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THE INHERITANCE OF SOME ROOT CHARACTERS ASSOCIATED WITH DROUGHT TOLERANCE IN RICE

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Abstract

The inheritance of some root characters as indicators for drought tolerance was studied in three rice crosses. These characters were, root length, root thickness, root dry weight and root-to-shoot ratio. Dominant alleles were found to be responsible for the inheritance of all root characters, with additive effects. High estimates of heritability in broad sense were observed for all traits, while, intermediate to low values of heritability in narrow sense were estimated. Root length was positively correlated with root thickness, root dry weight and root-to-shoot ratio. Root thickness was found to be closely related to both root weight and root-to-shoot ratio.

INTRODUCTION

Drought has been plaguing the agricultural world overcenturies and continues to be an important limiting factor to yields of crops. Drought or moisture stress is one of the factors that limit rice growth and yield and could range from milde to severe. Most cereals developed mechanisms for survival and adaptation to enable the crop to cope up with water deficits. Among the components of the avoidance mechanism of drought resistance, the root system is of major importance as it is associated with water and nutrient uptake. Therefore, it is generally agreed that the development of and maintencance of a large root system is among the essential factors for the increase in grain yield. The root systems of high yielding rice plants are characterized by large number, length and diameter of primary root axes with well developed lateral roots (Harada, 1995). Moreover, drought tolerance is associated with deep and thick roots, a dense root system and high root-to-shoot ratio (Chang *et al.*, 1974; Parao *et al.*, 1976; Yoshida and Hasegawa, 1982; Loresto *et al.*, 1983; Haque *et al.*, 1989 and Bashar *et al.*, 1992). Threfore, plant selection with desirable root characteristics have been a major objective in breeding drought resistant varieties of rice.

Several workers studied the genetic control of root characters and its importance to drought tolerance. Rooting depth, root thickness, root number, root

dry weight and root-to-shoot ratio were found to be under polygenic control and all except thick roots and high root-to-shoot ratio were controlled by dominant alleles with additive effects (Armento-Sato *et al.*, 1983; Mao, 1984 and Bashar *et al.* 1992). On the other hand, moderately high to high heritability estimates in broad sense were reported by Mao, (1984); Bashar *et al.* (1992) and El-Hissewy *et al.* (1994).

Keeping in view the importance of breeding for drought tolerance in rice, the present investigation aimed to study the genetic control of some root characters in three rice crosses including one of the well known drought tolerant variety, IET 1444 and two newly developed Egyptian rice varieties namely; Giza 175 and Giza 176.

MATERIALS AND METHODS

This investigation was carried out at the Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt to study the genetic control of root length, root thickness, root dry weight and root-to-shoot ratio in an effort to improve drought tolerance in rice varieties cultivated in Egypt.

The six populations (P1, P2, F1, F2, Bc1 and Bc2) of three rice crosses, namely (IET 1444 X Giza 176; IET 1444 x Giza 175 and Giza 176 x Giza 175) were planted in a randomized complete block design experiment with three replications in 1994 rice growing season. The replicate consisted of one row (2m long) of each parent, F1, Bc1 and Bc2 and two rows for the F2 of each cross. Thirty days old seedlings age were individually transplanted in 20 x 20 cm centers. Irrigation water was applied every 14 days. All agricultural practices such as weed control and fertilization were applied as recommended.

Data were collected at the maximum tillering stage (about 65 days from sowing). Levels of gene interaction were estimated by the scaling test following Mather (1949). Gene effects were determined determined according to Mather and Jinks (1971). Heritability in broad sense was computed following Allard (1960) and in narrow sense was estimated following the formula of Warner (1962). Correlation coefficients were worked out following Al-Jabouri *et al.* (1958).

RESULTS AND DISCUSSION

1- Comparison of means and scaling test

Means of parents of the crosses and the F1 generation means of the studied root characters are presented in Table 1. It is clear that, mean root length and root dry weight tended towards the long root and the heavy dry weight. Moreover, F1 means exceeded the high parents for cross 2 and cross 3 in case of root length and root dry weight of all crosses. On the other hand, F1 means were closer to the lower parent in case of root thickness and root-to-shoot. These findings indicate that dominant alleles are responsible for the inheritance of the root characters studied in the present investigation. Armento sato *et al.* (1983). Mao (1984), Bashar *et al.* (1992) and Loresto and Chang (1994) reported similar results.

Table 1 illustrates the scaling test parameters (A, B, C and D) estimated for the studied characters in the three crosses. Most of the computed parameters of scaling test were statistically insignificant. This in turn indicated the absence of non-allelic interaction and that the genetic control of these characters depends on simple gene action. However, the C parameter was significant for root length in cross 1 and cross 2, and the D parameter was significant for root thickness in cross 1 only. These results suggest that some allelic interactions such as additive X additive and/or additive X dominance may play a role in the inheritance of these characters in certain crosses which is contrary to the reports of Bashar *et al.* (1992) and Loresto and Chang (1993).

2. Genetic components and heritability estimates:

Estimates of dominance genetic variance "H" and the additive genetic variance "D" are illustrated in Table 2. These estiates indicate that the additive genetic variance is more important than the dominance genetic variance in all crosses for the studied characters. Moreover, the additive genetic variance was more than double the dominance genetic variance in cross 3 for root length, cross 1 and 2 for root thickness and cross 1 for root-to-shoot ratio characters. These findings support the conclusion that the additive type of gene action plays an important role in the genetic control of the studied root characters in the present investigation.

The estimates of heritability provide a measure of the effectiveness with which selection can be expected to exploit the genetic variability (Allard, 1960). Table 2 shows that relatively high estimates for heritability in broad sense were

Table 1. Means of parents, F1 generation and scaling test parameters for root characters of three rice crosses.

Parameter	Root length			Root thickness			Root dry weight			Root to-shoot ratio		
	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3
P	21.3±0.73	21.3±0.73	18.7±0.34	0.21±0.06	0.21±0.06	0.18±0.30	6.13±0.11	6.13±0.11	4.33±0.62	0.51±0.03	0.51±0.03	0.36±0.07
P1	20.2±0.66	22.2±0.13	19.1±0.68	0.17±0.06	0.18±0.03	0.16±0.02	6.36±0.21	6.36±0.21	4.53±0.56	0.29±0.06	0.39±0.06	0.25±0.08
P2	11.8±0.64	18.7±0.34	11.8±0.64	0.17±0.08	0.18±0.01	0.17±0.08	1.62±0.33	4.33±0.62	1.62±0.33	0.26±0.02	0.36±0.07	0.26±0.02
A	1.03	1.384	-1.335	0.011	0.032	-0.036	9.494	0.538	0.764	0.015	0.015	0.036
Scaling B	-1.061	0.676	1.722	0.771	0.081	0.051	1.223	1.066	-1.635	0.006	0.006	-0.051
C	2.113*	2.873*	1.874	0.036	0.626	0.087	0.372	-0.832	-1.258	0.002	-0.002	-0.023
Scaling D	-1.992	-1.569	-1.569	0.703*	0.512	0.432	-1.916	-1.916	-1.632	-0.021	0.033	0.039

* Significant at 0.05 level.

Table 2. Estimates of genetic components and heritability for root characters in three rice crosses.

Parameter	Root length			Root thickness			Root dry weight			Root to-shoot ratio		
	C1	C2	C3	C1	C2	C3	Cr1	Cr2	Cr3	C1	C2	C3
H	3.462	4.59	2.136	0.618	0.903	0.814	0.612	0.835	0.711	2.151	2.087	3.551
D	4.391	5.98	5.832	1.216	2.011	1.362	0.825	0.951	1.036	4.381	3.998	4.285
h2b	91.7	91.5	95.1	90.5	96.5	91.1	81.7	78.0	88.3	85.5	84.8	88.9
h2n	51.3	51.8	69.0	60.0	66.5	57.0	46.9	41.5	51.2	57.3	55.7	48.6

H = Dominance genetic variance D = Additive genetic variance h2d = Heritability in broad sense h2n= Heritability in narrow sense.

obtained for the four root characters in this study. These estimates ranged between 81.7% (in cross 1 for root dry weight) and 96.5% (in cross 2 for root thickness). On the other hand, moderate to low values of narrow sense heritability varying from 41.5% for root dry weight (in cross 20) to 69.6% for root length (in cross 3). These estimates are in line with those for different types of genetic variances which suggest that selection for such characters could be successfully practiced in later generations. Different results were obtained by several investigators, moderately high to high heritability estimates in broad sense and moderately low to high narrow-sense estimates for root dry weight and root-to-shoot ratio were found for root length and root thickness by Armento Sato *et al.* (1983), Mao (1984), Ekanayaka *et al.* (1985), Bashar *et al.* (1993) and El-Hissewy *et al.* (1994).

3. Association between root characteristics

The correlation coefficients in table 3 show that root length was positively correlated with all studied root characters. Root thickness was closely related to root dry weight and root-to-shoot ratio. Positive and highly significant correlation coefficients were also found between root dry weight and root-to-shoot ratio. Loresto *et al.* (1983) reported that among the root characters, root thickness is the most reliable and stable trait. Thick roots have a large and direct effect on drought resistance. Crop physiologists have also shown that traits associated with root thickness such as root dry weight and root-to-shoot ratio may be more important for drought avoidance than root thickness itself (Yambao *et al.*, 1992). Our results indicate characters studied, selection for any one of these character will successfully improve the other. Similar results were reported earlier by Ekanayake *et al.* (1985), Haque *et al.* (1989), Loresto and Chang (1993) and El-Hissewy *et al.* (1994).

Table 3. Simple correlation coefficient between root characters in three rice crosses.

Parameter	Root length			Root thickness			Root dry weight		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Root length	0.721**	0.803**	0.993**	0.732**	0.636**	0.683**	0.432*	0.365*	0.448*
Root thickness	-	-	-	0.681	0.549*	0.639**	0.311	0.421*	0.372*
Root dry weight	-	-	-	-	-	-	0.781**	0.887**	0.795**

*,** Significant and highly significant at 0.05 and 0.01 levels, respectively.

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وراثة صفات الجذر المرتبطه بتحمل الجفاف فى الأرز

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يتحتم على المربى دراسة وراثة مكونات التحمل للجفاف لكى يتمكن من التربية لأصناف تتحمل الجفاف فى الأرز والتى من أحد أدلتها القويه الجذر ومكوناته مثل طول الجذر ، سمكه، وزنه الجاف ونسبة المجموع الجذرى إلى المجموع الخضرى.

وقد أجريت هذه الدراسة على مكونات الجذر فى ثلاث هجن بين أصناف محليه ومستورده بإستخدام العشائر الستة اللازمه للتحليل الوراثى والتى تضمنت الآباء والجيل الأول والجيل الثانى والهجن الرجعيه لكلا الأبوين حيث زرعت هذه العشائر بالمزرعة البحثيه بمركز البحوث والتدريب فى الأرز بسخا عام ١٩٩٤ .

وقد أظهرت النتائج تحكم كل من آليلات الإضافة والسيادة فى وراثة جميع صفات الجذر . كما أن جميع الصفات أظهرت درجة توريث عالية بمعناها الواسع بينما كانت قيم درجة التوريث بالمعنى الضيق متوسطة إلى منخفضه مما يرجع إلى الإنتخاب لهذه الصفات فى الأجيال الإنعزاليه المتأخره. كما أظهرت دراسة العلاقات الإرتباطيه بين مكونات الجذر وجود علاقة معنوية موجبه بين كل من طول الجذر ، سمكه، وزنه الجاف وكذلك نسبة المجموع الجذرى إلى المجموع الخضرى كما وجد أن سمك الجذر يرتبط إرتباطا معنويا بالوزن الجاف ونسبة المجموع الجذرى إلى المجموع الخضرى، كما وجد أيضا إرتباط عالى المعنويه بين كل من الوزن الجاف للجذر ونسبة المجموع الجذرى إلى المجموع الخضرى.