SCREENING FOR DROUGHT TOLERANCE IN RICE (*ORYZA SATIVA* L.) AT BOTH THE VEGETATIVE AND REPRODUCTIVE STAGES OF GROWTH

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ABSTRACT

One hundred advanced rice breeding lines were screened for drought tolerance at both the vegetative and reproductive stages of growth at Umudike (Abia State, Nigeria) and Abakaliki (Ebonyi State, Nigeria) in 2000, while in 2001, 91 and 77 rice breeding lines were screened at Umudike and Abakalili respectively. Drought tolerance at the reproductive stage was measured as percentage spikelet fertility. At the seedling stage, drought tolerance and recovery from drought stress were taken at Abakaliki while at Umudike, drought tolerance and rate of leaf senescence were taken. Rice plants were planted in polythene bags for root length and weight characteristics. Results of the experiments in Umudike show that 32% of the rice lines had resistant/tolerant drought scores while 68% recorded susceptible drought scores, out of which 29% were highly susceptible. At the seedling stage, only 17% were resistant/tolerant while about 83% were susceptible. A Abakaliki, 95% of the rice lines were resistant/tolerant at the reproductive stage while 45% were resistant/tolerant at the seedling stage. 36% showed signs of recovery from drought stress after water supply was restored. Rate of leaf senescence did not show any clearly defined trend in relation to drought score. In 2001, 72.7% of the rice lines were resistant/tolerant at reproductive stage while 26.3% of the viable rice lines were resistant/tolerant at the seedling stage. There does not seem to be any relationship between drought score and root length and weight. The most resistant/tolerant rice lines in both locations in the two years were TOX 3445-14-2-3 and SIK 289-54-2-2-2-2-1 with a score of between 1 and 3 at both the vegetative and reproductive stages.

KEY WORDS: Rice breeding lines, drought tolerance, percentage spikelet fertility, drought recovery and rate of leaf senescence.

INTRODUCTION

Rice, the principal staple food for millions of people in most Asian countries, parts of Africa and Latin America, feeds most people in the world than any other crop (Andriesse, 1986). Feeding the world's growing population therefore will depend heavily on increased rice production. Althou,gh Africa produces less than 3% of the world total, the potential for the expansion of rice cultivation is great, particularly in the inland valleys and basins (Andriesse, 1986).

Nigeria is the greatest rice producing country in the West-African sub-region. However, this notwithstanding, the demand for rice in the country is increasingly higher than its production due to taste, urbanization and rapid population growth. According to the International Rice Research Institute report (IRRI, 1981), rice is progressively replacing other cereals and traditional food crops in West Africa because of increased urbanization and ease of cooking and storage. Most African countries are also resorting to importation because of high demand and inadequate local production.

The humid rainforest belt of South Eastern Nigeria has a bimodal rainfall distribution pattern. Drought is possible in the zone at the beginning of the rainy season around May-June, mid way into the rainy season around July/August (the August break) and towards the end of the rains from mid-October. The possibility of drought occurrence is even higher at the northern part of the humid rainforest zone, the derived savannah (Okocha, 1999).

Furthermore, the rainfall distribution pattern has become more erratic in these days of world climatic changes, and the risk of drought occurrence has become even higher (Okocha, 1999). Drought is one of the most important constraints to rice production in many rice-producing areas of the world (Herdt, 1991). It is a major constraint to rice production in the resource-limited rainfed ecosystems in West Africa (Tobita, 2001).

The drought resistance of rice is a total expression of its ability to stay alive, grow and ultimately produce grain under moisture stress for at least part of its life cycle (IRRI, 1975), and it is a product of the soil-plant-atmosphere continuum (Maurya and O'Toole, 1986). The rice plant resists drought by either avoiding or tolerating it. Drought avoidance (or escape) is the plants' ability to absorb sufficient water, or to suppress its loss of water early enough to prevent moisture stress in the cells or tissues. Drought tolerance or desiccation tolerance is the ability of the cells to survive and metabolically function even when the tissues are desiccated (Levitt, 1963).

Drought is a common limiting factor for crop production in rainfed fields of the following cultural types- upland, lowland (hydromorphic), fringes of inland valleys and deep water and sometimes in irrigated areas when water supplies are short (O'Toole and Chang, 1979). Severe drought at any growth stage affects grain production because plant growth is a continuous process. Water deficits during the reproductive stage inflict the most severe damage to grain yield (O'Toole and Chang, 1976).

With global shortages of water now emerging, reducing water consumption in crop production has been generally recognized as an essential strategy for sustainable agriculture (Boyerh, 1992, Zhang and Luo, 1999). It has also been gradually recognized as an important strategy for rice production, even for areas where water supplies are currently abundant. In addition, reduced levels of irrigation will decrease levels of water contamination and energy consumption, thus producing a significant positive impact for our environmental conservation efforts (Zhang and Luo, 1999). Successful expansion of rice cultivation depends not only on cultural practices and management but also on the suitability of rice varieties which must be drawn from existing germplasm or developed by combining desired characters from various germplasm sources (Ng et al, 1991) Therefore, development of rice varieties with resistance/tolerance to constantly fluctuating water regimes is required in order to enhance increased rice production.

The objective of the present research effort is to identify and select rice breeding lines with good resistance/tolerance to drought at the seedling as well as flowering/grain filling stages of development for possible development of drought tolerant rice varieties and/or incorporation into hybridization programme

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MATERIALS AND METHODS

The research materials comprised advanced rice breeding lines from the West Africa Rice Development Association's lowland rice breeder which were studied at both the vegetative and reproductive stages for drought tolerance at both Umudike and Abakaliki in 2000 and 2001.

Screening for drought at the reproductive stages:

One hundred (100) rice breeding lines were planted between 19th and 21st July 2000 at both Umudike and Abakaliki such that flowering and grain filling stages would coincide with the beginning of the dry season.

In Umudike, the experiment was sited at the Michael Okpara University of Agriculture research farm (05° 29' N, 07° 33' E, 122 M above sea level).

In Abakaliki, the experiment was located at the Ebonyi State agricultural development programme experimental field (06° 04' N, 08° 05' E, 104.4 M above sea level).

The rice lines were laid out in a randomized complete block design (RCBD) in three (3) replications. The plot size was 2 x 2m with a spacing of 20 x 20cm. In both years, 5-6 rice seeds were direct seeded into one hole. Fertilizer was applied at the rate of 80kg N/ha, 30kg P_2O_5/ha and 30kg K_2O/ha (WARDA, 1995) in two split applications (a basal application of 60kg N/ha, 30kg P_2O_5/ha and 30kg K_2O/ha, two weeks after germination, using NPK 20:10:10 and top dressed with urea at the rate of 20kg N/ha at the booting stage). A sampling size of five plants per plot was taken at random for data collection on plant height while yield data were assessed per square meter.

Drought score at the reproductive stage (spikelet fertility) was assessed at maturity according to standard evaluation system (SES) for rice (IRRI, 1988) with scale ranging from 1 to 9; where I means that more than 80% of spikelets are fertile, 3-between 61-80%). 5-between 41 and 60%; 7-between 11-40% and 9-less than 11% of spikelet are fertile.

Screening for drought at the seeding stage:

The rice lines were drilled into furrows, 50cm long and replicated twice. The experiments were set up in the last week of September, 2000 at both Umudike and Abakaliki, such that the rice lines would use the last rains in October for crop establishment. After the rains, supplementary irrigation was given, using hand watering can. Irrigation was given every other day during the morning hours to saturate the top soil. Irrigation was stopped on 30th November, 2000. drought score was taken on 19th December 2000.

In Abakaliki, irrigation was restored to assess drought recovery rate, while recovery score was taken after two weeks, according to Standard Evaluation System (SES), (IRRI, 1988) using the scale 1 – 9; where I means that 90-100% of plants recovered, 3-70 to 89%, 5-40 to 69%, 7-20 to 39% and 9-0-19% of plants recovered.

In Umudike, rate of leaf senescence was measured as follows: after the drought score, rice seedlings were monitored on Mondays, Wednesdays and Fridays to determine the number of days to effect complete death of leaves of seedlings. This was carried out to find out if the most susceptible rice lines would be the first to die completely as the drought stress progressed.

ROOT CHARACTERISTICS OF RICE LINES:

A pot experiment was established also in the last week of September, 2000 to investigate the characteristics of the roots of rice lines under study. Six seeds of each of the 100 rice lines were seeded in a polythene bag, 50cm in diameter. After germination, the pots were irrigated every other day to saturation points. On 18th December, 2000, the polythene bags were cut open and the sand carefully washed of the roots.

Data were collected on number of plants per polythene bag, length of the longest root, weight of dried roots and average weight of roots. This was carried out to determine any correlation between drought tolerance and development of rice root system.

Statistical analysis of experimental data was based on analysis of variance, standard error and coefficient of variation.

RESULTS AND DISCUSSION

A prevalent problem in crop production is shortage of water which limits not only the size of the plant but also the development of various plant parts and in some cases yield can be reduced to zero. (Boyer, 1982).

UMUDIKE:

The plant height of the rice lines varied between 55cm in Tox3118-45-1-1 to 135cm in FARO 28 in Umudike (Table 1). Results showed that majority (59%) of the rice lines recorded intermediate plant heights of between 81cm and 100cm while only 19% had between 100cm and 135cm (Tall plant types) and 22% had plant heights ranging from 55cm to 80cm (semi-dwarf plants).

Resistance to drought is considered to be the ability of plants to grow and yield satisfactorily under water deficit (Gupta and O'Toole, 1986; Turner, 1979; Boyer, 1992).

The result of drought tolerance score at the reproductive stage showed that 32% of the rice lines had resistance scores of between 1 and 3, while 68% showed susceptibility reaction of between 5 and 9 (SES, IRRI, 1988). According to O'Toole and Moya (1981), IRRI, (1980) and O'Toole (1982) decreased yield and grain weight and increase sterility were associated with degree and duration of water deficit at a particular growth stage.

Symptoms of drought tolerance at the vegetative stage ranged from gentle leaf rolling (and unrolling at night) to leaf tip drying and death of lower leaves (Chang et al, 1974, Loresto et al., 1976). The results of drought tolerance score at the vegetative stage showed that while 16% recorded resistant score of between 0 and 3, 84% were susceptible. Only 6% of the rice line showed drought tolerance reaction at both the reproductive and vegetative stages.

The rate of leaf senescence, that is ability to keep leaves green, ranged from 8 days in Tox4331-WAT-82-1-1-4-3-1, IR 4350-SRN-506-2-2-1, SIK P7-6-75-2-3-2-1, SIK 57-240-1, Tox 3440-32-5-3-1-2-3 and Tox 3552-80-3-3-3 to 80 days in IR 4350-SKN-506-2-2-1 and Bulukisa. It is interesting to note that rate of leaf senescence did not depend on drought tolerance/resistance as lines with severe susceptibility remained green longer than less susceptible genotypes. For example, SIK 289-54-2-2-2-2-1 with tolerance/resistance score of 1, was completely dead in 21 days whereas SIK 25-360-2 and SIK 120-6-8-1-4-5-2 with susceptibility scores of 7 and 5 died in 24 and 63 days respectively. Similarly, WAT-107-TGR-2-3 and ICA 80-4 with drought susceptibility scores of 7 and 9 dried up in 20 and 25 days respectively. This points to the fact that rate of leaf senescence in rice is genetic and does not depend on level of susceptibility to drought.

Grain yield ranged from 0.0T/ha (total crop failure) to 2.13T/ha (Table 1). A break-sown of yield ranges showed that 69% of the rice lines yielded below 0.5T/ha, 20% yielded between 0.5 to 1.0T'ha while only 10% yielded above 1T/ha. The very low yield values agree with the finding of O'Toole and Moya (1981), IRRI (1980) and O'Toole (1982) that decreased yield and grain weight and increased sterility were associated with water deficits. The most high yielding rice line was SIK 295-200-3-2 with a yield of 2.13T/ha

Abakaliki:

Plant height at Abakaliki varied between 51.7cm to 155.0cm. (Table 1). Drought tolerance score at the reproductive stage which is measured by spikelet fertility ranged from 1 to 5. Thus, 95% of the rice lines recorded drought score of between 1 and 3, while 47% had a resistant score of 1, 48% had scores of 3 which is moderately resistant reaction and only 5% had a score of 5 which is moderately susceptible reaction. The rice lines were more resistant to drought at the reproductive stage in Abakaliki than in Umudike because the soils at Abakaliki were more clayey, has better water retention capacity than the sandy soils of Umudike and are therefore more suitable for rice cultivation.

At the seedling stage, drought score varied from 0, which had no signs of drought stress to 7, which is susceptible reaction. 46% of the rice lines were resistant while 53% showed susceptible reactions.

Recovery from drought stress after water supply was restored is another method of assessing drought resistance/tolerance. In this study, 47% of the rice lines showed signs of recovery after irrigation was restored, 33% did not show any change from their earlier reaction while 24% worsened in their reaction to drought, thus resumption of water supply could not reverse the dangerous effect of drought in them.

Grain yield ranged from 0.7 to 4.7T/ha, out of which 83% yielded more than 1T/ha with 54% yielding above 2T/ha. Only 16% yielded below 1T/ha. Two rice lines viz: TOX 4331-WAT-82-1-1-4-3-1 and SIK P7-1-18-2-4-1 recorded crop failure as a result of late maturity. In general the rice lines performed better at Abakaliki than Umudike because of the better soil type in Abakaliki. 41% of the rice lines recorded resistant drought score of between 1 and 3 at both the vegetative and reproductive stages at Abakaliki.

In 2001, plant height varied between 66.0 to 133.0cm at Abakaliki (Table 2). About 72.7% of the rice lines recorded resistant/tolerant reaction at the reproductive stage, while 27.7% recorded susceptible reaction of between 5 and 9 to drought stress. Assessment of drought stress at the seedling stage failed in 2001 as seeds lost viability before September planting date. However, 12.8% of the entries or 26.3% of the viable rice lines recorded resistant/tolerant drought reaction of between 1 and 3.

Grain yield in 2001 varied between 0.2T/ha to 3.2T/ha. Only about 31.2% of the rice lines yielded above 1.0T/ha. The very low yields in 2001 can be explained by severe infestation by diseases and insect pests during the cropping season.

The rice plant has a shallow root system which is mainly concentrated in the upper soil layer to a depth of 20 to 25cm (Onwueme and Sinha, 1991). Results of the study on root characteristics (Table 3) showed that length of roots varied from 3cm in TOX 4003-30-2-23-2 to 29cm in SIK 25-355-3. Analysis of root length distribution pattern showed that 13% of the rice lines had roots that were between 3 and 10cm long, 72% had roots between 11.0 and 20.0cm, while only 9% had roots with lengths of between 21.0 and 29.0cm. Average weight of roots ranged from 0.03gm in SIK 25-349-4 to 2.14gm in FAROX 317-1-1-1. According to Morgan (1984), and Lal (1986) increased rooting depth, root dry mass and increased cuticle thickness lead to increased drought resistance. However in this study, there appeared not to be any trend between drought resistance score and length of roots and between length of roots and number of plants per pot on one hand and between length of roots and average weight of roots per plant on the other hand. There was also no definite trend between number of plants and average weight of roots per plant indicating that all these characters are mostly genetic in nature.

Table 1: Drought tolerance score, recovery and rate of leaf senescence of rice lines at Umudike and Abakaliki in 2000

		Umudike					Abakaliki				
S/no	Entries	Plant height (cm)	Spikelet fertility	Drought score	Leaf senescence	Yield (t/ha)	Plant height (cm)	Spikelet fertility	Drought score	Recovery	Yield (t/ha)
1	SIK 25-351-2	99.0	5	7	21	0.40	104.0	3	5	3	0.93
2	SIK 295-200-3-2	91.70	1	7	17	2.13	108.3	3	1	1	1.90
3	SIK289-54-2-2-2-2-1	73.7	1	1	21	0.53	87.7	1	3	5	1.63
4	SIK P7-1-18-5-1-4	85.3	1	5	33	0.43	101.7	1	7	5	2.43
5	SIK 25-360-2	88.0	1	7	24	0.80	89.3	5	1	3	2.33
6	SIK 120-6-8-1-4-5-2	83.3	3	5	63	0.20	155.0	3	1	3	1.83
7	SIK 25-355-3	87.0	1	5	29	0.80	90.3	3	1	1	077
8	TOX 4331-WAT-82-1-1-4-3-1	86.7	5	5	8	0.20	65.3	3	0	0	0.00
9	SIK 25-353-3	93.3	1	7	65	1.00	74.0	3	1	3	0.90
10	ROHYB I-I(ROK29)(CK)	91.3	1	7	66	0.40	128.0	3	3	5	3.97
11	SIK 295-191-4-2	101.0	1	3	13	0.73	135.7	1	7	5	2.23
12	WAT 107-TGR-2-1	97.3	1	3	67	0.40	105.3	3	5	3	3.57
13	SIK 57-249-2	87.0	5	9	10	0.2.	99.3	5	3	3	3.80
14	SIK 25-93-5-1	85.0	1	7	26	0.33	106.0	3	3	5	2.83
15	SIK 25-87-5-1	89.0	1	5	24	1.03	89.3	3	3	5	2.60
16	SIK 4-5-4-2-4	91.3	1	7	50	0.73	74.0	5	3	5	2.47
17	SIK 95	102.7	3	5	30	0.30	95.3	3	1	1	1.83
18	SIK 52-403	87.7	1	5	61	0.20	67.3	3	1	1	0.80
19	BW 311-9	84.7	3	5	61	0.63	106.7	1	3	1	2.53
20	TOX 4004-43-1-2-1(CK)	94.3	3	7	30	0.93	123.7	3	3	5	3.93
21	SIK P5-10-4-3-5-2-4	77.7	7	7	21	0.53	102.0	3	7	5	1.83
22	SIK 9-164-5-1-3	83.3	7	7	64	0.20	107.0	3	7	7	2.93
23	FAROX 317-1-1-1	65.0	7	0	64	0.10	98.0	3	5	5	2.53
24	SIK 25-246-4	87.0	1	7	25	0.63	105.0	3	5	7	1.83
Table 1 cont											
25	TOX 3449-88-1-1-2	95.3	7	5	60	0.10	96.3	3	3	3	1.80
26	TOX 1870-48-10-1-40	102.7	7	0	70	0.43	98.3	1	3	3	0.80
27	TOX 3499-84-2-1-3	88.3	7	7	30	0.73	133.0	3	1	1	0.90
28	SUAKOKO 10	96.3	5	7	29	0.50	134.0	3	5	5	3.93
29	TOX 3118-47-1-1	70.0	7	9	17	0.20	120.0	3	3	3	2.83
30	TOX 4004-8-1-2-2-3(CK)	90.0	7	7	36	0.23	130.0	3	5	7	3.67
31	FARO 51	65.0	7	7	36	0.10	83.0	1	5	1	3.70
32	RP 1045-25-2-1	70.0	7	5	71	0.10	82.0	5	7	3	1.93
33	TOX 728-1	68.3	7	3	75	0.10	91.7	3	5	3	2.37
34	IR 4350-SRN-506-2-2-1	108.3	1	9	8	0.10	115.3	1	5	5	2.63

35	TOX 3449-117-3-3-3		102.7	1	1	46	0.50		77.3	3	7	7	1.83
36	SIK P7-1-18-2-4-1		85.0	7			0.10		80.0	1	1	1	0.00
37	SIK P7-10-14-5-2-5-2		71.3	1	7	36	1.30		108.0	3	3	5	3.53
38	TOX 3445-14-2-3		102.3	1	3	56	1.10		106.7	3	3	3	2.23
39	IEI -3137		98.3	1	9	25	0.63		88.0	3	3	1	2.83
40	TOX 3499-84-2-1-3(CK)		98.3	7	7	25	0.10		145.0	1	5	5	3.53
41	SIK P7-6-75-2-3-2-1		75.0	7	9	8	0.04		99.3	3	1	1	1.83
42	SIK 9-164-5-3		88.3	7	5	36	0 10		90.0	3	5	3	2.13
43	TOX 4008-34-1-1-1-2		86.0	9	5	30	0.10		100.3	3	7	5	2.33
44	SIK 24-342-1		79.7	7	0	71	0.23		87.0	3	5	3	2.03
45	IR 72		76.7	9	9	15	0.10		59.7	3	5	3	1.53
46	SIK 94-1-45-4-2-4		81.7	9	9	17	0.10		85.0	3	3	1	0.93
47	CT 12077F2-1102-5		90.0	9	7	30	0.10		84.0	3	3	1	0.83
48	TOX 3118-47-1-1		55.0	9	7	15	0.00		79.7	1	5	1	1.00
49	ITA 406		70.0	9	5	30	0.00		74.3	5	3	1	0.70
50	SALUMPKITCINT(CK.)		95.3	9			0.10		85.3	3	5	1	1.07
51	SIK 131		80.0	5	5	33	0.43		88.3	1	5	3	1.30
52	MASHURI(ROK 25)		96.7	9	3	24	0.20		85.7	3	7	3	2.33
53	SIK 10-111-1-1-4		96.7	9	1	66	0.10		89.3	3	0	1	1.33
Table 1 cont													
54	SIK 273-388-2-1-2		73.3	9	5	21	0 10		51.7	3			0.83
55	SIK 57-240-1		71.7	9	9	8	0 23		106.7	1	1	1	3.67
56	SIK 25-349-4		86.7	9	7	31	0 20		88 7	3	3	5	2.80
57	H004-7-1-135		98.7	9	0	71	0 40		70 7	1	5	7	2.63
58	SIK 296-274-5-1		102.7	9	3	71	0.10		64.0	1	1	1	2.07
59	ITA 406(CK.)		80.0	9	7	74	0.10		74.0	1	3	3	1.83
60	WITA 4		66.7	9	7	26	0 00		94.3	1	5	5	1.90
61	TOX 1870-47-103-2-1-1		77 7	9	3	71	0.00		105.0	1	5	1	2.53
62	TOX 4331-WAT-80-1-1-3-3-1				7	31			85.0	3	5	0	1.93
63	SIK 6-3-4-4-2				7	33			72.0	3	5	3	1.73
64	SIK P4-1-8-4-3-4				7	30			124.0	3	3	1	3.20
65	CT-12249-F2-1191-1				7	28			103.0	1	3	1	3.53
66	BW 311-9		66.0	9	0	50	0.10		96.0	1	5	5	2.50
67	TOX 4008-34-1-1-1-2		93.3	1	7	30	0.60		100.7	1	7	1	4.10
68	TOX 728-1		83 3	5	7	33	0.40		89.3	1	5	3	2.17
69	WAT-107-TGR-2-3		103.7	1	7	20	0.40		79.3	1	3	1	2.93
70	ICA 80-4(CK.)		85.0	7	9	25	0.30		92 0	1	5	5	1.83
71	IR 4350-SKN 506-2-2-1		1.3.3	9	7	80	0.10		116 3	1	5	1	2.60
72	RP 1045-25-2-1		86.7	9	5	72	0.20		82 0	1	7	5	1.53
73	FAROX 317-1-1-1		81.7	9	7	15	0 10		98 7	1	5	7	3.57
74	FARO 51(CISADANE)				7	48			105.7	1	5	3	3.10
75	TOX 3226-5-2-2				7	55			111.3	1	5	1	3.60
76	RF 85C-C1-37-1-3-1-1-3-2				7	33			101 0	1	5	3	4.70
77	IR 58843-22-2-3-2-1-2-5				7	58			106 0	1	7	1	3.10
78	SUAKOKO 8		87.7	9	7	50	0.10		83 0	3	5	7	2.23
79	TOX 3932-21-3-2-2-1		87.3	9			0.20		85.0	1	1	3	1.93
80	TOX 4248-WAT-27-1		122.0	9	9	10	0.70		83.7	3	1	1	1.83
81	FARO 28(LOCAL CHECK)		135 0	3	9	15	1.23		107 3	3	3	3	1.57
82	TOX 3337-00-1-2-3-1		86.7	5			0.63		105 3	1	1	3	2.83
Table 1 cont													
83	TOX 3108-43-1-5-3-2-4		115.0	1	7	32	1.83		115.0	1	1	1	3.83
84	TOX 3133-75-1-2		101.3	1	5	56	1.53		125.0	1	3	3	3.23
85	TOX 3440-32-5-3-1-3-2		75.0	7	9	8	0.10		98.7	1	5	5	2.93
86	MAMBEFUCHI		126.7	7	5	56	0.10		138 0	3	5	5	3.50
87	TOMA		116.7	7	7	55	0 53		127 0	3	7	0	2.37
88	TOX 3545-41-2-2-2-2-2		110.3	1	7	33	1 03		89 3	1	7	7	1.63
89	TOMAKO		116.7	9	7	33	0.10		132.7	1	1	3	2.10
90	TOX 4008-34-1-1-2		113.3	1	7	58	1.23		84.3	1	5	7	0.80
91	TOX 3241-22-3-3-3		97 0	1	7	56	1 10		76.3	1	5	5	0.87
92	BULUKISA		100.0	3	3	80	1 10		92.0	1	5	3	1.10
93	WAB 450-4-1-1-P40-11B		82 3	5	0	80	0.30		76.7	1	5	7	1.53
94	TOX 3237-10-4-2-3-2		96 7	5	5	71	0 53		108 7	1	5	7	1.60
95	TOX 3254-3-3-1-2		71 7	7	7	23	0 60		115.3	3	5	5	2.43
96	TOX 3580-41-3-2-3-1-1-2		70.0	9	7	50	0 20		95 7	1	5	3	1.80
97	TOX 3118-47-1-1				7	58			127.3	1	3	3	3.53
98	TOX 4003-30-2-2-3-2		68.3	9	5	16	0.10		84.0	1	5	3	0.53
99	TOX 3552-80-3-3-3		71.7	9	9	8	0.20		83.7	1	3	0	1.63
100	TOX 3554-15-2-3-2-2-1		83.3	9	9	15	0.10		82.7	3	1	5	0.93
Std error			5.187	0.380	0.264	2.230	0 054		2 147	0.121	0.199	0 208	0.049

Table 2: Plant height, grain yield and drought tolerance score in Abakaliki in 2001

S/no	Entries	Plant height (cm)	Spikelet fertility	Drought score at seedling stage	Grain yield (t/ha)
1	SIK 25-351-2	92.3	3		
2	SIK 295-200-3-2	66.0	1	3	0.70
3	SIK289-54-2-2-2-2-1	96.7	1		1.03
4	SIK P7-1-18-5-1-4	95.0	1	7	0.30
5	SIK 25-360-2	90.3	1		1.23
6	SIK 120-6-8-1-4-5-2	106.0	1		0.30
7	SIK 25-355-3	109.3	1	5	0.67
8	TOX 4331-WAT-82-1-1-4-3-1	109.3	1		1.13
9	SIK 25-353-3	93.7	1		1.00
10	ROHYB I-I(ROK29)(CK)	115.0	1	7	0.50
11	SIK 295-191-4-2	112.0	5		0.40
12	WAT 107-TGR-2-1	92.7	3	5	0.70
13	SIK 57-249-2	97.3	3		0.50
14	SIK 25-93-5-1	103.7	1		0.90
15	SIK 25-87-5-1	75.7	1		0.90
16	SIK 4-5-4-2-4	89.3	1		0.10
17	SIK 95	106.3	3	3	0.20
18	SIK 52-403	95.0	1	1	1.00
19	BW 311-9	91.7	5	7	0.30
20	TOX 4004-43-1-2-1(CK)	103.0	3	5	0.53
21	SIK P5-10-4-3-5-2-4	96.3	3		1.40
22	SIK 9-164-5-1-3	110.3	5		0.80
23	FAROX 317-1-1-1	98.7	1	3	0.40
24	SIK 25-246-4	95.7	3	5	0.90
25	TOX 3449-88-1-1-2	133.0	5		2.30
26	TOX 1870-48-10-1-40	118.7	1	3	1.50
27	TOX 3499-84-2-1-3	98.7	3	5	1.10
28	SUAKOKO 10	98.3	5	5	0.50
29	TOX 3118-47-1-1	76.7	3	5	0.40
30	TOX 4004-8-1-2-2-3(CK)	84.3	5		0.90
31	FARO 51	113.0	7		0.50
32	RP 1045-25-2-1	73.7	1		0.40
33	TOX 728-1	109.3	3		0.90
34	IR 4350-SRN-506-2-2-1	113.7	1		
35	TOX 3449-117-3-3-3	96.7	1		
36	SIK P7-1-18-2-4-1	88.0	1	5	
37	SIK P7-10-14-5-2-5-2	95.3	1		
38	TOX 3445-14-2-3	93.7	5	5	2.20
39	IEI -3137	109.3	3	7	0.70
40	WAB 450-11-1-P26	90.7	1		0.87
41	WAB 450-11-1-1-P46-HB	83.3	1		0.50
42	TOX 3133-75-1-2	93.0	1	9	1.53
43	TOX 3580-41-3-2-3-1-1-2	96.0	5	5	2.03
44	SIK 24-342-1	88.3	1	5	0.83
45	WAB 450-11-13-P40-HB	108.0	1	3	1.50
46	WAB 450-11-1-P40-1-HB	99.7	1	9	1.10
47	WAB 450-11-1-P40-12-HB	85.3	1	0	0.00
48	TOX 3932-21-3-2-2-1	66.7	7	3	1.00
49	WAB 540-10-B-1A1-15	99.3	1	7	1.17
50	WAB 750-1-B-P-153-HB	79.7	3		0.00
51	SIK 131	99.3	7	5	0.00
52	MASHURI(ROK 25)	99.0	9	5	1.03
53	WAB 515-B-16A1-2	94.3	1	1	0.00
54	SIK 273-388-2-1-2	75.7	7		0.00
55	SIK 57-240-1	84.0	7		1.27
56	SIK 25-349-4	105.7	3		1.00
57	H004-7-1-135	99.3	3		0.30
58	TOX 3237-10-4-2-3-2	69.7	1		0.60
59	TOX 3254-3-3-1-2	76.7	5		
60	WAB 450-1-B-P91-HB	108.0	3	5	0.43
61	WAB 62-80(CHECK)	104.7	3	3	1.13
62	CT 12249-F2-1191-1	127.7	7		0.00
63	TOX 3337-30-1-5-2-4	73.7	1		0.80
64	TOMA	86.7	7	7	0.97
65	TOX 3552-8-3-3-3	89.7	5	9	0.40
66	BW 311-9	68.7	5	9	0.80
67	TOX 4008-34-1-1-1-2	92.3	5	5	0.77
68	WAB 874-B-41-A1-1	111.0	5		0.60
69	WAT 107-TGR-2-3	76.7	3		0.90
70	TCA 80-4	97.7	3		1.00
71	GB 90-2	96.0	3		0.80
72	RF 1045-25-2-1	99.3	3		0.90
73	TOX 3545-41-2-2-2-2	99.3	1	5	2.70
74	MAMBEFUCHI	95.3	1		0.20
75	TOX 4248-WAT-27-1	105.3	1	9	1.40
76	TOX 3108-43-1-5-3-2-4	117.3	1	9	3.03
77	TOX 4008 34-1-1-2	99.0	1		3.20
Std error		1.724	0.353		0.025

Table 3: Growth of rice roots under pot conditions in Umudike in 2006

		Umudike				
S/no	Entries	Drought tolerance score	Root length (cm)	No. of plants	Average root weight (g/plant)	Total root wt (g)
1	SIK 25-351-2	7	13	1	0.16	0.16
2	SIK 295-200-3-2	7	15	5	0.48	2.42
3	SIK289-54-2-2-2-2-1	1	20	4	0.09	4.34
4	SIK P7-1-18-5-1-4	5	18	5	1.76	8.81
5	SIK 25-360-2	7	18	5	0.43	2.14
6	SIK 120-6-8-1-4-5-2	5	17	4	0.28	1.10
7	SIK 25-355-3	5	29	4	0.27	1.08
8	TOX 4331-WAT-82-1-1-4-3-1	5	15	4	0.33	1.32
9	SIK 25-353-3	7	7	1	0.15	0.15
10	ROHYB I-I(ROK29)(CK)	7	23	4	0.89	3.57
11	SIK 295-191-4-2	3	19	5	0.79	3.96
12	WAT 107-TGR-2-1	3	10	2	0.40	0.80
13	SIK 57-249-2	9	14	3	0.44	1.32
14	SIK 25-93-5-1	7	14	7	0.66	4.63
15	SIK 25-87-5-1	5	17	4	0.34	1.34
16	SIK 4-5-4-2-4	7	13	7	0.45	3.18
17	SIK 95	5				
18	SIK 52-403		5	1	0.13	0.13
19	BW 311-9	5	14	4	0.99	3.95
20	TOX 4004-43-1-2-1(CK)	7	16	5	1.46	7.31
21.	SIK P5-10-4-3-5-2-4	7	14	5	1.05	5.24
22	SIK 9-164-5-1-3	7				
23	FAROX 317-1-1-1	0	15	4	1.03	4.12
24	SIK 25-246-4	7	13	4	0.83	3.30
25	TOX 3449-88-1-1-2	5	18	4	0.53	2.12
26	TOX 1870-48-10-1-40	0	13	2	0.21	0.42
27	TOX 3499-84-2-1-3	7	13	6	0.80	4.80
28	SUAKOKO 10	7	8	2	0.11	0.21
29	TOX 3118-47-1-1	9	16	5	1.32	6.62
30	TOX 4004-8-1-2-2-3(CK)	7	14	5	1.02	5.10
31	FARO 51	7	16	4	0.91	3.62
32	RP 1045-25-2-1	5	16	3	1.16	3.48
33	TOX 728-1	3	19	4	0.99	3.96
34	IR 4350-SRN-506-2-2-1	9	13	1	0.40	0.40
35	TOX 3449-117-3-3-3	1	9	4	0.22	0.88
36	SIK P7-1-18-2-4-1		16	4	0.56	2.24
37	SIK P7-10-14-5-2-5-2	7	11	5	0.73	3.67
38	TOX 3445-14-2-3	3	15	4	0.66	2.64
39	IEI -3137	9	11	3	1.20	3.91
40	TOX 3499-84-2-1-3(CK)	7	9	2	0.48	0.96
41	SIK P7-6-75-2-3-2-1	9	15	3	0.42	1.26
42	SIK 9-164-5-3	5	19	4	1.12	4.48
43	TOX 4008-34-1-1-1-2	5	27	4	0.55	2.20
44	SIK 24-342-1	0	10	1	0.30	0.30
45	IR 72	9	13	5	0.95	4.75
46	SIK 94-1-45-4-2-4	9	14	4	0.80	3.20
47	CT 12077F2-1102-5	7	17	5	1.08	5.40
48	TOX 3118-47-1-1	7	16	5	0.93	4.65
49	ITA 406	5	16	3	0.70	2.10
50	SALUMPKITCINT(CK.)		16	3	1.20	3.60
51	SIK 131	5	9	6	1.20	7.20
Table 3 conts						
52	MASHURI(ROK 25)	3	16	5	0.46	2.30
53	SIK 10-111-1-1-4	1	21	3	0.41	1.23
54	SIK 273-388-2-1-2	5	17	5	1.71	8.55
55	SIK 57-240-1	9	15	4	0.36	1.44
56	SIK 25-349-4	7	7	1	0.30	0.30
57	H004-7-1-135	3	21	2	1.02	2.04
58	SIK 296-274-5-1	7	14	2	1.02	2.04
59	ITA 406(CK.)	7	17	5	0.28	1.40
60	WITA 4	3	13	3	1.49	4.47
61	TOX 1870-47-103-2-1-1	7	17	4	1.19	4.76
62	TOX 4331-WAT-80-1-1-3-3-1	7	12	5	0.75	3.75
63	SIK 6-3-4-4-2	7	14	5	1.80	9.00
64	SIK P4-1-8-4-3-4	7	16	5	0.90	4.50
65	CT-12249-F2-1191-1	0	13	2	1.41	2.82
66	BW 311-9	7	18	2	0.65	1.30
67	TOX 4008-34-1-1-1-2	7				
68	TOX 728-1	7	10	3	0.79	2.37
69	WAT-107-TGR-2-3	9	19	5	0.49	2.45
70	ICA 80-4(CK.)	7	13	5	0.30	1.50
71	IR 4350-SKN 506-2-2-1	5	15	3	1.47	4.41

72	RP 1045-25-2-1		7	12	5	1.60	8.30
73	FAROX 317-1-1-1		7	11	5	2.14	10.70
74	FARO 51(CISADANE)		7	16	3	1.01	3.03
75	TOX 3226-5-2-2		7	21	5	1.70	8.50
76	RF 85C-C1-37-1-3-1-1-3-2		7	17	4	0.46	1.84
77	IR 58843-22-2-3-2-1-2-5		7	15	6	1.54	9.24
78	SUAKOKO 8		7	15	4	0.62	2.48
79	TOX 3932-21-3-2-2-1						
80	TOX 4248-WAT-27-1		9	13	5	0.32	1.59
81	FARO 28 (LOCAL CHECK)		9	12	4	0.23	0.92
82	TOX 3337-00-1-2-3-1		9	12	4	0.90	3.60
83	TOX 3108-43-1-5-3-2-4		7	16	4	0.48	1.92
84	TOX 3133-75-1-2		5	14	5	0.68	3.40
85	TOX 3440-32-5-3-1-3-2		9	12	5	0.37	1.85
86	MAMBEFUCHI		5	12	5	0.66	3.30
87	TOMA		7	14	5	0.40	2.00
88	TOX 3545-41-2-2-2-2-2		7	5	1	0.97	0.97
89	TOMAKO		7	16	4	0.53	2.12
90	TOX 4008-34-1-1-2		7	16	4	0.54	2.16
91	TOX 3241-22-3-3-3		7	12	3	0.87	2.61
92	BULUKISA		3	23	4	0.57	2.28
93	WAB 450-4-1-1-P40-11B		0	5	2	0.26	0.52
94	TOX 3237-10-4-2-3-2		5	22	5	1.28	6.40
95	TOX 3254-3-3-1-2		7	16	4	0.80	3.20
96	TOX 3580-41-3-2-3-1-1-2		7	21	4	1.76	7.04
97	TOX 3118-47-1-1		7	10	3	0.80	2.40
98	TOX 4003-30-2-2-3-2		5	3	4	0.20	0.80
99	TOX 3552-80-3-3-3		9	14	5	0.20	1.00
100	TOX 3554-15-2-3-2-2-1		9	14	5	0.30	1.50
Std error			0.2511	0.4604	0.1411		0.2404

CONCLUSION

This work has confirmed that genetic variation exists between the rice genotypes as there are differences among the genotypes in relation to their susceptibility to drought. The most resistant/tolerant rice line in both locations in the two years were TOX 3445-14-2-3 and SIK 289-54-2-2-2-2-1 with a score of between 1 and 3 at both the vegetative and reproductive stages and these could therefore be incorporated into hybridization programme for the development of drought resistance rice varieties.

The following rice lines – TOX 4331-WAT-80-1-1-3-3-1, SIK 6-3-4-4-2, $SIKP_4$-1-8-4-3-4, CT-12249-F_2-1191-1, FARO 51 (CISADANE), TOX 3226-5-2-2, RF 85C-C1-37-1-3-1-1-3-2 and IR 58843-22-2-3-2-1-2-5 were very late maturing and could not be harvested.

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