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Full Length Research Paper

Genetic studies on leaf rolling and some root traits under drought conditions in rice (*Oryza sativa* L.)

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Crossing was made between three resistant and two susceptible parents to determine the genetic characteristics under drought conditions during 2002 and 2003 rice growing seasons. The resistant varieties were IET 1444, Moroberekan and Gaori, while the susceptible varieties were Sakha 101 and Sakha 102. Measurements on genetic variability, inbreeding depression, heritabillity, potence ratio, heterosis and genetic advance, were calculated for parents, F_1 and F_2 populations from the three studied crosses. The F_2 and F_3 lines derived from six crosses were grown in a RCBD experiment in three replications to study the genetic of leaf rolling. The total number of lines in F_2 segregated 3:1 (rolled : unrolled) and F_3 lines segregated in 1:2:1 (rolled : segregating : unrolled). The results showed that plants which showed more leaf rolling appeared to be less drought resistance. It was also found that the recovery ability was associated with drought resistance and leaf unrolling character. Measurements on genetic variability, heterosis, inbreeding depression, potence ratio, heritabillity and genetic advance under selection were calculated. Desirable significant heterosis was found for grain yield/plant, root length, root thickness and root:shoot ratio for all the studied crosses. Potence ratio indicated over dominance for all studied characters in the three crosses except for root thickness and root : shoot ratio in the cross II (IET1444 x Sakha 102), for grain yield/plant and root length in the cross III (Moroberekarn x Sakha 101). High heritabillity values were associated with high genetic advance for days to heading and plant height in all studied crosses, while there were no associations with high genetic advance in the other characters.

Key words: Drought, Moroberekan, Gaori, rice.

INTRODUCTION

Drought is a major constraint to rice production of rain fed and upland ecosystems. Developing improved drought-resistant lines has been a major breeding objective in rain fed rice improvement programs under such environment. Choosing parents for crossing is one of the most important steps in a breeding program. No selection methods can identify good cultivars if the parents used in the program are not suitable. Breeders have different approaches to parent choice and have achieved success in different ways.

Leaf rolling was the first visual symptom of drought reaction and occurs due to the inability of leaves to sustain the transpiration demand of the plant (Blum, 1988). Leaf rolling during stress reduces the leaf surface exposure to sun light energy and decrease transpiration leading to closure of stomata, so that gaseous exchange and CO_2 entry into cells are reduced and photosynthesis is decreased. Leaf rolling is the most important criteria found useful in assessing levels of drought tolerance in large scale screening (Chang et al., 1974).

Although progress can be made by selection for yield in the target environments, using root traits that are associated with drought tolerance can hasten that progress. Root development has long been recognized as an important factor in determining the adaptability of a given plant species to varying water conditions. Root characteristics that are responsible for the adaptability to drought stress are root length, root thickness, and root : shoot ratio (Passioura, 1982). The Selection for desirable root characteristics has been a major objective in breed-

Table 1. The 10 rice varieties under drought condition

Varieties	Origin	Plant type	*Drought score at vegetative stage
Moroberekan	Guinea	Tall	1
IET1444	India	Semidwarf	2
Gaori	Korea	Semidwarf	3
Giza 159	Egypt	Tall	4
Giza 178	Egypt	Semidwarf	4
Giza 171	Egypt	Tall	5
Giza 177	Egypt	Semidwarf	8
Sakha 101	Egypt	Semidwarf	8
Sakha 102	Egypt	Semidwarf	9
Sakha 104	Egypt	Semidwarf	4

*1-3, resistant; 4-5, intermediate; and 6-9, susceptible (De Datta et al., 1988).

Table 2. Some soil constants determined before each irrigation.

Soil depth(cm)	F.C.%	W.P.%	Bulk density g/cm^3
0-15 cm	45.68	24.70	1.12
15-70 cm	41.30	22.40	1.18
30-45 cm	38.75	20.28	1.23
45-60 cm	35.16	18.60	1.30
Mean	40.22	21.50	1.21

Where, F.C.% = field capacity, W.P.% = permanent wilting

ing for drought resistant varieties of rice plant (O'Tool et al., 1980). The deep roots of rice plant help to explore different levels of soil moisture and root thickness may be important in water uptake and translocation as resistance to water flow may be less in thick roots. In addition, thick roots are able to penetrate deeper soil layers (Bashar, 1987).

The varieties with high root : shoot ratios were more drought resistant (Yamauchi and Aragones, 1997). Results of the studies indicated that most drought resistant varieties remained tall during water stress while susceptible varieties were reduced in height. Plant height is positively significantly correlated with root length, root thickness and dried shoot weight (Mao, 1984).

This investigation aimed at studying the genetics of leaf rolling, some root and shoot characters and their relation with drought resistance characters.

MATERIALS AND METHODS

Rice varieties

The present investigation was carried out at the Farm of the Rice Research and Training Center, Sakha, Kafr El- Sheikh, during the 2002 and 2003 rice growing seasons. Ten introduced and local rice varieties were utilized in this study namely; IET 1444, Moroberekan, Gaori, Giza 159, Giza 171, Giza 177, Giza 178, Sakha 101, Sakha 102, and Sakha 104. Those varieties had a wide variation in vegetative, yield and its component characters (Table 1).

Seeds of all cultivars were grown in the nursery and after thirty days from sowing, seedlings of each parent were individually transplanted into the permanent field in ten rows. Each row was five meters long and contained 25 hills. Randomized complete block design was used with three replications. Weeds were chemically controlled by applying 2 liters of Saturn/feddan four days after transplanting. Nitrogen fertilizer was applied at 40 KgN/fed.

All these varieties were tested under drought conditions for two years for yield performance and other important characters that are related to drought resistance such as leaf rolling. Significant differences were detected among theses varieties for all studied characters, indicating that these varieties differs genetically and some of them could be used as a drought resistant parents .

Soil water relations

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to a depth of 60 cm. Soil samples were also collected just before each irrigation and 48 h after irrigation. Field capacity was determined in the field. Permanent wilting point and bulk density were determined according to Klute (1986) to a depth of 60 cm. The average values are presented in Table 2.

Six crosses were made involving three resistance varieties namely IET 1444, Moroberekan and Gaori crossed with each of two susceptible varieties, Sakha 101 and Sakha 102 for studying genetics of leaf rolling in F_2 and F_3 generations. Three other crosses

Table 3. Scores and symptoms for leaf rolling and drought resistance at vegetative stage. Modified from Loresto and Chang (1981); IRRI (1988) and De-Datta et al. (1988).

Scores	Reaction	Leaf rolling	Leaf firing
0	Highly resistant	No symptoms of stress	No symptoms
1	Resistant	No rolling	Slight leaf tip drying
3	Moderately resistant	Partially rolled, unrolled in evening	Leaf tip drying extended to ¼ in top three leaves
5	Intermediate	Partially; unrolling at late evening and early morning.	Half of yanger leaf blades dried, all lower leaf dried.
7	Susceptible	Complete, unrolling in morning	¾ of yanger leaf blade dried.
9	Highly susceptible	Like tube; no unrolling in morning	All leaves dried

involved some of the previous varieties were used to study the genetics of yield and some root characters under drought conditions.

In 2002 season, P_1, P_2, F_1 and F_2 plants were grown in a randomized complete block design with three replications. Each replicate consisted of two rows for each of P_1, P_2, F_1 populations and ten rows for each F_2 population. Additionally, 25 F_3 lines were randomly selected in each three replications, making a total of 75 F_3 lines (1875 plants) for testing. The rows were five meters long with 20 cm between rows and comprised 25 hills each of a single plant. Weeds were chemically controlled by applying 2 liters Saturn/feddan, four days after transplanting. Nitrogen fertilizer was applied at 40 Kg N/fed. Flush irrigation was used every 10 days in the afternoon and this was observed as sufficient to distinguish the differences in lines and segregating generations for their recovery ability.

Data were recorded on 30 plants at random in each parent and F_1 cross and on 200 plants in each F_2 cross for all characters studied. With respect to root characters, a large iron cylinder up to 20 cm in diameters and 60 cm in length were used. They were driven into the soil with a hammer and dug out with spade or pulled out by means of a hook and the soil was separated from the roots by washing. This can be done directly in the field but generally the soil samples are transported to a special washing facility. After taking the quantitative data, the shoot was separated from the root using sharp knife and dried in an oven at 70°C for five days.

Root length (cm) [the length of the root from the base of the plant to the tip of the longest root], root thickness [the average diameter (mm) of the tip portion (about 1cm from the tip) of three random secondary roots at the middle position of the root/plant], and root : shoot ratio [ratio of the root dry weight (g) to the shoot dry weight (g)] at maximum tillering stage was measured. Days to heading was recorded after flowering and at maturity; grain yield /plant was recorded by collecting the filled grains from all the tillers in a single plant and their weight recorded.

In 2003, the experimental materials consisting of the parents, F_1, F_2 and F_3 generations of six crosses were sown and thirty days old seedlings were transplanted in a randomized complete block design with three replications. Leaf rolling observation was recorded at different hours of day from early morning to late evening, during the vegetative stage, starting from transplanting date (30 days after sowing) to panicle initiation stage (70 days after sowing), after each irrigation period (every 10 days). Leaf rolling was estimated by a visual estimation and the susceptible varieties and lines first to start the rolling symptoms in the morning, and the highly susceptible lines did not unroll at early morning hours. Rolling in other parents or lines started at around 8 a.m. as the transpiration demand increased; and in some lines or varieties unrolling started around 1700 h, while in others at 1800 h or later. Unrolled plants were tagged for further observation. Leaf rolling was recorded based on methods earlier proposed (Loresto and Chang, 1981; IRRI, 1988; De Datta et al., 1988) (Table 3).

Genetical parameters

The genetical parameters in the present study were computed as follows:

1) Heterosis relative to mid parent (%) = F_1-MP / MP x 100.
2) Inbreeding depression (I.D.) % = F_1-F_2 /F_1 x100.
3) Potence ratio = F_1-MP/ HP-MP.

Where F_1, F_2, MP, and HP are the means of the F_1, F_2 generations, mid parent, and the higher parent, respectively.

4) Heritability in broad sense (h^2) = δ^2 G/ δ^2 ph x 100.
Where δ^2 G and δ^2 ph are the genotypic and phenotypic variances of F_2 population, respectively (Gamble, 1962).

5) Genetic advance under selection (GS) = h^2 x K x $\sqrt{\delta^2}$ ph

Where K is the selection differential and equal 2.06 for 5% selection intensity (Lush, 1949; Johanson et al., 1955).

RESULTS AND DISCUSSION

The frequency distribution (not given here), proved that all characters studied were quantitatively inherited. Means, standard error and variances of six studied traits i.e. days to heading, plant height, grain yield/plant, root length, root thickness and root : shoot ratio for P_1, P_2, $F_1$and F_2 populations are presented in Table 5. The t- test and F-test showed significant differences between parents and for genetic variances among F_2 plants, for the three studied crosses; IET1444 x Sakha 101, IET1444 x Sakha 102 and Moroberekan x Sakha 101.

Genetic variability parameters

Cross I (IET1444 x Sakha 101): Highly significant and positive heterotic effects were found for all the studied traits (Table 6). Comparing mean values, the F_1 values

Table 4. Recovery score after irrigation (first day after irrigation).

Scores	Reaction	Description of symptoms individual plant/line		
		Leaf colour	Leaf rolling	Leaf tip drying
1	Resistant	All dark green	Unrolled	Slight
3	Moderately resistant	All green	Partially rolled	¼ leaf tip drying
5	Intermediate	Greenish, lower leaves dried	Partially rolled	½ leaf blade dried
7	Susceptible	Top central leaves greenish, lower leaves yellowish	Rolled	¾ leaf drying
9	Highly susceptible	Yellowish	Tightly rolled	Near complete leaf drying

were higher than both mid-parent and higher parent for all these studied traits (Table 5), indicating the presence of over dominance of the higher parent for these traits which were verified by the computed positive values of potence ratio 2.92, 2.43, 6.34,1.97, 1.43 and 1.69 for all traits, respectively (Table 6). Similar results were obtained by Souframanien et al. (1998).

Significant positive values of inbreeding depression were obtained for root length, root thickness and root: shoot ratio (Table 6). Comparing mean values of these traits (Table 5), the F_2 values were less than those of F_1. Significant effects for both heterosis and inbreeding depression were associated for these traits (Table 6). This is logical and acceptable since the expression of heterosis in F_1 will be followed by considerable reduction in F_2 performance.

High heritability values (Table 6) were estimated for days to heading, plant height, and root : shoot ratio. Moderately high values for grain yield and root thickness, and low values for root length were obtained. Johanson et al. (1955) reported that heritability estimates along with the genetic gain were more valuable than the former alone in predicting the effect of selection.

If heritability was mainly owing to non-additive gene effect, the expected gain would be low; if there was an additive gene effect, a high genetic advance might be expected (Panse, 1957). Dixit et al. (1970), reported that high heritability were not always associated with high genetic advance for characters. But to make effective selection, high heritability should be associated with high genetic advance.

From the foregoing, individual plant selection in early segregating generations for days to heading and plant height should be effective and satisfactory for successful breeding purpose. The selection would be effective in advanced generations for grain yield, root length, root thickness and root : shoot ratio.

Cross II (IET 1444 x Sakha 102): Highly significant and positive heterotic effects were obtained for all the studied traits (Table 6). Comparing mean values, the F_1 values exceeded the higher parent for days to heading, plant height, grain yield and root length (Table 5). These findings indicated the existence of over dominance and were verified again by the respective values of potence ratio which were exceeding unity. The F_1 values for the two traits; root thickness and root : shoot ratio were between both mid-parent and higher parent values, indicating that the presence of partial dominance which were verified by the computed values of potence ratio which were less than unity, 0.13 and 0.26 (Table 6).

Regarding the effect of inbreeding depression, significant positive values were obtained for plant height, root length, root thickness and root : shoot ratio. Examining the mean values of these traits, the F_2 values were less than these of F_1. Significant effects for both heterosis and inbreeding depression were associated for these four traits (Table, 6). This is also logical since the expression of heterosis in F_1 will be followed by considerable reduction in F_2 performance.

With respect to heritability, high heritability values were observed for days to heading, plant height, root length, root thickness and root : shoot ratio. The values were 90.0, 79.0, 70.0, 80.0 and 75.0. Moderate value was estimated for grain yield, (59.0). High heritability values for heading date, plant height and grain yield/plant have been detected previously (Ganesan and Subramanian, 1994). High genetic gain was associated with high heretability values in days to heading and plant height, indicating that the selection would be effective in early generations for these traits.

Cross III (Moroberekarn x Sakha 101): Significant and highly significant and positive heterotic effects were detected for plant height, grain yield/plant, root length and root : shoot ratio (Table 6). The highest percentage of heterosis as deviation from mid-parent was found at root : shoot ratio (54.76%) followed by plant height (20.49%). Comparing mean values in Table 5, it was found that the F_1 performance exceeded the higher parent for the two traits (Table 5).

These findings indicated that the existence of over dominance and was ascertained again by the respective values of potence ratio which were exceeding unity. The percentages of heterosis as deviation from mid-parent were not significant for days to heading and root thickness and the F_1 values were between both mid-parent and higher parent for days to heading, indicating the

Table 5. Means, standard errors and variances of P_1, P_2, F_1 and F_2 populations of the studied characters for the studied rice crosses.

Cross/trait	P_1(IET 1444)	P_2 (Sakha 101)	F_1	F_2
IET 1444XSakha 101				
Days to heading (day) $\bar{X}$	100.0±1.78	95.0±1.12	105.40±1.08	114.0±0.98
σ^2	15.3	10.42	11.63	46.52
Plant height(cm) $\bar{X}$	75.0±2.0	68.0±1.56	80.0±1.49	95.0±1.22
σ^2	18.00	11.75	13.40	107.20
Grain yield/plant(g) $\bar{X}$	18.0±1.35	15.0±1.48	26.02±1.22	28.0±0.89
σ^2	31.0	21.30	28.84	144.20
Root length(cm) $\bar{X}$	33.0±083	21.0±0.72	38.82±0.69	34.0±0.44
σ^2	7.80	5.90	5.51	33.02
Root thickness(mm) $\bar{X}$	1.10±0.05	0.65±0.02	1.20±0.0145	1.12±0.012
σ^2	0.0023	0.0018	0.00124	0.009
Root :shoot ratio $\bar{X}$	0.58±0.012	0.32±0.014	0.67±0.0138	0.61±0.010
σ^2	0.0012	0.0017	0.00148	0.0104
IET 1444XSakha 102				
Days to heading (day) $\bar{X}$	99.0±0.91	100.0±0.99	106.7±1.32	105.0±0.77
σ^2	25.20	20.00	25.08	66.00
Plant height(cm) $\bar{X}$	57.0±0.75	81.0±0.87	90.0±0.85	85.0±0.65
σ^2	19.00	10.00	18.00	120.00
Grain yield/plant(g) $\bar{X}$	18.0±0.79	13.40±0.10	22.43±0.96	22.0±0.91
σ^2	48.00	62.00	55.00	220.00
Root length(cm) $\bar{X}$	33.0±0.58	18.0±0.96	36.95±0.63	33.50±0.82
σ^2	3.18	5.70	5.25	36.80
Root thickness(mm) $\bar{X}$	1.10±0.0068	0.53±0.008	0.85±0.0081	0.82±0.005
σ^2	0.00072	0.00088	0.00086	0.0078
Root :shoot ratio $\bar{X}$	0.58±0.019	0.28±0.020	0.47±0.022	0.44±0.019
σ^2	0.0036	0.0050	0.0048	0.028
MoroberkanXSakha 101				
Days to heading (day) $\bar{X}$	92.0±1.63	95.0±1.43	94.0±1.52	105.0±1.85
σ^2	9.50	11.50	10.85	65.20
Plant height(cm) $\bar{X}$	85.0±0.97	68.0±0.82	92.8±0.98	95.0±0.85
σ^2	22.00	16.00	18.00	117.00
Grain yield/plant(g) $\bar{X}$	20.0±1.75	15.0±1.85	17.90±1.71	22.0±1.10
σ^2	76.0	66.0	61.0	211.0
Root length(cm) $\bar{X}$	35.0±0.90	21.0±0.80	29.0±0.89	26.0±0.58
σ^2	19.00	12.40	14.30	83.50
Root thickness(mm) $\bar{X}$	98.0±0.05	65.0±0.11	99.80±0.07	98.0±0.13
σ^2	0.12	0.11	0.10	0.22
Root :shoot ratio $\bar{X}$	0.53±0.016	0.32±0.018	0.65±0.014	0.58±0.023
σ^2	0.15	0.19	0.14	0.25

presence of partial dominance for this trait, where the value of potence ratio was less than unity.

For the effect of inbreeding depression, significant negative values were obtained for heading date, plant height and grain yield/plant (Table 6). This could be a consequence of the F_2 values which were higher than those of F_1 with comparing mean values of these traits (Table 5). Significant positive inbreeding depressions were found for root length, and root : shoot ratio, because of F_2 values were less than those of the F_1. Significant effects for both heterosis and inbreeding depression were associated for root : shoot ratio (Table 6). Again, this is logical and expected, since the expression of heterosis in F_1 will be followed by considerable reduction in F_2 perfor-

Table 6. Heterosis, inbreeding depression, potence ratio, heritability in broad sense and genetic advance for the characters studied in the rice crosses IET 1444 x Sakha 101, IET 1444 x Sakha 102 and Moroberekan x Sakha 101.

Cross/trait	Heterosis %	Inbreeding depression %	Potence ratio	Heritabiliy %	Δ G
IET 1444XSakha 101					
Days to heading(day)	8.43**	-8.15**	2.92	75.0	10.53
Plant height(cm)	11.93**	-18.70**	2.43	84.0	17.89
Grain yield/plant(g)	57.69**	-7.60**	6.34	65.0	16.06
Root length(cm)	43.77**	12.41**	1.97	47.0	5.56
Root thickness(mm)	37.93**	6.66**	1.43	69.0	0.13
Root :shoot ratio	48.88**	8.95**	1.69	82.0	0.16
IET 1444XSakha 102					
Days to heading (day)	7.23**	1.59	14.40	90.00	15.06
Plant height(cm)	15.38**	5.55**	4.00	79.00	17.82
Grain yield/plant (g)	42.67**	-11.45**	2.90	59.00	18.02
Root length(cm)	44.90**	9.33**	1.52	70.00	8.74
Root thickness (mm)	4.93**	3.52*	0.13	80.00	0.14
Root :shoot ratio	9.30**	6.38**	0.26	75.00	0.25
MoroberekanXSakha101					
Days to heading (day)	2.17	-11.70**	0.66	76.0	12.64
Plant height (cm)	20.49**	-3.05*	1.84	85.0	18.93
Grain yield/plant (g)	2.28*	-22.90**	0.16	62.0	18.55
Root length(cm)	3.59*	10.34**	0.14	50.0	9.41
Root thickness (mm)	0.22	1.80	1.10	57.0	0.55
Root :shoot ratio	54.76**	10.76**	2.09	77.0	0.79

** and* :High significant and significant: at 0.01 and 0.05 significant respectively, Δ G=genetic advance.

mance.

Heritability estimates were high for days to heading (76.0%), plant height (85.0%) and root: shoot ratio (77.0%); moderate high for grain yield/plant (62.0%) and root thickness (57.0%); while it was low for root length (50.0%). It is very interesting to note that characters having high heritability values gave high values of genetic advance, indicating that there was additive gene effect and this is very important to make effective selection (Ganesan and Subramanain, 1994). This is was very clear in the three characters; days to heading, plant height and grain yield/plant.

It could be indicated that, for most traits, the expression of heterosis in F_1 might be followed by a considerable inbreeding depression in F_2 performance, indicating that the non-additive gene effects governed the inheritance of such traits. This is consistent, since there is a tendency towards homozygosity which is accelerated by 50 percent for each selfed gene ratio. In other cases, the significant heetrosis in F_1 was associated by insignificant inbreeding depression in F_2. This contradiction might be due to the effect of linkage on F_2 performance (Ram, 1994). Other contradiction was the insignificant heterosis in F_1 associated with significant inbreeding depression in F_2. This might be due to the lower magnitude of the non-additive type of gene action.

Genetics of leaf rolling

For leaf rolling (L.R), the susceptible varieties and crosses started showing the rolling symptoms 7 days after irrigation in the morning and evening. While, the resistant varieties did not roll at early morning hours, but rolling starts at around 1 p.m. as the plant transpiration demand increased after 10 days from irrigation. These results were recorded based on the methods earlier proposed (Loresto and Chang, 1981; IRRI, 1988; De Datta et al., 1988) (Table 3).

The data for recovery was recorded based on present plant recovery in lines after irrigation by six hours according to scale for recovery as proposed by Loresto and Chang (1981) to differentiate plants or lines in segregating and non-segregating generations.

Many of the tolerant plants in segregating generations did not roll and leaves remained to meet the transpiration demand of the plant. Similar results were reported by O'Toole and Maguling (1981). The segregation for this

Table 7. Reaction of F_2 population and F_3 lines for leaf rolling and unrolling of different rice crosses.

Parents/Cross	F_2 Population		X^2 (df=1)	F_3 lines		
	Rolled	Unrolled		Rolled	Segregating	Unrolled
IET 1444Xsakha 102	658	186	1.98	17	26	16
IET 1444Xsakha 101	775	305	3.02	18	29	17
MoroberekanXSakha 102	646	190	1.15	16	34	19
MoroberekanXSakha 101	654	268	4.19	17	32	14
GaoriXSakha 102	605	157	3.83	13	36	19
GaoriXSakha 101	693	279	2.47	17	32	16

$X^2 = 0.48$

Table 8. Recovery ability of non segregating rolled and unrolled F_3 lines.

Cross	Total lines	Rolled					Total lines	Unrolled				
		Recovery Scores						Recovery Scores				
		1	3	5	7	9		1	3	5	7	9
IET 1444XSakha 102	17	3	1	6	7	0	16	13	3	0	0	0
IET 1444XSakha 101	18	2	5	2	5	4	17	13	4	0	0	0
MoroberekanXSakha 102	16	1	6	0	4	5	19	11	5	3	0	0
MoroberekanXSakha 101	17	4	0	2	8	3	14	10	3	1	0	0
GaoriX Sakha 102	13	0	0	2	5	6	19	15	4	0	0	0
GaoriX Sakha 101	17	2	3	2	5	5	16	14	2	0	0	0
Total	98	12	15	14	34	23	101	76	21	4	0	0
%		12.2	15.3	14.3	34.7	23.5		75.2	20.7	3.9		

trait in all crosses studied at F_2 generation which is shown in Table 7 was found to fit a ratio of 3 rolled to 1 unrolled implying therefore that segregation is at one locus only. Also, the segregation of F_3 generation was detected to fit a ratio of 1 rolled : 2 segregated : 1 unrolled which would ascertained that segregation is at one locus only. The X^2 values for this trait were 0.44, 1.98, 3.02, 1.15, 4.19, 3.83 and 2.47 for the six crosses studied which was lower than the tabular X^2 value with 1d.f.

Relationship of leaf rolling and drought tolerance character was found for the parents or lines which have no leaf rolling and had score of 0 to 3 for drought tolerance. Plants showing leaf rolling at early stage of stress appears to have poor drought tolerance. Leaf rolling also reduces the photosynthetic surface and light absorption area and thus leads to reduce assimilate levels. Varieties like Moroberekan and IET 1444 which starts rolling after 8 days from irrigation and unrolled with morning and evening had score from 1-2 for drought tolerance (Table 2). The rice variety, Gaori had still the score of 3 for drought tolerance and did not roll at morning or evening during the first week after irrigation. Giza 178 and Sakha 104 started rolling at midday till evening during late stage of stress (from 7-10 day) had score of 5 for drought tolerance. While the other varieties; Giza 159, Giza 171, Sakha101 started rolling within a week after irrigation at midday and evening and had score of 7 for drought tolerance. Sakha 102 rolled at the initiation of drought and had susceptible score for drought (7 or 9). These suggest a close relationship between leaf rolling and drought tolerance (Table 2).

Recovery scores for non segregating rolled and unrolled lines were recorded in Table 8. Scoring system for recovery (Table 4) has been developed for breeding lines, using percent plant recovery, 10 days after irrigation (IRRI, 1988). Recovery scores were higher for all the breeding lines and segregating population in the first days after irrigation. The results revealed that tagged plants which were unrolled, had a high recovery scores as compared to rolled plant, during observation of individual plant or lines. These observations were recorded based on a new scale developed earlier (Table 4). Loresto et al. (1976) and Murty and Ramakrishnayya (1982) have reported the marked differences in drought recovery 12-20 h after irrigation.

It was observed that recovery ability is associated with drought resistance and leaf unrolling. About 72% of rolled F_3 lines had poor recovery scores (5-9). However, around 28% of rolled F_3 lines had high recovery scores of (1-3). While, 96% of unrolled F_3 lines had high recovery ability

Table 9. Transegressive segregation (T.S.) of drought resistance in F_2 and F_3 generations of different rice crosses.

Cross	T.S. in F_2 Population		T.S. in F_3 lines	
	No. of lines	% of F_2 lines	No. of lines	% of F_3 lines
IET 1444 x Sakha 102	111.00	13.15	8.00	16.00
IET 1444 x Sakha 101	151.00	11.78	25.00	20.00
Moroberekan x Sakha 102	120.00	11.00	31.00	17.70
Moroberekan x Sakha 101	135.00	9.50	38.00	10.80
Gaori x Sakha 102	100.00	9.40	7.00	14.00
Gaori x Sakha 101	120.00	9.80	19.00	19.00

(1-3), and around 4% of unrolled F_3 lines had poor recovery scores (5-9).

Blum (1988) reported that leaf rolling as drought symptoms occurs because of the inability of leaves to sustain the transpiration demand of the plant. From the present findings the resistant parents showed leaf rolling symptoms at later periods of stress. The lines that rolled earlier had early symptoms of drying of leaves, flowed by drying of upper leaves. Transgressive segregation in the crosses involving the resistant varieties were recorded based on leaf rolling observation. The transgressive segregants (Table 9) for drought resistance were detected in all crosses studied which varied from 9.4 to 13.15% in the F_2 generation and from 10.8 to 20.0% in the F_3 generation. These results would indicate that these superior lines had better leaf rolling and consequently better drought resistance than their corresponding resistant parents and that could be due to drought resistance.

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