Agro-Science

Journal of Agriculture, Food, Environment and Extension
Volume 4, Number 1, January 2005 pp 29-33

ISSN 1119-7455

URL: http://www.agrosciencejournal.com/

YIELD AND YIELD COMPONENT ANALYSIS OF TWELVE UPLAND RICE GENOTYPES

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ABSTRACT

Eleven rice genotypes obtained from National Cereals Research Institute, Badeggi, Nigeria, and a local variety were evaluated under field culture in Nsukka for a period of two years (1998 and 1999). Multiple correlation and path coefficient analysis were used to study yield and yield components. Genotypic stability analysis was performed on the yield and the two traits most related to yield using mean yield-coefficient of variation (CV). The genotype, ITA 324 had the highest grain yield and percentage fertile spikelets in both years. All the yield components were significantly (p = 0.05) and positively correlated with yield in the second year. Tiller number per plant and percentage of fertile spikelets had the strongest genotypic correlations with yield in both years. The yield stability estimates of the genotypes and the traits most related to yield showed that the genotypes independently expressed their traits in the different stability groups. Four groups of yield stability conditions were established as - high yield and low variation, high yield and high variation, low yield and low variation and low yield and high variation. The direct effect of percentage fertile spikelets on yield was positive and of higher magnitude than the direct effects of tiller number, panicle number, spikelet number and 1000 grain weight. Selecting upland rice genotypes with stable and high number of filled grains would sustain high yields in such genotypes especially as the yield components are complementary in action.

Keywords: Upland rice, *Oryza sativa*, Yield component, Path coefficient analysis

INTRODUCTION

Rice (*Oryza sativa* L.) growers strive to plant rice varieties developed from research to optimize yield and quality. Increased production of rice under upland conditions in Nigeria has improved rice production although; it is far from attaining self-sufficiency in rice production (Courtois, 1988). To meet increasing demands for rice, selection of adaptable and high yielding genotypes from multi-locational evaluations for selection and release to farmers was considered valuable and necessary.

Yoshida (1983) reported that the major yield components in rice are number of panicles per unit area, spikelet number panicle^{-1}, spikelet fertility percentage and grain weight normally expressed as 1,000 grain weight. International Rice Research Institute (IRRI) (1997) stated that traits contributing to yield potential in rice include tillering ability, leaf length, leaf width, number of leaf, number of panicle length of grain and amount of grains on the panicle. Lavanya *et al.* (1997) reported that high performance of hybrids can mainly be attributed to heterosis for the number of productive tillers plant^{-1} and number of filled grains panicle^{-1}. In semidwarf rice, Gravois and Helms (1992) showed that at different seeding rates, the direct effects of filled grain panicle^{-1} on rice yield were moderate and positive. Ramalingam *et al.,* (1993) observed that total filled grains showed both positive genotypic association as well as direct effect on rice yield.

Francis and Kannenberg (1978) developed the mean yield – coefficient of variation (CV) approach of determining genotypic stability and described it as a simple and descriptive method for grouping genotypes on the basis of yield and consistency of performance. Stable genotypes are those whose CVs are below the mean of the CVs and yield above the grand mean yield of all the genotypes. The genotypic stability of yield over environments or seasons reveals anticipated consistency of yield from such genotype(s) across spatial or temporal environment.

Information obtained from correlation coefficients can be augmented by partitioning the correlations into direct and indirect effects for a given set of priori cause and effect interrelationships (Dewey and Lu, 1959). Path coefficient analysis has proved useful in providing further information that describes priori cause-and-effect relationships that might have been confounded by correlation coefficients. Yield and yield components have such priori cause-and-effect relationship (Kang *et al.,* 1983 and Milligan, *et al.,* 1990).

The utilization of stability of yield traits and inferences from significant genotypic correlation between yield and its components should permit selection of predictable rice genotypes for upland ecosystem. Our objective was to study rice yield and yield components relationships for upland rice genotypes under different seasons through the use of path-coefficient analysis.

MATERIALS AND METHOD

The experiment was carried out in the Department of Crop Science, Faculty of Agriculture experimental field, University of Nigeria, Nsukka. Nsukka lies within latitude 06^{o} 51′ N, longitude 07^{o} 29′ E and at altitude 400m above sea level. The experiment was carried out in 1998 and 1999. Seeds collected from the 1998 plantings were used as planting materials for 1999 planting. The seeds were sown by the end of June to coincide with the main sowing period of rice around Nsukka agroecology.

Eleven rice genotypes collected from National Cereals Research Institute, Badeggi, Nigeria, that had been evaluated for over ten years, and one local variety (Farox 16) were evaluated. The designation of the genotypes used for the study were as listed in Table 1. Straight fertilizers were applied three weeks after planting at the rate of 30kg N, P and K ha^{-1}. Nitrogen (30kg N ha^{-1}) was re-applied as top dressing at the onset of booting stage at the same rate.

Table 1: Designation and values of yield and yield components of the upland rice genotypes used for the study in 1998 and 1999

Genotype Designation	Tiller number plant^{-1}	Panicle number m^{-2}	Spikelet number panicle^{-1}	1000-seed weight (gm)	Percent fertile spikelets	Grain yield t ha^{-1}
			Yield and yield components (1998)			
Tox 3154-17-1-3-2-2	7.67	151.67	136.33	24.62	66.0	3.26
Tox 3004-136-1-3-2-2	5.67	128.33	138.67	23.47	66.33	2.69
Tox 3440-132-3-3-1	4.67	141.67	131.0	21.62	64.33	2.94
ITA 324	7.33	148.33	147.67	25.03	68.33	5.22
Tox 3499-84-2-Hc-83	5.0	133.33	121.33	20.54	55.0	2.7
BR 57-282-8-Hc-83	7.0	138.33	133.33	16.6	54.33	2.7
Tox 4008-34-1-1-1-2	9.0	141.67	176.0	25.97	66.67	3.44
De Priuni (Naputo)	6.0	150.0	133.67	32.47	64.67	3.0
FAROX 317-1-1-1	5.33	106.67	145.0	18.08	49.33	2.57
SPT 7106-2-3-3-1	4.67	155.0	96.33	18.99	49.0	2.69
ITA 368	6.0	130.0	113.0	23.53	49.33	2.97
FAROX 16 (local check)	4.33	125.0	99.67	20.55	47.0	2.57
F-LSD (0.05)	1.55	17.42	4.32	3.25	5.62	0.45
			Yield and yield components (1999)			
Tox 3154-17-1-3-2-2	6.67	123.33	135.33	23.09	56.33	2.05
Tox 3004-136-1-3-2-2	5.33	86.67	137.33	23.13	54.0	1.8
Tox 3440-132-3-3-1	4.33	80.0	130.0	20.96	44.67	1.71
ITA 324	6.33	91.67	142.67	24.48	58.67	2.61
Tox 3499-84-2-Hc-83	4.67	125.0	120.33	19.83	41.0	1.65
BR 57-282-8-Hc-83	6.33	101.67	132.0	16.16	42.33	1.76
Tox 4008-34-1-1-1-2	8.0	141.67	177.0	25.68	58.00	2.44
De Priuni (Naputo)	5.67	98.33	130.67	30.55	58.33	1.99
FAROX 317-1-1-1	4.67	76.67	147.67	18.18	39.0	1.67
SPT 7106-2-3-3-1	4.33	65.0	96.33	18.85	39.33	1.8
ITA 368	5.33	95.0	114.67	22.1	40.0	1.82
FAROX 16 (local check)	4.00	53.33	100.33	19.96	37.33	1.57
F-LSD (0.05)	1.04	12.19	2.23	1.59	5.74	0.24

Table 2: Mean squares for rice yields and yield components for the two years

Source of variation	d.f	Tiller number plant^{-1}	Panicle number m^{-2}	Spikelet number panicle	Percentage of fertile spikelets	1000 seed weight	Yield (t ha^{-1})
Year (Y)	1	304.22^{**}	26068.06^{**}	7.34	2156.05^{**}	9.43	23.95^{**}
Genotypes (G)	11	3.03^{*}	1150.63^{**}	2808.59^{**}	416.65**	96.16^{**}	1.44*
G x Y	11	5.37*	894.57^{**}	2.77	25.45^{*}	7.37	0.26^{**}
Error	44	0.67	87.39	4.35	11.62	1.22	0.02

; = Significant at $P < 0.05$ and 0.01 respectively*

Table 3: Multiple genotypic correlation of yield and yield components of the rice genotypes in both years

1998	PFS	TNP	NSP	NPM	GWT	GY
PFS	-	0.54^{*}	0.72^{*}	0.48^{*}	0.65^{*}	0.58^{*}
TNP		-	0.68^{*}	0.43	0.37	0.43
NSP			-	-0.02	0.34	0.43
NPM				-	0.43	0.46
GWT					-	0.41
1999						
PFS	-	0.74*	0.76^{*}	0.81^{*}	0.43^{*}	0.79^{*}
TNP		-	0.65^{*}	0.55^{*}	0.81^{*}	0.80^{*}
NSP			-	0.64^{*}	0.36	0.62^{*}
NPM				-	0.34	0.48^{*}
GWT					-	0.58^{*}

Where: PFS = Percentage fertile spikelets, TNP = number of tillers per plant, NSP = number of spikelets per panicle, NPM = number of panicles per square meter, GWT = grain weight and GY = grain yield.

The experimental design was randomized complete block (RCB) with three replications. Plot measured 4m x 3m and seeds were sown 20cm apart between rows and 15cm apart within rows. Three seeds were sown to be able to maintain two seedlings per hill. All cultural practices employed in rice production, which include weeding, fertilizer application, bird scaring, threshing and winnowing were done as necessary. Data were collected based on standard evaluation system for rice (SES) (IRRI, 1988). Data on tiller number plant^{-1}, number of spikelets panicle^{-1}, percentage of filled spikelets and 1,000 grain weight were measured from twenty randomly selected hills of middle rows in each plot.

Table 4: Grouping of rice genotypes by yield, fertile spikelets (%) and tiller number/plant using yield and CV% values

Group	Fertile spikelets (%)	Tiller number plant^{-1}	Yield (t ha^{-1})
1 HIGH YIELD AND LOW VARIATION	TOX 3154-17-3-2-2, TOX 3084-136-1-3-2-2, ITA 324 TOX 4008-34-1-1-1-2 De priuni	RR57-282-8-HC-83	TOX 3154-17-1-3-2-2, TOX 4008-34-1-1-2 De priuni
2 HIGH YIELD AND HIGH VARIATION	TOX 3440-132-3-3-1 FAROX 317-1-1-1	TOX 3154-17-1-3-2-2, ITA 324 TOX 4008-34-1-1-1-2	ITA 324
3 LOW YIELD AND LOW VARIATION	ITA 368	TOX 3084-136-1-3-2-2, TOX 3440-132-3-3-1, De priuni SPT 7106-2-3-3-1, FAROX 16	TOX 3084-136-1-3-2-2, BR57-282-8-HC-83, FAROX 317-1-1-1, SPT 7106-2-3-3-1,
4 LOW YIELD AND HIGH VARIATION	TOX 3499-84-2-1-3, BR57-282-8-HC-83, SPT 7106-2-3-3-1, FAROX 16	TOX 3499-84-2-1-3, FAROX 317-1-1-1, ITA 368.	TOX 3440-132-3-3-1 TOX 3499-84-2-1-3, ITA 368, FAROX 16

Grain yield (t ha^{-1}) was estimated from harvests from sampling units of 5m^2 within the middle rows in each plot.

Combined analysis of variance for the two years was carried out for each of the yield and yield related traits. A mixed model of random years and fixed treatment was used as was described by McIntosh (1983). Genotypic correlation (r_g) between the yield component traits and yield was obtained from the genotypic covariance between the two traits and the geometric of their genotypic variance (Obi, 1990).

$$r_g = \frac{\sigma^2{}_{g(XY)}}{\sqrt{(\sigma^2{}_{g(XX)})(\sigma^2{}_{g(YY)})}}$$

Where: $\sigma^2_{g(xy)}$ is genotypic variance of cross product of the traits x and y, $\sigma^2_{g(xx)}$ is genotypic variance of the trait x and $\sigma^2_{g(yy)}$ is genotypic variance of the trait y.

The genotypic stability of yield and those of the two most related traits to yield were estimated by mean – CV approach as described by Francis and Kannenberg (1978). In this approach, mean CV and grand mean yield divides the table into four groups. The groups of yield stability conditions estimated were as follows:

Group 1 - High yield and low variation
Group 2 - High yield and high variation
Group 3 - Low yield and low variation
Group 4 - Low yield and high variation.

Stable genotypes for traits are those whose CVs are below the mean CV and yield higher than the grand mean yield. The sets of correlation coefficients were subjected to path-coefficient analysis and the direct and indirect effects of each year (Fig. 1) were estimated according to the procedure of Dewey and Lu (1959).

RESULTS AND DISCUSSION

Yield and yield component values of the rice genotypes (Table 1) were significantly (P = 0.05) different in the two years. Genotype ITA 324 gave the highest grain yield in both years and was significantly (P = 0.05) different from other genotypes for the period with the exception of Tox 400834 1-1-1-2 in the second year. The genotype also had the highest percentage fertile spikelets in the two years and was statistically similar to Tox 3154-17-1-3-2-2, Tox 3004-136-1-3-2-2, Tox 3440-132-3-3-1, Tox 4008-34-1-1-1-2 and De Priuni with the exception of Tox 3440-132-3-3-1 that had significant difference from it in 1999. Farox 16 had the least grain yield in both years and was statistically the same with some of the genotypes.

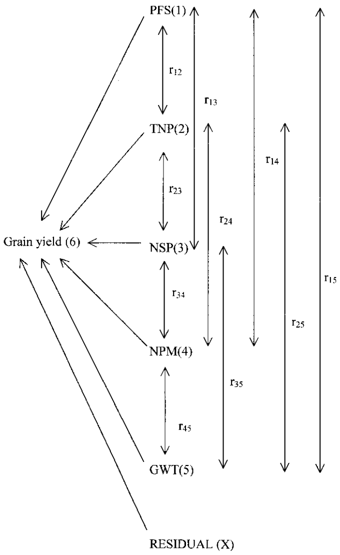

Fig. 1: Path diagram showing casual relationship between the five predictor variables, Percentage fertile spikelets (PFS), Tiller number per plant (TNP), Number of spikelets per panicle (NPS), Number of panicles per square meter (NPM) and 1,000 grain weight (GWT), and the response variable, yield as was used for the two years. The variable residual is the underdetermined portion

Table 2 shows the mean squares of the yield and yield components across the two years. There was no significant year effect on 1,000-grain weight and number of spikelets panicle^{-1}. The effect of years was highly significant (P = 0.01) on tiller number plant^{-1}, panicle number m^{-2}, percentage of fertile spikelets and grain yield, (t ha^{-1}) indicating wide range of variations between the two years.

Table 5: Path coefficient analysis showing the direct and indirect effects of the yield components on yield for the two years

Pathway	1998	1999
Percentage fertile spikelets → yield		
Direct effect, P_{16}	0.336	0.881
Indirect effect via tiller number per panicle = P_{26} x r_{12}	0.159	0.207
Indirect effect via number of spikelets per panicle = $P_{36}r_{13}$	-0.012	-0.004
Indirect effect via number of panicles per square meter = $P_{46}r_{14}$	0.076	-0.348
Indirect effect via 1000-grain weight = $P_{56}r_{15}$	0.016	0.056
Correlation, r_{16}	0.58	0.79
Tiller number of panicle → yield		
Direct effect, P_{26}	0.294	0.282
Indirect effect via percentage fertile spikelets = $P_{16}r_{21}$	0.205	0.651
Indirect effect via number of spikelets per panicle = $P_{36}r_{23}$	-0.011	-0.003
Indirect effect via number of panicles per square meter = $P_{46}r_{24}$	0.068	-0.237
Indirect effect via 1000-grain weight	0.009	0.105
Correlation, r_{26}	0.57	0.8
Number of spikelets per panicle → yield		
Direct effect, P_{36}	-0.017	-0.005
Indirect effect via percentage fertile spikelets = $P_{16}r_{31}$	0.242	0.668
Indirect effect via tiller number per plant = $P_{26}r_{32}$	0.200	0.184
Indirect effect via number of panicles per square meter = $P_{46}r_{34}$	-0.003	-0.275
Indirect effect via 1000-grain weight = $P_{56}r_{35}$	0.008	0.047
Correlation, r_{36}	0.43	0.62
Number of panicles per square meter → yield		
Direct effect, P_{46}	0.159	-0.43
Indirect effect via percentage fertile spikelets = $P_{16}r_{41}$	0.161	0.713
Indirect effect via tiller number per plant = $P_{26}r_{42}$	0.126	0.155
Indirect effect via number of spikelets per panicle = $P_{36}r_{43}$	0.000	-0.003
Indirect effect via 1000-grain weight = $P_{56}r_{45}$	0.011	0.044
Correlation, r_{46}	0.46	0.48
1000 Grain weight → yield		
Direct effect, P_{56}	0.025	0.13
Indirect effect via percentage fertile spikelets = $P_{16}r_{51}$	0.218	0.378
Indirect effect via tiller number per plant = $P_{26}r_{52}$	0.109	0.227
Indirect effect via number of spikelets per panicles = $P_{36}r_{54}$	-0.006	-0.002
Indirect effect via number of panicle per square meter = $P_{46}r_{36}$	0.068	-0.155
Correlation, r_{56}	0.41	0.58
Residual	0.56	0.46

There was highly significant (P = 0.01) genotypic effect on yield and its components indicating that they are indeed genetically different. The genotype by year (G x Y) interaction was significant for most of the traits with the exception of number of spikelets and grain weight. This could be as a result of genotypic differences, which resulted in the variation. The traits with non-significant G x Y effect might be showing consistency inspite of the various differences that existed in the two years (Kang, 1998).

The results presented in Table 3 show the multiple genotypic correlation coefficient (r_g) of the rice yield and yield components. All the yield traits were significantly and positively correlated with yield in the second year which implied that improvement of one trait will improve the other. Also, there were positive significant inter-correlations among most of the yield related traits, which shows that those traits are complementary in action. Number of tillers plant^{-1} and percentage of fertile spikelets had higher correlation values with yield in both years. This agrees with the work of Lavanya *et al.* (1997) who stressed the positive contribution of heterotic effect of number of productive tillers and filled grains to high performance of rice hybrids.

The result of the genotypic stability of yield and the two most related traits to yield showed that genotypes independently expressed their traits in different stability groups (1-4), (Table 4). The table shows that genotypes Tox 3154-17-1-3-2-2, Tox 4008-34-1-1-1-2 and De Priuni had stable and high yields of 2.66, 2.94 and 2.5 t ha^{-1} respectively, whereas, genotype ITA 324 had high but unstable yield of 3.83 t ha^{-1}. In most cases from the table, genotypes with high yield and low variation of percentage fertile spikelets had high and stable or unstable grain yield of rice irrespective of the stability status of their number of tillers.

Table 6: Path coefficients of rice grain yield showing components of direct and indirect effects of the yield components. Analysis was based on data from 12 upland rice genotypes grown in 1998 and 1999 in Nsukka, Nigeria

1998	**Path coefficient by yield components**					**Genotypic**
Traits	*PFS*	*NTP*	*NSP*	*NPM*	*1000-GWT*	**correlations**
PFS	[0.336]	0.159	-0.012	0.076	0.009	0.58
NTP	0.205	[0.294]	-0.011	0.068	0.009	0.57
NSP	0.242	0.200	[-0.017]	-0.003	0.008	0.43
NPM	0.161	0.126	0.000	[0.159]	0.011	0.46
1000-GWT	0.218	0.109	-0.006	0.068	[0.025]	0.41
Residual						0.56
1999						
PFS	[0.851]	0.207	-0.004	-0.348	0.056	0.79
NTP	0.651	[0.282]	-0.003	-0.237	0.105	0.8
NSP	0.668	0.184	[-0.005]	-0.275	0.047	0.62
NPM	0.713	0.155	-0.003	[-0.43]	0.044	0.48
1000-GWT	0.378	0.227	-0.002	-0.155	[0.13]	0.58
Residual						0.46

Where: PFS = Percentage fertile spikelets; NTP = number of tillers per plant; NSP = number of spikelets per panicle; NPM = number of panicles per square meter and 1000-GWT = 1000-grain weight. Values on the diagonal (highlighted) are direct effects of rice yield components on yield while off-diagonal values are indirect effects through the specific path.

Also, most genotypes with low yield and low or high variation of percentage fertile spikelets had low or high variation of grain yield irrespective of the stability status of their number of tillers. This indicates higher contributions of percentage fertile spikelets to grain yield.

The direct effects of percentage fertile spikelets per panicle from the path analysis were positive and of greater magnitude than direct effects of other four traits in both years (Table 5). Number of spikelets per panicle had negative direct effect on yield for the two years. Number of panicles per square meter also had negative direct effect on yield in the second year. However, the positive indirect effects of the two traits through percentage of fertile spikelets indicated that genotypes that had high number of spikelets and number of panicle per square meter ensured high percentage fertile spikelets and thus had higher grain yields. The indirect effects seem to be the cause of high correlation of number of spikelets per panicle and number of panicles per square meter with grain yield (Singh and Chaudhary, 1979). Earlier report by Gravois and Helms (1992) indicated that panicle density had higher direct effect on grain yield and that grain maturity differences in the secondary and tertiary tillers may reduce rice quality due to increased grain filling. This was mostly applicable in flooded rice on which the study was carried out. However, in the present study that was done under upland rice conditions where water is always a limiting factor (De Datta, 1981), all the productive tillers filled their grains within a reasonable time frame that there were no marked maturity differences within the genotypes.

Path-coefficients obtained (Table 6) will be very useful when deciding upon selection criterion in upland rice genotypes. The percentage of fertile spikelets was the most important factor that increased yield. The direct effect for number of tillers per plant on rice yield was positive and moderate. It can thus be regarded as being secondary contributor to yield.

The study showed that to obtain high grain yield under upland rice conditions, the genotype to be planted must be stable in expression of percentage fertile spikelets and have high tillering ability, number of panicles, number of spikelets per panicle and number of filled grains. Therefore, an upland rice genotype with stable and high number of filled grains, which will sustain high yield in the genotype especially as the yield components are complementary in action, will be selected.

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