectively in the second crop. The average yield per hill for F_1 rice plants with division was 28.2 and 36.2 g in the first crop and 17.3 and 21.2 g in the second crop for F_1 seed and cutting, respectively.

Table 4. Grain yield production of vegetatively propagated F_1 hybrids.

Group	Popul*-ation	First crop, 1970				Second crop, 1970			
		Grain yield per hill (g)		No. of F_1 plants increased from one seed or Cutting	Total yield increased from one seed or cutting(g)	Grain yield per hill (g)		No. of F_1 plants increased from one seed or Cutting	Total yield increased from one seed or cutting(g)
		Without division	With division			Without division	With division		
Japonica (early maturing)	P_1(CK)	22.7	—			21.7	—		
	P_2	25.8	—			22.2	—		
	F_1 S	28.8	37.4	3.6	131.5	22.7	9.3	9.8	84.1
	F_1 C	28.7	35.5	5.5	193.9	—	—	—	—
Japonica (late maturing)	CK	27.9	—			23.2	—		
	P_1	31.0	—			18.6	—		
	P_2	29.1	—			23.1	—		
	F_1 S	35.8	36.2	5.5	195.3	17.3	19.4	11.8	219.6
	F_1 C	37.5	35.9	7.0	244.5	—	16.6	7.5	109.5

	CK	23.6	—			23.6	—		
	P_1	33.0	—			26.6	—		
Indica	P_2	31.7	—			23.0	—		
	F_1 S	39.6	41.0	3.8	150.4	30.6	22.5	16.5	316.9
	F_1 C	36.9	37.2	6.0	220.6	31.7	25.8	11.8	296.6
Average	F_1 S	34.9	38.2	4.3	159.1	23.5	17.3	12.7	221.9
	F_1 C	34.4	36.2	6.2	220.0	—	21.2	9.7	203.1

*CK, P_1, P_2=Check and parental varieties, respectively.
F_1S, C=F_1 plants raised from seeds and cuttings, respectively.

Based on the data obtained in this experiment, the number of F_1 seed necessary for producing sufficient amount of F_2 seeds to be grown on one hectare of land can be calculated as follows. When F_2 seeds are to be increased only through division of tillers during the tillering stage, about 320 F_1 seeds are estimated to be sufficient to provide enough F_2 seeds for growing one hectare of land in just one crop if it is assumed that the amount of seed needed for growing one hectare of paddy is about 60 kg and one F_1 seed can produce about 190 g of F_2 seeds in one crop through division of tillers. If, however, stubbles of F_1 plants are also to be used for further increase of F_2 seeds, approximately 128 cuttings can be obtained from each F_1 seed by assuming that an average of 8 plants can be increased from one F_1 seed through division and each increased F_1 plant can produce 16 panicles in the previous crop. By assuming 40% of rice cuttings will germinate, 128 cuttings will give rise to 51 rice seedlings ready to be transplanted in the following crop which will occupy about 2.5m^2 of land at the spacing of 25 x 20cm. These 51 F_1 plants will again be treated with division during the tillering stage so that the number of F_1 plants will be increased from 51 to 408 plants and the planted area will also be expanded from 2.5m^2 to 20.4m^2. Since nearly 97% of replanted tillers will survive, 396 F_1 plants are expected to mature and produce a total of 11 kg of F_2 seeds with an average yield production of 27.8 g per plant. Thus, one F_1 seed can produce about 190 g of F_2 seeds in the first planting and its stubbles will again yield about 11 kg of F_2 seeds in the following crop, adding the total F_2 seed production from one F_1 seed to as much as 11.2 kg in two crops of repeated vegetative reproduction. It is estimated therefore that approximataly 5 to 6 F_1 seeds planted in the first crop will suffice to produce enough F_2 seeds for the planting of one hectare of F_2 rice in the next first crop.

Heterosis in Grain Yield.

Heterosis of grain yield expressed in the percentage of mid- parent, high parent and standard commercial check variety values for vegetatively propapated F_1 hybrids is shown in Table 5. It was observed that with the exception of seed grown F_1 plants of late maturing japonica cross in the second crop, substantial amount of heterosis in grain yield was evident in all crosses of F_1 hybrids. This was not surprising since these three cross combinations were selected among crosses which showed significant heterosis of grain yield in their F_1 hybrids. F_1 plants from rice cuttings genereally expressed higher heterosis in grain yield than F_1 plants from rice seeds in the same cross with the exception of indica cross in the first crop, showing that vegetatively propagated F_1 plants may be associated with superior yielding ability than conventional seed grown F_1 plants. The poor performance of F_1 plants from cuttings for indica cross in the first crop may be largely attributable to their under-development of major agronomic characters caused probably by their early heading. In view of the generally superior performance of vegetatively propagated F_1 plants over the conventional seed grown F_1 plants, it appears highly likely that more residual heterosis can be utilized in F_2 population derived from vegetatively propagated F_1 plants if it is assumed that substantial amount of heterosis in grain yield of F_1 hybrid will be left over in F_2 population and the degree of decrease in heterosis of vegetatively propagated F_1 plants is similar to that of seed grown F_1 plants.

Table 5. Mean percentage values for grain yields of vegetatively propagated F_1 hybrids in relation to their mid-parent, high parent and check variety values.

Group	F_1 plants from	First crop, 1970			Second crop, 1970		
		Mid-parent	High parent	Check variety	Mid-parent	High parent	Check variety
Japonica (early maturing)	Seeds	118.5	111.6	126.9	103.2	102.3	104.6
	Cuttings	118.1	111.2	126.4	—	—	—
Japonica (late maturing)	Seeds	118.9	115.5	128.3	82.8	74.9	74.6
	Cuttings	124.6	121.0	134.4	—	—	—
Indica	Seeds	122.2	120.0	167.8	123.4	115.0	129.7
	Cuttings	113.9	111.8	156.4	127.8	119.2	134.3

SUMMARY

The performance of three vegatatively propoagated F_1 hybrid crosses of rice evaluated at the Chiayi Agricultural Experiment Station in the first and second crops of 1970 are reported.

More than 70% of cuttings taken from F_1 stubbles germinated in the first crop but less than 7% of them germinated in the second crop. However, more than 90% of

replanted tillers at the tillering stage survived in both crops.

The growth of F_1 plants raised from rice cuttings appeared normal in both crops. In early maturing japonica group, F_1 plants from cuttings were found to grow better than those grown from seeds but F_1 plants from cuttings of indica cross headed too early to attain their full growth in the first crop. F_1 plants developed by division method were taller in the first crop but were shorter in the second one when compared with those without division. F_1 plants with division generally headed later and produced less panicles than those without division, especially in the second crop.

Grain yields of F_1 plants raised from rice cuttings were higher than those of F_1 plants grown from rice seeds for late maturing japonica and india crosses in the first and second crops respectively. Accordingly, the amount of heterosis in grain yield of F_1 plants from cuttings was higher than that of F_1 plants from seeds in these two crosses. Grain yield and heterosis of F_1 plants from cuttings for indica cross in the first crop were lower than those of F_1 plants from seeds. Both F_1 plants from seeds and cuttings of early maturing japonica cross appeared to yield similarly. Grain yields of F_1 plants with division treatment were generally higher in the first crop but lower in the second one when compared with those of F_1 plants without division.

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水稻第一代什交後裔之無性繁殖及其表現

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摘　　要

本文係報告嘉義農業試驗分所於民國59年第1，2期作就三種水稻第一代什交後裔以扦插及分株方法繁殖時，其主要農藝特性之表現情形。

以 F_1 稻稈製成插條扦插時其成功之百分比，第一期作高達70%以上，但第二期作則只有7%，惟在分蘗期將 F_1 分蘗切開插植之分株法，其成活率第一期作及第二期作均高達90%以上。

以扦插法繁殖之 F_1 稻株，其生育情形頗為正常，在早熟品種之什交組合，以扦插繁殖之 F_1 稻株，其發育情形似較由種子繁殖之 F_1 稻株（對照）者為佳，惟在秈稻品種之什交組合，以扦插繁殖之 F_1 稻株，在第一期作則因提早抽穗而影響其發育。以分株法繁殖之 F_1 稻株，一般均較無經分株之 F_1 稻株（對照）第一期作高而第二期作則低，分株法繁殖之 F_1 稻株，較對照者早熟而每株穗數亦少，尤其以第二期作為甚。

以扦插法繁殖之 F_1 稻株，在晚熟品種之第一期作及秈型品種之第二期作，其每株谷重均較對照者為高，故其表現在每株谷重之什種優勢亦較對照者為高，以扦插法繁殖之秈型品種組合之 F_1 稻株其每株谷重及其什種優勢均較對照者為優，就早熟品種組合之 F_1 而言，扦插法與對照兩者之每株谷重及其什種優勢均頗相似，由分株法繁殖之 F_1 稻株其每株谷重在第一期作較無經分株之對照者為高，但在第二期作則較低。