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Genetic analysis of some root and shoot characters in rice under rainfed upland situation

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Abstract

Genetic analysis of root and two shoot characters under rainfed upland situation indicated that maximum root length in two crosses (Nilajee/Annada and Hasakumra/ Annada), tillers per plant in Nilajee/Annada and root weight per plant in Hasakumra/Annada were under the control of additive gene action. Root thickness, root volume, roots per plant in both the crosses and plant height in Nilajee/Annada were under the control of nonadditive gene action. Both additive and nonadditive gene actions were involved in the expression of root branching, root-to-shoot ratio and proportion of thick roots per plant in both the crosses; for root weight per plant in Nijajee/Annada and for tillers per plant and plant height in Hasakumra/Annada.

Key words : Rice, root characters, shoot characters, genetic analysis

Introduction

Rice varieties with deep and thick root system are highly desirable under rainfed upland situation where drought is a common production constraint. Earlier workers [1-3] have documented the role of deep and thick root system of rice in imparting drought tolerance. Although the entire north-east India including Assam is endowed with hundreds of traditional varieties adapted to the rainfed upland situation and several of them have been reported to be drought tolerant [4-5], the role of rice root system in imparting drought tolerance in those varieties have not been adequately researched. However, study made on root system of 63 varieties under rainfed upland situation identified Nilajee and Hasakumra along with few others as drought tolerant varieties possessing long and thick roots (Unpublished data). To explore the possibility of utilizing them as donor parents for deep and thick roots in the varietal development programme, it is essential to understand the nature and magnitude of gene action involved in the inheritance of these characters. The present investigation was conducted to understand the genetic architecture of important root and shoot characters in 2 crosses of rice under rainfed upland situation.

Materials and methods

The material comprised of parents (p_1 and p_2), F_1, F_2, B_1 and B_2 generations of 2 crosses, viz Nilajee/ Annada and Hasakumra/Annada. The parents, viz Nilajee and Hasakumra possess deep and thick root system, while Annada possesses shallow and thin root system. One part of seeds of the 11 entries (3 parents, 2 F_1, 2 F_2 progenies and 4 back crosses developed from the crosses Nilajee/Annada and Hasakumra/ Annada) were sown in dry, light textured granular soils of the rainfed upland field on 20- 03-96. The trial was laid out in randomized block design with 3 replications. The parents, F_1 and backcrosses were sown in 2 rows each, and each F_2 in 5 rows in a replication. The row length was 2m, and row-to-row and plant-to-plant distances were 45 and 40 cm, respectively.

Irrigation was provided to the soil immediately after sowing to ensure germination and to establish uniform plant stand. The rate and method of fertilizer application, intercultural operations and need based plant protection measures were adopted as per recommended package of practices. Five randomly sampled plants per entry per replication for the nonsegregating (parents and F_1s) and 10 randomly sampled plants per entry per replication for the segregating (F_2s, Bc_1s and Bc_2s) generations were dug up with their entire root systems at booting stage. The root systems were thoroughly washed in tap water to remove the soil particles and plant debris. Utmost care was taken during cleaning the root system so that not even a single root or rootlet was removed. Data for the different shoot and root characters viz tillers per plant, plant height (cm), maximum root length (cm), root thickness (mm), root volume (m^1), roots per plant, root weight per plant (g) and root-to-shoot ratio were recorded following standard procedures.

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Root branching was scored as follows :

Scale	Description
1	Very high branching (>80% of the roots highly branched)
2	Good branching (61 to 80% of the roots highly branched)
5	Medium branching (41 to 60% of the roots highly branched)
7	Low branching (21 to 40% of the roots branched)
9	Very low branching (<21% of the roots slightly branched)

Another root character i.e. proportion of thick roots per plant (PTR) was computed as :

$$PTR = \frac{\text{Total weight of thick roots}}{\text{Total root weight}} \times 100$$

where thick roots were defined as the root thickness $\geq$ 0.7 mm.

The analyses of variance for RCBD were carried out for all the 10 characters as per standard procedure [6] cross-wise. The A, B, C and D scaling tests [7-8] were applied prior to the use of six-parameter model [9-10] for the estimation of various genetic components.

Results and discussion

The analysis of variance (Table 1) showed that the six generations (P_1, P_2, F_1, F_2, Bc_1 and Bc_2) differed significantly for all the characters in both the crosses except for tillers per plant and root volume in the cross Nilajee/Annada and for root weight per plant in the cross Hasakumra/Annada. This could be due to lack of significant genetic differences among the progenies.

The scaling tests (Table 2) indicated presence of epistasis for all the characters in the cross Hasakumra/Annada and for all the characters except for tillers per plant and maximum root length in the cross Nilajee/Annada. Therefore, the six-parameter model was applied in all the cases except tillers per plant and maximum root length in the cross Nilajee/Annada to estimate the various gene effects in view of epistasis indicated by the individual scaling tests.

The results of generation mean analysis (Table 3) showed that additive (d) gene effects were important for tillers per plant, root branching, root weight per plant and root-to-shoot ratio in the cross Hasakumra/Annada. In contrast, Armenta *et al.* [11] reported both additive and nonadditive gene actions for root-to-shoot ratio.

Dominance gene effects were significant for root volume in the cross Nilajee/Annada, for roots per plant in Hasakumra/Annada and for root thickness in both the crosses indicating that these characters were governed by dominance gene action.

Both additive (d) and dominance (h) gene effects were important for root branching, root weight per plant and root-to-shoot ratio in the cross Nilajee/Annada, for plant height and maximum root length in the cross Hasakumra/Annada and for proportion of thick roots per plant in both the crosses. Similar gene action for root-to-shoot ratio in rice was reported by Armenta *et al.* [11]. The results further indicated that plant height and proportion of thick roots per plant in the cross Hasakumra/Annada were predominantly under the control of additive while root branching, root weight per plant, root-to-shoot ratio and proportion of thick roots per plant in the cross Nilajee/Annada and maximum root length in the cross Hasakumra/Annada were predominantly under the control of nonadditive gene action.

All the types of epistatic interactions, viz i (additive $\times$ additive), j (additive $\times$ dominance), and (dominance $\times$ dominance) were important for root-to-shoot ratio and proportion of thick roots per plant in the cross Nilajee/Annada and for tillers per plant and root volume in Hasakumra/Annada. Both (i) and (l) interactions were

Table 1. Analysis of variance for 10 traits in rice under rainfed upland situation

Source	df	Mean Squares									
		Tillers/ plant	Plant height	Maximum root length	Root thickness	Root volume	Root branching scores	Roots/ plant	Root weight/ plant	Root-to-shoot ratio	Proportion of thick roots/plant
					Nilajee/Annada						
Replications	2	2.270	379.21*	2.547	0.003	49.761	0.247	1412.482	0.559	0.003	111.670
Progenies	5	15.251	481.754**	22.074**	0.033**	52.514	6.996**	8647.739**	5.714*	0.042**	195.710**
Error	10	4.869	70.676	1.014	0.005	17.820	0.135	1103.652	1.655	0.001	13.752
					Hasakumra/Annada						
Replications	2	0.872	54.068*	4.561	0.030	11.754	0.116	871.552	0.400	0.002	7.382
Progenies	5	30.969*	98.477**	23.203*	0.085**	68.349*	6.456**	6533.212*	5.105	0.026**	242.304**
Error	10	6.183	10.296	6.732	0.008	17.148	0.169	1829.223	2.599	0.001	17.962

*, ** P = 0.05 and 0.01, respectively

Table 2. Scaling tests for 10 traits in rice under rainfed upland situation

Scale	Tillers/plant	Plant height	Maximum root length	Root thickness	Root volume	Root branching	Roots/plant	Root weight /plant	Root-to-shoot ratio	Proportion of thick roots/plant
					Nilajee/Annada					
A	2.80	−22.7*	0.02	−0.17	8.53*	−1.33*	53.07*	−1.01	−0.23*	−26.1*
B	−2.06	17.7*	−0.50	0.07*	13.72*	−0.40*	63.34*	0.94*	−0.09*	−10.7*
C	−2.46	6.21	−.88	−0.87*	−14.54*	7.60*	−46.01*	−11.15*	−1.03*	−52.6*
D	0.86	5.64	−0.70	−0.39*	−18.40*	4.67*	−81.21*	−5.55*	−0.35*	−7.9*
					Hasakumra/Annada					
A	−10.07*	−18.70*	−0.18	−0.57*	−21.87*	1.07*	−43.13	−3.21*	0.40*	−10.13*
B	−1.92	8.81*	−4.00*	−0.72*	−11.54*	2.93*	−65.8*	−0.83	−0.25*	10.93*
C	−1.07*	−9.21*	−10.34*	−0.44*	−18.45*	2.67	277.99*	−2.97	0.07	9.73
D	5.46*	0.34	−3.08	0.42*	7.48*	−0.67	193.46*	0.54	−0.04	4.47

*P = 0.05

Table 3. Estimates of gene effects for 10 traits in rice under rainfed upland situation

Cross	m	d	h	i	j	l	Type of epistasis
			Tillers/Plant				
Hasakumra/Annada	17.33**	−6.94**	−10.255	−10.92*	−4.075*	22.91**	D
			Plant height				
Nilajee/Annada	84.46**	−2.5	3.885	−11.28	−20.305**	16.35	C
Hasakumra/Annada	63.8**	−10.92**	10.815*	−0.68	−13.755**	10.57	C
			Maximum root length				
Hasakumra/Annada	25.20**	4.66**	10.01*	6.16	1.91	−1.98	D
			Root thickness				
Nilajee/Annada	0.792**	−0.072	0.981**	0.776**	−0.120	−0.681	D
Hasakumra/Annada	0.913**	0.142	−0.694**	−0.846**	0.078	2.136**	D
			Root volume				
Nilajee/Annada	23.067**	−1.73	41.127**	36.792**	−2.595	−59.042**	D
Hasakumra/Annada	25.47**	−2.00	−8.465	−14.96*	−5.165**	48.37**	D
			Root branching				
Nilajee/Annada	4.933**	−2.134**	−9.665**	−9.332**	−0.467	11.066**	D
Hasakumra/Annada	3.6**	−2.667**	0.933	1.334	−0.933*	−5.335*	D
			Roots/plant				
Nilajee/Annada	145.93**	−26.27	28.215	162.42*	−5.135	−278.83**	D
Hasakumra/Annada	254.43**	−27.00	−531.725**	−386.92**	11.325	495.85**	D
			Root weight/plant				
Nilajee/Annada	8.018**	−1.804**	11.881**	11.092**	−0.975	−11.030**	D
Hasakumra/Annada	9.187**	−2.589**	−0.909	−1.074	−1.194	5.114	D
			Root-to-shoot ratio				
Nilajee/Annada	0.312**	−0.127**	0.665**	0.710**	−0.070**	−0.388**	D
Hasakumra/Annada	0.601**	0.260**	0.065	0.075	0.323**	−0.224*	D
			Proportion of thick roots/plant				
Nilajee/Annada	38.4**	−13.5**	19.3**	15.8*	−7.7**	21.0*	C
Hasakumra/Annada	47.667**	20.333**	−10.067**	−8.934	−10.533**	8.134	D

*, ** P = 0.05 and 0.01, respectively; D = Duplicate; C = Complementary

important for roots per plant in both the crosses; for root volume, root branching and root weight per plant in cross Nilajee/Annada and for root thickness in Hasakumra/Annada. Additive × dominance interaction played a major role for plant height in both the crosses and for proportion of thick roots per plant in cross Hasakumra/Annada. Both (j) and (l) interactions were involved in the inheritance of root branching and root-to-shoot ratio in the cross Hasakumra/Annada. Duplicate epistasis was displayed by root thickness, root volume, root branching, roots per plant, root weight per plant and root-to-shoot ratio in both the crosses; by tillers per plant, maximum root length and proportion of thick roots per plant in cross Hasakumra/Annada. Complementary epistasis was exhibited by plant height in both the crosses and by proportion of thick roots per plant in cross Nilajee/Annada.

The three-parameter model was applied to all the cases where the scaling tests indicated absence of epistasis as well as in cross Hasakumra/Annada for maximum root length and root weight per plant as the six-parameter model failed to detect epistatic interactions. The mean values were significant (Table

Table 4. Estimates of m, d and h for characters showing absence of epistasis in rice

Cross	Character	Parameter		
		m	d	h
Nilajee/ Annada	Tillers per plant	18.42*	–3.43	–3.07
	Maximum root length	24.89**	3.18**	6.24
Hasakumra/ Annada	Maximum root length	19.7**	2.75**	11.99
	Root weight	10.92**	–1.395**	–6.023

*P = 0.05, **P = 0.01

4). All these characters were under the control of additive gene actions. These results are in agreement with those of Das *et al.* [12] for maximum root length.

Digenic interactions were significant for most of the characters in both the crosses, however, their magnitude varied depending on the character(s)/ parent(s) chosen. Epistasis was observed more frequently in the crosses where the parents had greater diversity [13]. Epistatic components are known to constitute a sizeable part of variation in the character which show higher estimates of dominance effects [14]. In the present study also, higher estimates of (h) for root thickness in both the crosses, for root volume in Nilajee/Annada and for roots per plant in Hasakumra/Annada were associated with significant epistatic interaction(s) in the respective crosses. However, in certain crosses, eg. Nilajee/Annada for root-to-shoot ratio and proportion of thick roots per plant all the types of gene effects (d, h, i, j and l) were significant.

In the present study, maximum root length in both the crosses, tillers per plant in Nilajee/Annada and root weight per plant in Hasakumra/Annada were under the control of additive gene action. Therefore, simple breeding procedures such as pedigree method could be advantageous for improvement of these traits in the respective crosses.

Nonadditive gene action was involved in the inheritance of root thickness root volume and roots per plant in both the crosses and of plant height in Nilajee/Annada. Therefore, the conventional breeding method which exploits only additive genetic variation may not be much help for the improvement of these traits in the respective crosses. Since gene expression varies from environment to environment, multi environmental approach is suggested for such studies. Further innvestigations on this aspect would be helpful to specify the genetic architecture of these traits in the respective crosses. Both additive and nonadditive gene actions were important for root branching, root-to-shoot ratio, proportion of thick roots per plant in both the crosses, for root weight per plant in Nilajee/Annada and for tillers per plant in Hasakumra/Annada. Also, digenic interactions were detected for all these characters in respective crosses. Therefore, to exploit both additive and dominance or additive, dominance and epistatic gene effects, reciprocal recurrent selection or biparental mating in F_2 or subsequent generation may be employed for the improvement of these characters in the respective crosses. Under such situation, selection of plants with desirable root and shoot attributes may be postponed to the advanced generations to permit epistatic gene action to get fixed.

References

1. **Chang T. T. and Vergara B. S.** 1975. Varietal diversity and morpho-agronomic characteristics of upland rice. *In*: Major Research in Upland Rice. International Rice Research Institute, Los Banos, Philippines pp 72-90.
2. **Yoshida S. and Hasegawa S.** 1982. The rice root system: Its development and function. *In*: Drought resistance in crops with emphasis on rice. International Rice Research Institute, Los Banos, Philippines pp 97-114.
3. **O' Toole J.C.** 1982. Adaptation of rice to drought prone environments. *In*: Drought resistance in crops with emphasis on rice. International Rice Research Institute, Los Banos, Philippines.
4. **Kalita U. C., Borkakati Reena and Barua D. K.** 1990. Evaluation of rice germplasm for drought tolerance in *Ahu*. *In*: Proceeding, International Symposium on Rice Research: New Frontiers. Directorate of Rice Research, Hyderabad pp 9-10.
5. **Seetharaman R., Sharma S. D. and Shastry S. V. S.** 1991. Germplasm conservation and use in India. *In*: Rice Breeding, International Rice Research Institute, Los Banos, Philippines pp 187-199.
6. **Panse V. G. and Sukhatme P. V.** 1967. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.
7. **Mather K.** 1949. Biometrical genetics. Dover Publication, New York.
8. **Hayman B. I. and Mather K.** 1955. The description of genetic interaction in continuous variation. Biometrics, **11** : 69-81.
9. **Hayman B. I.** 1958. The separation of epistatic from additive and dominance variation in generation means. Heredity, **12** : 371-390.
10. **Jinks J. L. and Jones R. M.** 1958. Estimation of the components of heterosis. Genetics, **43**: 223-234.
11. **Armenta Soto J. L., Chang, T. T., Loresto G. C. and O'Toole J. C.** 1983. Genetic analysis of root characteristics in rice (*Oryza sativa* L.) SABRAO J., **15**: 103-116.
12. **Das R. K., Miah M. M. and Loresto G. C.** 1991. Genetic variability in root and shoot characters of selected rice genotypes. Int. Rice Res. Newsl., **16** : 5.
13. **Gorsline G. W.** 1961. Phenotypic epistasis for ten quantitative characters in maize. Crop Sci., **1** : 55-58.
14. **Gambel E. E.** 1962. Gene effects in corn (*Zea mays* L.) 1. Separation and relative importance of gene effects for yield. Canad. J. Pl. Sci., **42**: 339-348.