Excised Embryo Culturing in the Study of Inheritance of Root Types in Rice

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Due to obvious difficulties in handling the roots for its characteristic position the study of root system regarding its genetical aspects is very limited. Like all aerial portions root is also under genotypic control. Particularly rice (Oryza sativa and allied species) is such a type of crop which has an exceptionally wider range of adaptability fitting all possible agro-ecological situations. This fitness of the crop must have been conferred by both natural selection and selection by man. Hence it is easily conceivable that this fitness as well as flexibilities are a function of varying genotypes controlling the anchorage of the plant.

In recent years studies have been taken on the root types of alfalfa by Adams', Jones and Hanson and Heinrichs and Morley on its creeping rootedness. “It appeared that although the creeping root character versus tap or branch-root was quite highly heritable the degree of spread seems to be strongly influenced by non additive genotypic and environmental factors and perhaps by genes determining vigour of growth”. Unfortunately such informations regarding genotypes of root types in rice appear to be completely lacking. Although Nagai et al. have published a series of papers entitled “cultivated rice varieties from the view point of root characters” informations about the nature of inheritance of root characters are not yet known. Roy has recently reported that when two varieties of rice are planted together, each may influence the yield of the other and interaction takes place mainly through water which indicates indirectly the interaction between the root systems of different rice varieties.

The scope of the present investigation really arose (1959-1960) while studying the responses of different varieties of cultivated types of paddy to embryo culture technique. Considerable variations with regard to the rate of growth and the number of roots were noticed in different varieties under common cultural conditions. In order to ascertain to what extent these variations are heritable, genetic studies involving two varieties of paddy were taken up.

The present study further opens up fresh possibilities in the study of inheritance of root-types in crops which following usual procedure on field material is extremely limited by the type of the crop. Further, the experimental conditions being fairly controlled and kept uniform the genetic variability to the nutrient requirement and uptake by different varieties can also be critically studied.

Material and Methods

The varieties, ‘Ashkata’ and ‘Baok’, which showed marked difference in their root system (Fig. 1) already detectable at the seedling stage were selected for the present study. “Ashkata”, an Indian variety which is a long duration and lodging type, was obtained from Chinsura Rice Research Station, Government of West

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Lengths were the same in the three experiments. Same assumption could also be made in case of 'Ashkata', the other parent used in the present investigation, where the F values obtained were 1.24 with 2.56 d.f., in the case of comparison of experimental means on maximum root lengths and 0.97, 2.55 d.f., in environmental variations the parental types and the F2 segregates were grown simultaneously. 80 F2 and 40 parental types, 20 each, were grown at a time and this experiment was repeated three times at an interval of one week. Repetitions were made with the seeds obtained from three different F1 plants. Maximum length of roots was measured from each seedling at the age of 20 days. The number of roots were also counted at the same time. The data obtained from these experiments have been summarised in Tables 2 & 3.

**Experimental Results and Their Interpretations**

In case of 'Baok' from the analysis of variance of the results obtained in three experiments the values of F turn out to be (1) 0.08 with 2.57 d.f., in the case of comparison of experimental means on maximum root length and (2) 0.59 with 2.56 d.f. in the case of comparison of experimental means on number of roots. These F values are smaller than the significance values and hence it may be assumed that the mean number of roots as also the mean of maximum root lengths were the same in the three experiments. Same assumption could also be made in case of ‘Ashkata’, the other parent used in the present investigation, where the F values obtained were 1.24 with 2.56 d.f., in the case of comparison of experimental means on maximum root lengths and 0.97, 2.55 d.f., in

Bengal. “Baok”, an Indonesian photoinensitive variety, which is also a long duration type with stiff straws, was obtained from Central Rice Research Institute, Cuttack.

Crossings were made between these two varieties in September 1959 following hot water emasculation method. Ten F1 seeds were obtained. Immediately after harvesting, 5 of the hybrid seeds obtained were put to dissected embryo culture, four of which germinated and out of those four, three survived up to maturity. Maximum root length and number of roots for each of these hybrids was noted at the age of 20 days. These data have been presented in Table 1. Seeds of these plants were obtained at the end of February 1960. F2 plants were raised from these seeds in the same year. To avoid environmental variations the parental types and the F2 segregates were grown simultaneously. 80 F2 and 40 parental types, 20 each, were grown at a time and this experiment was repeated three times at an interval of one week. Repetitions were made with the seeds obtained from three different F1 plants. Maximum length of roots was measured from each seedling at the age of 20 days. The number of roots were also counted at the same time. The data obtained from these experiments have been summarised in Tables 2 & 3.

**Experimental Results**

**Table 1. Maximum length and number of roots in the ‘Ashkata’ × ‘Baok’ F1 plants at the age of 20 days.**

<table>
<thead>
<tr>
<th>Plant No.</th>
<th>Max. length of root (cm)</th>
<th>Number of roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>7.0</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>6.0</td>
<td>2</td>
</tr>
<tr>
<td>Mean</td>
<td>6.43</td>
<td>2.7 = 3</td>
</tr>
</tbody>
</table>
the case of comparison of experimental means on number of roots. On the basis of the above findings the pooled means obtained for the parental varieties on both the characters have been compared using the F-statistics. As the calculated values of F 131.02 with 1,117 d.f. in case of root length, 101.43 with 1,115 d.f. in case of number of roots, being highly significant at 1 percent level of significance it may be concluded that the two varieties differ significantly in respect of both maximum root length and the number of roots. The analysis of variance of the results obtained from the different F2 families shows that the values of F come to 1.46 with 2,232 d.f., in the case of comparison of means of F2 families on the maximum root length and 2.09 with 2,235 d.f., in the case of comparison of means of F2 families on number of roots. As these F values are smaller than the significance values it may be concluded that there is no significant difference between the F2 families in respect of the characters studied. These F2 families having derived from the three F1 hybrids involving identical parents should have the same genetical variations. Any significant interfamily variation would be due to the effect of environment. Analyses of variation between families indicate that this component for both the characters in F2s are not significant. Hence the variations observed within the F2 families must have a genetic basis.

The coefficients of variation for root length are of equal order in both the parents (Table 4). Whereas coefficients of variation for root number in the parental lines are different (Table 5). The coefficient of variation in F2 plants regarding root length (Table 4) is larger than either of the parents, showing segregation for this character. This rules out the possibility of a simple Mendelian inheritance of this character unless the heritability is assumed to be exceptionally low. Both the distribution pattern and the variance characterize the polygenic inheritance for this character. The coefficient of variation for the F2 plants, regarding root number (Table 5), is larger than either of the parents indicating the same type of segrega-
tion as in the case of root length. It should be mentioned here that the coefficient of variation in regard to number of roots is rather high in case of 'Ashkata', which indicates that this is either due to the presence of residual heterozygosity for this character or due to the instability of the character itself.

Since root length of seedlings has shown quantitative nature of inheritance, further partitioning of the total genetic variance into fixable and non-fixable components would be very useful in obtaining further details about the gene action. In this experiment, from the nature of distribution it is very difficult to say to what extent this variation is due to the additive or interaction genetic variance. The pooled mean of the root lengths and the pooled mean of the number of roots in the case of F2 plants (Table 4 & 5) are close to the parental means (6.36 cm in case of root length and 3.01 in case of number of roots), which indicate absence of any dominance in regard to these characters. The F1 means (Table 1) also support the same conclusion. Thus the present observation indicates that these genotypic variations are predominantly additive in nature. More detailed data would be required to ascertain if some non-additive factors are also involved in the inheritance of such characters as clearly shown by Heinrichs and Morley (1960, 1962).

Further, the present observation, although determined at the seedling stage, confirms that the difference in growth rate shown by the two parental varieties is nevertheless genetically controlled. This consistent difference in growth rate, noted at a particular age of the seedling under strictly controlled conditions, may be considered to be due to the genetic control of the growth rates by the two distinct genotypes represented by these indica and javanica varieties of *Oryza sativa,*
Sinnott\textsuperscript{10} has attributed such differences in growth response to be due to differential meristematic activities.

**General Conclusions**

In rice breeding programme one of the main objectives is to find out a suitable strain, which can utilize effectively a heavy amount of manuring. Because both the stand of the crop and its yield have been found directly related to its capacity of increased utilization of fertilizers. The high yielding japonica varieties, which are also short culmed, non-lodging types, easily withstand the effect of heavy manuring. It has been claimed by Matsubayashi \textit{et al.} that one of the factors affecting the change in the absorption velocity of various nutrients such as nitrogen, potassium and phosphorus is directly associated with the characteristics and the distribution of the root system of the plants. Further, the amount of nitrogen as well as phosphorus absorption has been found to have close relation to the number of new roots which the individual plants are capable of producing. It may be inferred therefore that those varieties which are capable of producing more number of new roots would also be able to withstand heavy manuring and would be non-lodging types. ‘Baok’, a javanica variety used as one of the parents in the present experiment is a non lodging high yielding type and can stand heavy manuring. This variety when compared with ‘Ashkata’ the other indica parent produces significantly higher number of roots. Results obtained from the present experiment have shown that this character of the root system is heritable and its mode of inheritance is similar to other quantitative characters. The relative capacities for production of higher number of roots by different varieties under strictly identical cultural conditions may, therefore, be used as a suitable genetical index in screening different varieties or F\textsubscript{2} segregates for selection purposes. Similarly the relative efficiencies of individual plants in a large population of F\textsubscript{2} segregates in regard to their capacities for utilizing heavy amount of chemical fertilizers can also be determined. In this respect, culturing of embryos in culture medium under controlled conditions appears to offer promising scope to rice breeders.

**Summary**

Considerable variations in the number of roots and in their rate of growth in different varieties of paddy have been observed when dissected embryos were cultured. To ascertain whether these variations are heritable two varieties ‘Ashkata’ with long but fewer roots and ‘Baok’ with shorter and larger number of roots were used as parents. F\textsubscript{1} and F\textsubscript{2} populations from the above cross were analysed and the following inferences have been made:

1. The two varieties differed significantly in respect of both the maximum root length and the number of roots.
2. The coefficients of variation for the F\textsubscript{2} plants regarding the number of roots and the maximum root lengths were larger than either of the parents.

The variance observed characterize the polygenic inheritance for root length as well as number of roots. Further, the present observation, although determined at the seedling stage, confirms that the difference in growth rates shown by the two parental varieties is nevertheless genetically controlled. Embryo culture technique
has thus opened up a new scope to determine more easily than hitherto possible the mode of inheritance of various characteristics associated with the root systems, including relative capacities for utilizing heavy amount of chemical fertilizers by different varieties of paddy.

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References


P. N. Bhaduri and Malabika Ghosh: イネの根系の遺伝の研究における切除胚の培養の利用

イネの異なる変種において、根の数や成長速度の変異が切除胚を培養したときに見られた。この変異が遺伝するかどうかを確かめるために 2 変種、長い少ない根をもつ ‘Ashkata’ と短いが多数の根をもつ ‘Boak’ とが選ばれた。この交雑から得られた F1 と F2 の集団を分析し、つぎの結果を得た。
（1）2 変種は根の数や成長速度の変異が切除胚を培養したときに見られた。この変異が遺伝するかどうかを確かめるために 2 変種、長い少ない根をもつ ‘Ashkata’ と短いが多数の根をもつ ‘Boak’ とが選ばれた。この交雑から得られた F1 と F2 の集団を分析し、つぎの結果を得た。
（2）根の数と根の長さの両者について、F2 植物の変異係数はどちらの両親よりも大であった。

ここで得られた変異は根の長さおよび根の数に対してポリジェンによる遺伝であることを示している。
なおこの観察は芽生えの時期 (20 日後) になされたが、両親の変異による成長速度の差が遺伝的に支配されていることが明らかになった。胚培養の技術は、イネの変種の多くが、化学肥料を多量に利用する能力を失って、根系と関係あるいは形質の遺伝型をたやすくきめる新しい方法を開拓したものである。