Global Journal of Agricultural Research
Vol.10, No.5, pp.10-27, 2022
Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Combining Ability Estimates and Heterosis for Yield and Yield Components in Rice (*Oryza sativa* L.) in Nigeria

Sahabi Ayuba[1]*, T. Vange[1], G.O.S. Ojo[2], A.E. Ochigbo[1]
[1]Department of Plant Breeding and Seed Science, Joseph Sarwuan Tarka University Makurdi, Benue State Nigeria
[2]Department of Crop Production, Joseph Sarwuan Tarka University Makurdi, Benue State Nigeria

Citation: Ayuba S; Vange T; Ojo G.O.S.; OchigboA.E (2022) Combining Ability Estimates and Heterosis for Yield and Yield Components in Rice (Oryza sativa L.) in Nigeria, *Global Journal of Agricultural Research*, Vol.10, No.5, pp.10-27

ABSTRACT: *The study was carried out to determine the combining ability estimates and heterosis for yield and yield components in rice (Oryza sativa L.) in Nigeria. A seven plant diallel was planted across three locations using a randomized complete block design with three replications. Parameters assessed include days to 50% heading, plant heights, panicle lengths, panicle weights, number of seeds per panicle, number of productive tillers, number of panicle branches, yields per hectare, 100 grain weight. Assessment of GCA and SCA were carried out. Percentage heterosis were also determined for all traits studied. Significantly higher yield was recorded by P5, P4, P3, P6, P7, P2, and P1 with means of 5.86t/ha, 5.26 t/ha, 5.09 t/ha, 4.94 t/ha, 4.91 t/ha, 4.74 t/ha and 4.49 t/ha respectively across three locations studied. Hybrids P1xP5, P3xP6, P4xP7, P3xP5 produced significantly higher yields of 6.14 t/ha, 6.13 t/ha, 6.22 t/ha), 6.95 t/ha compared to their parental means. Similarly, significant difference were recorded in all other traits studied among parents and hybrids. GCA means squares were significantly higher than that of SCA for most of the traits studied. Additive variance was shown to predominate for plant heights and productive tillers while dominance was higher in yield per plants. Narrow sense heritability was higher on days to flowering, plant heights, panicle length and productive tillers. Yield in general was found to be significantly higher for combining ability in P5, P3 and P4. The overall GCA status for the ten agronomical traits studied showed that P5, P3, P1 and P2 are higher general combiners. Hybrids P3xP5, P5xP6, P2xP3, P5xP7 and P2xP7 produced higher total overall SCA, however, some produced more dominance on a particular trait than others. Both positive and negative heterosis for mid-parent, standard and better parent were also observed.*

KEYWORDS: rice, yield, combining ability, heterois.

INTRODUCTION

Rice is considered the most important staple crop in the world with Africa accounting for one-third of global rice imports due to high population growth rate and rapid urbanization (Macauley and Ramadjita, 2015). Rice production in the world has witnessed considerable increase in the last two decades due mainly to improved technology such as high yielding varieties and better crop management practices (Seck *et al*., 2012). Rice consumption is growing faster than that of any other major staple on the continent with demand expected to continue in the foreseeable future (Seck *et al*., 2013).

Over the last decade, Nigeria has witnessed improvements in rice varieties with evidences of success in the development of early maturing varieties having higher grain yield, better grain quality, high milling recovery and nutrient content much more than what was obtained in the local unimproved varieties, as is evident in the improved FARO lines (Oluwaseyi *et al*., 2016). These improvement programs are always targeted towards an area of need in a particular environment or to tackle a prevailing problem in a crop of interest. In spite of the strides achieved so far in rice breeding, further and speedy improvement of rice varieties in Nigeria are imperative but have been hampered by a number of constraints and several factors militating against rice production/processing such as low yielding varieties, late maturing varieties, among other factors (Oluwaseyi *et al*., 2016, Dimkpa *et al*., 2015).

The need to increase yield has become a top priority with potential for sustainable development in terms of ensuring food security and social stability in sub-Saharan Africa. Therefore, this study was undertaken to determine the combining ability estimates and heterosis for yield and yield components in rice (*Oryza sativa* L.) in Nigeria**.**

LITERATURE REVIEW

Development of high yielding varieties depends upon the amount of genetic variability inherent in the cultivars which is an essential component for breeding and in selecting desirable genetic material (Atlin, 2003). Genetic variability in crops provides an array of genotypes that can be selected which depends on the amount and direction of genetic association of the traits in the base population. In other words, the genetic improvement of any breeding population mainly depends upon the amount of genetic variability present (Govindaraj *et al*., 2015). Therefore, success of plant breeding activities entirely depends on the existence of genetic variability with respect to desired traits in the plant population to enhance the adoption of appropriate breeding strategies for the utilization of their inherent potential (Efisue *et al*., 2009; Adhikari *et al*., 2018).

Information on combining ability and heterosis of parents and crossings is crucial in breeding efforts. Genetic variety is crucial to the effectiveness of yield improvement efforts because it helps to broaden gene pools in any given crop population. General combining ability (GCA) is a measure of additive gene activity that relates to the average performance of a genotype in a series of hybrid combinations, whereas specific combining ability (SCA) is the performance of a parent in a specific cross in reference to general combining ability, in otherwords, SCA is linked to the genes' dominance and epistatic effects (non-additive effects) (Ali *et al.*, 2014). Estimations of general and specific combining ability can help with parent selection. The ability of parents (GCA) and hybrids (SCA) to combine traits is used to reveal the nature of gene activity involved in the inheritance of features (Gupta *et al.*, 2011; Begna, 2021).

The exploitation of heterosis is considered an outstanding application of the principles of the science of genetics in agriculture as it has led to a breakthrough in yield in several crop plants. The expression of heterosis is greatly influenced by the magnitude of genetic differences among parents involved in the crosses (Barhate *et al.*, 2021).

METHODOLOGY

Seven parents obtained from National Cereal Research Institute Badeggi (NCRI) name (1) FARO 26 (2) FARO 64 (3) FARO 57 (4) FARO 33 (5) FARO 66 (6) FARO 44 (7) FARO 31. Passport information on parents (Table 1) used for crosses were also obtained. The parents were planted and crossed in all possible combinations to obtain F1 hybrids (excluding reciprocals). The parents and 21 F1 hybrids were planted across three locations using a randomized complete block design with three replications to evaluate their performance. The land was cleared and harrowed manually, 3 – 5 seeds were planted and later thinned to 2 seedlings per planting hole at spacing of 20 x 20cm manual weed control with hoe were carried out. Fertilizer application at the rate of 200 kg/ha N, 60kg/ha P_2O_5 and 60kg/ha K_2O (Terres and Geraldi, 2007).

Parameters assessed include plant height, days to 50% heading, panicle lengths, panicle weights, number of seeds per panicle, number of productive tillers, number of panicle branches, yield per plot (also extrapolated to yield in tones per hectare) 100 seed weights. Diallel analysis in line with Griffinga (1956) model II and method II that is parents and F1 hybrids excluding reciprocals.

Table 1: Passport information on parents used for crosses. (1) FARO 26 (2) FARO 64 (3) FARO 57 (4) FARO 33 (5) FARO 66 (6) FARO 44 (7) FARO 31

Variety Name	National Code	Original Name	Outstanding Characteristics	Origin/Source	Developing Institute
FARO 44	NGOS-91-44	SIPI-692033	• Good cooking qualities • Tolerant to iron toxicity • Stress tolerant • Lower breakage characteristic • Resistant to blast disease	Taiwan	WARDA/IITA/NCRI
FARO 64	NGOS-15-69	ART15-7-16-38-1-B-B-2	• Early maturing • High yielding • Drought tolerance	Africa Rice	Africa Rice Centre and NCRI
FARO 33	NGOS-91-33	FAROX-233-1-1-1	• Long grain type	Nigeria (NCRI)	NCRI, Bida
FARO 66	NGOS-17-71	ART351:2-2-B-5-B	• Submergence tolerant • High yielding • Long and medium slender grains and • Moderately tolerant to iron toxicity	Africa Rice	Africa Rice Centre and NCRI, Badeggi
FARO 31	NGOS-91-31	FAROX-228-3-1-1	• Medium grain type	Nigeria (NCRI)	NCRI, Bida
FARO 57	NGOS-05-57	TOX4004-43-1-2-1	• High yielding • Medium maturing • Long slender grains • Resistant to blast disease • Resistant to drought • Resistant iron toxicity and • Resistance to rice yellow mottle virus disease • Good cooking quality	WARDA/IITA	NCRI, Badeggi, Ibadan
FARO 26	NGOS-91-26	TOS-78	• Medium grain type • High tillering ability	Nigeria (NCRI)	FDAR (NCRI)

RESULTS

From the results obtained, table 2 shows mean performance for ten quantitative traits studied among parents and their hybrids while table 3 shows mean squares of general combining ability (GCA) and specific combining ability (SCA) of seven rice parents and their hybrids for the ten quantitative traits across three locations. Additive variance was shown to predominate for plant heights and productive tillers as seen in genetic parameters for the ten quantitative traits of seven rice lines and their hybrids across three locations (Table 4). Table 5 shows GCA of each parent for quantitative traits studied while table 6 shows SCA of hybrids for each traits studied. Whereas table 7 shows overall GCA status for the ten agronomical traits studied, table 8 shows overall SCA of all the hybrids studied. Tables 9, 10, 11 shows both positive and negative heterosis for mid-parent, standard and better parent among 21 crosses of rice across the three locations

Table 2: Mean Performance for the Ten Quantitative Parameters Studied among the Seven Rice Parents and their Hybrids across three Locations

Entries	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle Weight (g)	Seed per Panicle	Productive Tillers	Panicle Branches	Yield per Plot (kg/ha)	Yield per Hectare (t/ha)	Grain Weight (g)
P1	100.11	79.56	25.33	2.90	101.67	25.11	10.00	1795.11	4.49	3.00
P1xP2	89.44	93.22	25.89	2.92	154.11	16.00	12.22	1989.67	4.97	2.87
P1xP3	105.00	103.44	27.89	3.00	183.78	17.67	10.00	2055.78	5.14	3.03
P1xP4	97.44	96.44	27.89	2.92	166.56	16.00	10.00	1861.67	4.65	2.90
P1xP5	103.56	100.22	30.33	3.58	168.56	20.22	11.78	2474.00	6.14	3.20
P1xP6	98.89	81.11	27.89	3.06	158.89	16.78	10.00	1963.33	4.85	2.53
P1xP7	97.78	97.89	27.89	3.32	199.22	16.00	10.00	1899.89	4.75	2.57
P2	84.00	98.67	25.89	3.00	144.33	13.22	12.11	1895.00	4.74	2.77
P2xP3	91.33	113.11	29.89	4.09	187.44	11.89	10.00	2312.56	5.78	2.57
P2xP4	90.78	95.00	27.67	2.94	154.33	15.67	10.00	2371.78	5.93	2.77
P2xP5	92.56	120.44	30.00	3.27	167.67	16.44	12.00	2345.56	5.87	3.07
P2xP6	89.67	86.11	27.89	3.28	156.00	12.22	10.00	1909.44	4.77	2.57
P2xP7	91.44	98.89	27.89	3.49	198.22	14.67	10.00	2336.33	5.85	2.60
P3	108.00	113.00	29.67	4.18	189.22	12.00	8.89	2040.33	5.09	2.60
P3xP4	96.00	93.67	28.44	3.50	169.89	14.33	10.00	2453.89	6.13	2.60
P3xP5	107.56	119.00	29.89	4.46	170.11	16.33	11.89	2776.67	6.95	2.87
P3xP6	97.89	90.78	27.89	3.43	176.11	12.22	9.11	2277.67	5.69	2.63
P3xP7	96.44	93.33	28.89	3.58	197.33	14.00	10.00	2392.00	5.98	2.70
P4	96.11	91.33	27.89	2.86	158.56	15.44	10.00	2103.33	5.26	2.63
P4xP5	101.11	125.78	30.44	3.99	170.89	16.67	11.78	2614.11	6.54	3.23
P4xP6	96.56	86.89	28.00	3.14	159.78	12.44	10.00	2304.67	5.77	2.77
P4xP7	95.44	99.22	28.11	3.21	198.78	14.78	10.00	2487.78	6.22	2.77
P5	106.78	119.00	31.89	4.32	161.44	15.89	12.33	2347.33	5.86	3.03
P5xP6	97.67	90.44	29.11	3.46	166.89	14.44	10.00	2487.78	6.22	3.30
P5xP7	97.67	110.22	29.89	4.08	197.33	16.89	10.00	1936.33	4.85	2.70
P6	96.22	81.89	27.89	3.19	155.56	12.00	9.00	1974.78	4.94	2.73
P6xP7	93.22	92.44	28.00	3.41	190.89	14.67	10.00	1888.44	4.72	2.73
P7	95.22	98.89	28.00	3.36	199.22	13.56	10.00	1964.67	4.91	2.87
Min	83.00	78.00	24.00	2.50	99.00	11.00	7.00	1704.00	4.26	2.40
Max	112.00	130.00	33.00	4.60	203.00	26.00	13.00	2886.00	7.22	3.40
Mean	96.92	98.93	28.44	3.43	171.53	15.27	10.40	2187.85	5.47	2.81
HSD	1.85	2.42	0.66	0.29	5.15	1.65	0.49	8.77	0.10	0.00
CV %	0.62	0.79	1.30	2.70	1.69	3.50	2.63	0.13	0.59	0.00

Key: P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

Table 3: Mean Square of General and Specific Combining Ability of Seven Rice Parents and their Hybrids for Ten Quantitative Traits across three Locations

Parameters	**General Combining Ability (GCA)**	**Specific Combining Ability (SCA)**	**GCAxL**	**SCAxL**	**Residuals**
Days to 50% flowering	1185.658	43.326	2.751	3.451	0.359
Plant height (cm)	4811.142	418.195	0.979	1.425	0.616
Panicle length (cm)	68.583	4.865	0.205	0.122	0.138
Panicle weight (g)	6.843	0.510	0.056	0.039	0.009
Seed per panicle	13145.960	1726.081	8.364	7.260	8.354
Productive tillers	254.514	16.979	1.634	1.238	0.286
Panicle branches	29.407	3.317	0.040	0.025	0.075
Yield per plot	1432162.000	420987.200	55196.360	17217.660	8.058
Yield per hectare	9.061	2.619	0.337	0.107	0.001
Grain weight	0.993	0.266	0.046	0.032	0.000

L = Location

Global Journal of Agricultural Research
Vol.10, No.5, pp.10-27, 2022
Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Table 4: Genetic Parameters for the Ten Quantitative Traits of Seven Rice Lines and their Hybrids across three Locations

Parameters	Additive Variance (VA)	VAxE	Dominance Variance (VD)	VDxE	Narrow Sense Heritability (h2)	Broad Sense Heritability (H2)	Dominance Ratio
Days to 50% flowering	28.223	0.000	4.431	1.031	0.829	0.959	0.560
Plant height (cm)	108.479	0.000	46.308	0.270	0.697	0.994	0.924
Panicle length (cm)	1.571	0.006	0.527	0.000	0.701	0.936	0.819
Panicle weight (g)	0.156	0.001	0.052	0.010	0.683	0.913	0.820
Seed per panicle	281.945	0.082	190.980	0.000	0.586	0.982	1.164
Productive tillers	5.855	0.029	1.749	0.317	0.711	0.923	0.773
Panicle branches	0.644	0.001	0.366	0.000	0.593	0.930	1.066
Yield per plot	24029.539	2813.237	44863.286	5736.533	0.310	0.890	1.932
Yield per hectare	0.153	0.017	0.279	0.035	0.316	0.890	1.908
Grain weight	0.018	0.001	0.026	0.010	0.319	0.791	1.721

Global Journal of Agricultural Research
Vol.10, No.5, pp.10-27, 2022
Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Table 5: General Combining Ability Effects (gi) of each Parent for the Ten Quantitative Traits Studied

Parents	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle Weight (g)	Seed per Panicle	Productive Tillers	Panicle Branches	Yield per Plot (kg/ha)	Yield per Hectare (t/ha)	Grain Weight (g)
P1	1.882**	-6.665**	-1.009**	-0.312**	-15.309**	3.415**	0.092**	-185.363**	-0.473**	0.071**
P2	-6.908**	1.409**	-0.725**	-0.158**	-7.309**	-0.981**	0.586**	-49.721**	-0.122**	-0.055**
P3	3.870**	5.323**	0.522**	0.334**	10.099**	-1.302**	-0.489**	94.044**	0.236**	-0.095**
P4	-0.649**	-1.307**	-0.132**	-0.220**	-3.877**	-0.153ns	-0.155**	88.637**	0.226**	-0.017ns
P5	4.252**	12.520**	1.769**	0.451**	-0.877**	1.180**	0.993**	202.921**	0.506**	0.220**
P6	-1.007**	-11.097**	-0.330**	-0.139**	-5.840**	-1.709**	-0.674**	-80.215**	-0.203**	-0.051**
P7	-1.439**	-0.183ns	-0.095*	0.044*	23.111**	-0.450**	-0.353**	-70.302**	-0.171**	-0.073**
S. Error	**0.187****	**0.118**	**0.038**	**0.021**	**0.282**	**0.118**	**0.017**	**16.475**	**0.041**	**0.019**

Key: * = significant at 0.05 probability, ** = significant at 0.01 probability, P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

Table 6: Specific Combining Ability Effects of each Hybrid for the Ten Quantitative Traits Studied

Hybrids	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle Weight (g)	Seed per Panicle	Productive Tillers	Panicle Branches	Yield per Plot (kg/ha)	Yield per Hectare (t/ha)	Grain Weight (g)
P1xP2	-2.454**	-0.451**	-0.818**	-0.034ns	5.201**	-1.704**	1.148**	36.898ns	0.098ns	0.043ns
P1xP3	2.324**	5.858**	-0.065ns	-0.448**	17.460**	0.284ns	0.000ns	-40.756ns	-0.094ns	0.250**
P1xP4	-0.713**	5.488**	0.590**	0.029ns	14.213**	-2.531**	-0.333**	-229.460**	-0.568**	0.039ns
P1xP5	0.497*	-4.562**	1.133**	0.013ns	13.213**	0.358*	0.296**	268.590**	0.642**	0.102**
P1xP6	1.090**	-0.056ns	0.787**	0.081**	8.509**	-0.198ns	0.185**	41.059ns	0.062ns	-0.294**
P1xP7	0.411ns	5.809**	0.553**	0.165**	19.892**	-2.235**	-0.136**	-32.299ns	-0.071ns	-0.239**
P2xP3	-2.553**	7.451**	1.651**	0.487**	13.127**	-1.099**	-0.494**	80.380**	0.199**	-0.091**
P2xP4	1.411**	-4.031**	0.083ns	-0.103**	-6.009**	1.531**	-0.827**	145.009**	0.359**	0.032ns
P2xP5	-1.713**	7.586**	0.515**	-0.453**	4.324**	0.975**	0.025ns	4.503ns	0.015ns	0.094**
P2xP6	0.657**	-3.130**	0.503**	0.149**	-2.380**	-0.358*	-0.309**	-148.472**	-0.373**	-0.135**
P2xP7	2.867**	-1.265**	0.269**	0.177**	10.892**	0.827**	-0.630**	268.503**	0.675**	-0.080**
P3xP4	-4.145**	-9.278**	-0.386**	-0.039ns	-7.861**	0.519**	0.247**	83.355**	0.203**	-0.094**
P3xP5	2.509**	2.228**	-0.843**	0.245**	-10.639**	1.185**	0.988**	291.849**	0.737**	-0.065*
P3xP6	-1.898**	-2.377**	-0.744**	-0.187**	0.324ns	-0.037ns	-0.124**	75.985**	0.191**	-0.028ns
P3xP7	-2.911**	-10.735**	0.022ns	-0.226**	-7.404**	0.482**	0.444**	180.404**	0.453**	0.061*
P4xP5	0.583*	15.636**	0.367**	0.332**	4.114**	0.370*	0.543**	134.701**	0.338**	0.224**
P4xP6	1.287**	0.364*	0.022ns	0.078**	-2.034**	-0.963**	0.432**	108.392**	0.285**	0.028ns
P4xP7	0.608*	1.784**	-0.102*	-0.038ns	8.015**	0.111ns	0.111**	281.590**	0.700**	0.050ns
P5xP6	-2.503**	-9.907**	-0.769**	-0.282**	2.077**	-0.296ns	-0.716**	177.219**	0.454**	0.324**
P5xP7	-2.071**	-1.043**	-0.225**	0.157**	3.571**	0.889**	-1.037**	-384.139**	-0.952**	-0.254**
P6xP7	-1.256**	4.796**	-0.015ns	0.081**	2.090**	1.556**	0.630**	-148.892**	-0.369**	0.050ns
S. Error	**0.545**	**0.344**	**0.111**	**0.062**	**0.821**	**0.345**	**0.050**	**47.915**	**0.119**	**0.056**

Key: * = significant at 0.05 probability, ** = significant at 0.01 probability, P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

Table 7: Overall general combining ability status for 10 agronomic characteristics of seven rice parental lines

Parents	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle Weight (g)	Seed per Panicle	Productive Tillers	Panicle Branches	Yield per Plot (kg/ha)	Yield per Hectare (t/ha)	Grain Weight (g)	Total Score
P1	4	7	6	5	3	7	1	1	6	4	44
P2	7	3	5	3	7	3	5	3	1	3	40
P3	5	6	4	6	2	5	4	7	5	6	50
P4	1	2	2	4	5	1	2	6	4	1	28
P5	6	5	7	7	1	4	7	2	7	7	53
P6	2	4	3	2	6	6	6	5	3	2	39
P7	3	1	1	1	4	2	3	4	2	5	26
Norm											**40**

Key: P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

Table 8: Overall specific combining ability status for 10 agronomic characteristics of seven rice parental lines

Parents	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle Weight (g)	Seed per Panicle	Productive Tillers	Panicle Branches	Yield per Plot (kg/ha)	Yield per Hectare (t/ha)	Grain Weight (g)	Total Score
P1xP2	15	3	18	3	9	19	21	3	5	5	101
P1xP3	14	17	4	19	20	4	1	4	4	18	105
P1xP4	6	15	14	2	19	21	10	16	16	4	123
P1xP5	2	13	20	1	18	6	8	18	17	14	117
P1xP6	7	1	17	7	14	3	6	5	2	20	82
P1xP7	1	16	13	12	21	20	5	2	3	17	110
P2xP3	18	18	21	21	17	15	13	7	7	11	148
P2xP4	10	12	5	9	10	17	18	11	11	3	106
P2xP5	11	19	12	20	8	14	2	1	1	12	100
P2xP6	5	11	11	10	5	7	9	12	13	15	98
P2xP7	19	5	8	13	16	11	16	17	18	10	133
P3xP4	21	20	10	5	12	10	7	8	8	13	114
P3xP5	17	9	19	16	15	16	19	20	20	9	160
P3xP6	12	10	15	14	1	1	4	6	6	2	71
P3xP7	20	7	2	15	11	9	12	15	14	8	113
P4xP5	3	8	9	18	7	8	14	10	10	16	103
P4xP6	9	2	3	6	2	13	11	9	9	1	65
P4xP7	4	6	6	4	13	2	3	19	19	6	82
P5xP6	16	21	16	17	3	5	17	14	15	21	145
P5xP7	13	4	7	11	6	12	20	21	21	19	134
P6xP7	8	14	1	8	4	18	15	13	12	7	100
Norm											110

Key: P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

Global Journal of Agricultural Research
Vol.10, No.5, pp.10-27, 2022
Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Table 9: Heterosis for Plant Height, Days to 50% Flowering and Panicle Length among 21 Crosses of Rice across three Locations

	Plant Height (cm)						**Days to 50% Flowering**						**Panicle Length (cm)**					
Crosses	MID.HET		BET.HET		STD.HET		MID.HET		BET.HET		STD.HET		MID.HET		BET.HET		STD.HET	
P1xP2	4.62	**	-5.52	**	-5.73	**	-2.84	**	-10.65	**	-6.07	**	1.09	ns	0.00	ns	-7.54	**
P1xP3	7.44	**	-8.46	**	4.61	**	0.91	ns	-2.78	**	10.27	**	1.42	*	-5.99	**	-0.39	ns
P1xP4	12.87	**	5.59	**	-2.47	**	-0.68	ns	-2.66	**	2.33	*	4.80	**	0.00	ns	-0.39	ns
P1xP5	0.95	*	-15.78	**	1.35	*	0.11	ns	-3.02	**	8.75	**	6.02	**	-4.88	**	8.33	**
P1xP6	0.48	Ns	-0.95	ns	-17.98	**	0.74	ns	-1.22	ns	3.85	**	4.80	**	0.00	ns	-0.39	ns
P1xP7	9.71	**	-1.01	ns	-1.01	ns	0.11	ns	-2.33	**	2.68	**	4.59	**	-0.39	ns	-0.39	ns
P2xP3	6.88	**	0.10	ns	14.38	**	-4.86	**	-15.43	**	-4.08	**	7.60	**	0.75	ns	6.75	**
P2xP4	0.00	Ns	-3.72	**	-3.93	**	0.81	ns	-5.55	**	-4.67	**	2.90	**	-0.79	ns	-1.18	ns
P2xP5	10.67	**	1.22	**	21.80	**	-2.97	**	-13.32	**	-2.80	**	3.84	**	-5.93	**	7.14	**
P2xP6	-4.61	**	-12.72	**	-12.92	**	-0.49	ns	-6.81	**	-5.84	**	3.72	**	0.00	ns	-0.39	ns
P2xP7	0.11	Ns	0.00	ns	0.00	ns	2.05	*	-3.97	**	-3.97	**	3.51	**	-0.39	ns	-0.39	ns
P3xP4	-8.32	**	-17.11	**	-5.28	**	-5.93	**	-11.11	**	0.82	ns	-1.16	*	-4.12	**	1.58	*
P3xP5	2.59	**	0.00	ns	20.34	**	0.15	ns	-0.41	ns	12.95	**	-2.89	**	-6.27	**	6.75	**
P3xP6	-6.84	**	-19.67	**	-8.20	**	-4.14	**	-9.36	**	2.80	**	-3.09	**	-5.99	**	-0.39	ns
P3xP7	-11.91	**	-17.41	**	-5.62	**	-5.09	**	-10.70	**	1.28	ns	0.20	ns	-2.62	**	3.18	**
P4xP5	19.60	**	5.70	**	27.20	**	-0.33	ns	-5.31	**	6.18	**	1.85	**	-4.54	**	8.73	**
P4xP6	0.32	Ns	-4.86	**	-12.13	**	0.40	ns	0.35	ns	1.40	ns	0.39	ns	0.39	ns	0.00	ns
P4xP7	4.32	**	0.34	ns	0.34	ns	-0.23	ns	-0.69	ns	0.23	ns	0.59	ns	0.39	ns	0.39	ns
P5xP6	-9.95	**	-24.00	**	-8.54	**	-3.78	**	-8.53	**	2.57	**	-2.61	**	-8.72	**	3.96	**
P5xP7	1.17	**	-7.38	**	11.46	**	-3.31	**	-8.54	**	2.56	**	-0.18	ns	-6.27	**	6.75	**
P6xP7	2.28	**	-6.51	**	-6.51	**	-2.61	**	-3.12	**	-2.10	*	0.20	ns	0.00	ns	0.00	ns
S. Error	**0.47**		**0.54**		**0.54**		**0.74**		**0.86**		**0.86**		**0.15**		**0.18**		**0.18**	

Key: * = significant at 0.05 probability, ** = significant at 0.01 probability, P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

Table 10: Heterosis for Panicle Weight (g), Seed per Panicle and Productive Tillers among 21 Crosses of Rice across three Locations

	Panicle Weight (g)						**Seed per Panicle**						**Productive Tillers**					
Crosses	MID.HET		BET.HET		STD.HET		MID.HET		BET.HET		STD.HET		MID.HET		BET.HET		STD.HET	
P1xP2	-1.02	ns	-2.67	ns	-13.01	**	25.29	**	6.77	**	-22.64	**	-16.52	**	-36.28	**	18.02	**
P1xP3	-15.21	**	-28.17	**	-10.63	**	26.35	**	-2.88	**	-7.75	**	-4.79	ns	-29.64	**	30.32	**
P1xP4	1.62	ns	0.80	ns	-12.91	**	28.01	**	5.05	**	-16.40	**	-21.09	**	-36.28	**	18.02	**
P1xP5	-0.97	ns	-17.27	**	6.55	*	28.12	**	4.41	**	-15.39	**	-1.35	ns	-19.46	**	49.18	**
P1xP6	0.38	ns	-4.18	ns	-8.94	**	23.54	**	2.14	*	-20.25	**	-9.57	**	-33.17	**	23.78	**
P1xP7	6.23	*	-0.99	ns	-0.99	ns	32.42	**	0.00	ns	0.00	ns	-17.24	**	-36.28	**	18.02	**
P2xP3	13.98	**	-2.08	ns	21.85	**	12.39	**	-0.94	ns	-5.91	**	-5.72	ns	-10.08	*	-12.29	**
P2xP4	0.68	ns	-1.78	ns	-12.21	**	1.91	*	-2.66	**	-22.53	**	9.30	**	1.45	ns	15.56	**
P2xP5	-10.79	**	-24.44	**	-2.68	ns	9.67	**	3.85	**	-15.84	**	12.96	**	3.48	ns	21.29	**
P2xP6	5.87	*	2.72	ns	-2.38	ns	4.04	**	0.29	ns	-21.70	**	-3.11	ns	-7.59	ns	-9.86	*
P2xP7	9.81	**	3.97	ns	3.97	ns	15.39	**	-0.50	ns	-0.50	ns	9.53	**	8.19	*	8.19	*
P3xP4	-0.43	ns	-16.20	**	4.27	ns	-2.30	**	-10.22	**	-14.73	**	4.46	ns	-7.19	*	5.73	ns
P3xP5	4.86	*	3.08	ns	32.77	**	-2.98	**	-10.10	**	-14.61	**	17.13	**	2.79	ns	20.48	**
P3xP6	-6.79	**	-17.80	**	2.28	ns	2.16	**	-6.93	**	-11.60	**	1.86	ns	1.86	ns	-9.84	*
P3xP7	-4.96	*	-14.29	**	6.65	*	1.60	**	-0.95	ns	-0.95	ns	9.56	*	3.27	ns	3.27	ns
P4xP5	11.10	**	-7.79	**	18.77	**	6.80	**	5.85	**	-14.22	**	6.38	*	4.89	ns	22.94	**
P4xP6	4.14	ns	-1.36	ns	-6.26	*	1.73	*	0.77	ns	-19.80	**	-9.32	**	-19.43	**	-8.21	*
P4xP7	3.38	ns	-4.37	ns	-4.37	ns	11.12	**	-0.22	ns	-0.22	ns	1.91	ns	-4.32	ns	9.00	*
P5xP6	-7.99	**	-20.05	**	2.98	ns	5.29	**	3.37	**	-16.23	**	3.57	ns	-9.10	**	6.54	ns
P5xP7	6.25	**	-5.63	*	21.55	**	9.43	**	-0.95	ns	-0.95	ns	14.69	**	6.27	ns	24.56	**
P6xP7	4.18	ns	1.59	ns	1.59	ns	7.61	**	-4.18	**	-4.18	**	14.78	**	8.19	*	8.19	*
S. Error	**0.08**		**0.10**		**0.10**		**1.12**		**1.29**		**1.29**		**0.47**		**0.54**		**0.54**	

Key: * = significant at 0.05 probability, ** = significant at 0.01 probability, P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

Table 11: Heterosis for Panicle Branches, Yield per Plot (kg/ha) and Yield per Hectare (t/ha) among 21 Crosses of Rice across three Locations

	Panicle Branches						**Yield per Plot (kg/ha)**						**Yield per Hectare (t/ha)**					
Crosses	MID.HET		BET.HET		STD.HET		MID.HET		BET.HET		STD.HET		MID.HET		BET.HET		STD.HET	
P1xP2	10.54	**	0.91	ns	22.20	**	7.84	*	5.00	ns	1.27	ns	7.77	*	4.93	ns	1.29	ns
P1xP3	5.88	**	0.00	ns	0.00	ns	7.20	*	0.76	ns	4.64	ns	7.17	*	0.79	ns	4.62	ns
P1xP4	0.00	ns	0.00	ns	0.00	ns	-4.49	ns	-11.49	**	-5.24	ns	-4.58	ns	-11.60	**	-5.23	ns
P1xP5	5.51	**	-4.46	**	17.80	**	19.45	**	5.40	ns	25.92	**	18.69	**	4.78	ns	25.14	**
P1xP6	5.26	**	0.00	ns	0.00	ns	4.16	ns	-0.58	ns	-0.07	ns	3.04	ns	-1.62	ns	-1.09	ns
P1xP7	0.00	ns	0.00	ns	0.00	ns	1.06	ns	-3.30	ns	-3.30	ns	1.14	ns	-3.19	ns	-3.19	ns
P2xP3	-4.76	**	-17.42	**	0.00	ns	17.53	**	13.34	**	17.71	**	17.60	**	13.48	**	17.80	**
P2xP4	-9.54	**	-17.42	**	0.00	ns	18.64	**	12.76	**	20.72	**	18.57	**	12.67	**	20.79	**
P2xP5	-1.80	**	-2.68	**	20.00	**	10.58	**	-0.08	ns	19.39	**	10.66	**	0.06	ns	19.50	**
P2xP6	-5.26	**	-17.42	**	0.00	ns	-1.32	ns	-3.31	ns	-2.81	ns	-1.41	ns	-3.38	ns	-2.85	ns
P2xP7	-9.54	**	-17.42	**	0.00	ns	21.06	**	18.92	**	18.92	**	21.33	**	19.23	**	19.23	**
P3xP4	5.88	**	0.00	ns	0.00	ns	18.44	**	16.67	**	24.90	**	18.42	**	16.54	**	24.93	**
P3xP5	12.06	**	-3.57	**	18.90	**	26.57	**	18.29	**	41.33	**	26.84	**	18.54	**	41.58	**
P3xP6	1.84	*	1.22	ns	-8.90	**	13.45	**	11.63	**	15.93	**	13.50	**	11.71	**	15.96	**
P3xP7	5.88	**	0.00	ns	0.00	ns	19.45	**	17.24	**	21.75	**	19.67	**	17.47	**	21.94	**
P4xP5	5.51	**	-4.46	**	17.80	**	17.47	**	11.37	**	33.06	**	17.57	**	11.55	**	33.22	**
P4xP6	5.26	**	0.00	ns	0.00	ns	13.03	**	9.57	**	17.31	**	13.28	**	9.76	**	17.66	**
P4xP7	0.00	ns	0.00	ns	0.00	ns	22.31	**	18.28	**	26.63	**	22.36	**	18.25	**	26.77	**
P5xP6	-6.24	**	-18.90	**	0.00	ns	15.12	**	5.98	ns	26.63	**	15.32	**	6.20	ns	26.83	**
P5xP7	-10.43	**	-18.90	**	0.00	ns	-10.19	**	-17.51	**	-1.44	ns	-9.91	**	-17.24	**	-1.15	ns
P6xP7	5.26	**	0.00	ns	0.00	ns	-4.13	ns	-4.37	ns	-3.88	ns	-4.00	ns	-4.26	ns	-3.74	ns
S. Error	**0.07**		**0.08**		**0.08**		**65.38**		**75.49**		**75.49**		**0.16**		**0.19**		**0.19**	

Key: * = significant at 0.05 probability, ** = significant at 0.01 probability, P1 = FARO 26, P2 = FARO 64, P3 = FARO 57, P4 = FARO 33, P5 = FARO 66, P6 = FARO 44, P7 = FARO 31,

DISCUSSION

Exploiting from diallel analysis in rice breeding has been generally conducted to evaluate combining ability for quantitative traits. Estimation of genetic parameters such as heritability and combining abilities inferences about the predominant actions of genes, indicates appropriate selection strategy to be applied in breeding programme and allow identification of best parents (Torres and Geraldi, 2007).

Table 2 showed mean performance for ten quantitative traits studied among parents and their hybrids. P5 (FARO 66) produced significantly higher mean in terms of yield 5.86 tonnes per hectare followed by P4 (FARO 33), P3 (FARO 57), P6 (FARO 44), P7 (FARO 31), P2 (FARO 64) and P1 (FARO 26) with 5.26 t/ha, 5.09 t/ha, 4.94 t/ha, 4.91 t/ha, 4.74 t/ha and 4.49 t/ha across three locations studied. Significantly higher yields in tonnes per hectare was produced by Hybrids P1xP5 (6.14), P3xP6 (6.13), P4xP7 (6.22), P3xP5 (6.95) compared to their parental means. Similarly, significant difference were recorded in all other traits studied among parents and hybrids.

Table 3 showed general combining ability (GCA) and specific combining ability (SCA). GCA means squares were significantly higher than SCA means squares for most of the traits studied indicating preponderance additive gene action which is similar to findings of Ojo *et al.* (2007).

Additive variance was shown to predominate for plant heights and productive tillers (Table 4) which indicates that genetic gain for such trait will be possible (Bagheri *et al.*, (2008). Dominance was found to be higher in yield per plants which indicates that heterosis might result due to dominance effect in recessive genes (Singh, 2013). Narrow sense heritability was found to be higher on days to flowering, plant heights, panicle length and productive tillers indicates that selection progress can be made in improving yield based on these traits (Fischer, 2001; Abdullah, 2009; Breseghello and Coelho, 2013).

Table 5 showed general combining ability of each parent for quantitative traits studied. Low and negative values produced for days to 50% heading implies that earlier maturity desired in breeding programmes in rice cultivars hence parent 4 (P4) can be exploited for these trait. The effect of plant height for combining ability was found to be higher in parent 5 (P5) hence, increasing this important component for yield. Similarly, panicle length was found be higher and positive in P5. Yield in general was found to be significantly higher for combining ability in parents (P5), P3 and P4 indicating that exploiting such parents can bring about positive increase in yield generally (Patel *et al.*, 2015). Viana and Matta (2003) reported a similar result and asserted that the SCA is a relative performance of a cross that is associated with non-additive gene action predominantly dominance epistasis or genotype by environmental interaction. The results also corresponds with findings of Zainab *et al.* (2014) who also indicated that significant higher SCA variance effect controlling certain traits studied showed that there was preponderance of non-additive gene action for such traits. Similarly, the results are also in agreement with the findings of Bano and Singh (2019) and Hassan *et al.* (2013). SCA are useful in identifying crosses with desirable traits (Acquaah, 2009).

Table 6 showed specific combining ability of hybrids for each traits studied. For each significant positive and negative SCA was observed indicating high and low values of SCA for such trait respectively. Higher values of SCA for a given trait is indicating prevalence of dominant gene effect for that trait hence, selecting or exploiting such traits is best suited for heterosis breeding Reif *et al.* (2007) in their study reported higher GCA effects indicating additive allelic effect. GCA is directly related to the breeding value of parents and is associated with addition of genetic effect. Hence, higher GCA observed in this study indicate breeding value associated to genetic effect.

Overall GCA status for the ten agronomical traits studied (Table 7) showed that P5 (53), P3 (50), P1 (44) and P2 (40) are higher general combiners respectively. Therefore, additive genetic gain can be exploited from these parents. A better understanding of combining ability can provide guidance for using them more effectively in crop improvement and hybrid performance. Combining ability has been applied extensively in hybrid breeding program and have been commonly estimated using diallel cross mating design (Liu *et al.*, 2004).

Hybrids P3xP5, P5xP6, P2xP3, P5xP7 and P2xP7 produced higher total overall SCA respectively (Table 8) which indicates that dominance gene effect are predominant in these hybrids. However, some hybrids produced more dominance on a particular traits than others. For instance, P3xP4 has more dominant effect on plant height, P1xP5 produced higher dominant effect on panicle lengths. These information can be exploited in choosing a breeding programme for a particular trait of interest. P3xP5, P4xP7 and P1xP5 have higher dominant effect on yield respectively (Roy and Senapati, 2012; Zhou *et al.*, 2012).

Tables 9, 10, 11 showed both positive and negative heterosis for mid-parent, standard and better parent. Positive signifying a better performance than parents while negative signifying a downward performance compared to parents (Borah *et al.*, 2017). Positive heterosis is an indication that yield advantage using hybrids compared to parents is achievable (Barhate *et al.*, 2021). The higher the vigour of hybrids compared to their parents was defined (Acquaah, 2009).

CONCLUSION

In conclusion, parents and their F1 hybrids differ significantly in most of the traits studied. There was preponderance of additive gene effects due to positively higher GCA for the traits studied, hence such parents can be exploited for increased yield in breeding programs. High SCA as seen in the F1 hybrids indicates prevalence of dominance. Gene effect for such a trait is best suited for heterosis breeding. Additive genetic gain can be exploited from parents P5, P3, P1 and P2 since they show higher GCA for the traits studied. Although, dominance effects were predominantly seen in hybrids P3xP5, P5xP6, P2xP3, P5xP7, P2xP7 due to their higher total overall SCA, some hybrids produced more dominance on a particular trait than others. This information can be exploited in choosing a breeding program for a particular trait of interest. Positive heterosis is an indication that advantage can be derived by using hybrids compared to their parents. Genetic variance studied will also help to determine selection for such traits in that high additive variance, dominance variance and heritability will aid selection of a given trait of interest.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the management of the National Cereal Research Institute Baddegi Niger State Nigeria for providing the germplasm used for the research. Also want to acknowledge the management of the Federal University of Agriculture Zuru (FUAZ) for allowing their facilities to be used as screenhouse for the crosses and also their research farm as field for the experiment.

REFERENCES

Abdullah, B. (2009). Progress of rice improvement through recurrent selection. *Journal Agronomi Indonesia (Indonesian Journal of Agronomy), 37*(3).

Acquaah, G. (2009). *Principles of plant genetics and breeding*. John Wiley & Sons.

Adhikari, B.N., Pokhrel, B.B. and Shrestha, J. (2018). Evaluation and development of finger millet (*Eleusine coracana* L.) genotypes for cultivation in high hills of Nepal. Farming and Management, 3(1), 37- 46.

Bagheri, N., Jelodar, N.B. and Ghanbari, A. Diallel analysis study of yield and yield related traits in rice genotypes. *International Journal of Agricultural Research*, 3: 386 – 396.

Bano, D. A. and Singh, S. P. (2019). Combining ability studies for yield and quality traits in aromatic genotypes of rice (*Oryza sativa*. L.). *Electronic Journal of Plant Breeding, 10*(2), 341-352.

Barhate, K.K., Borole, D.N. and Misal, R.A. (2021). Heterosis for yield and yield contributing characters in rice (*Oryza sativa* L.). *J. Pharmacogn. Phytochem*, *10*, 384-389.

Begna, T. (2021). Combining ability and heterosis in plant improvement. *Open J Plant Sci* 6(1): 108-117.

Borah, P.U. L. I. N., Sarma, D. E. B. O. J. I. T., & Hazarika, G. N. (2017). Magnitude of heterosis for yield and its components in hybrid rice (Oryza sativa L.). *International Journal of Agricultural Science and Research*, *7*(2), 209-216.

Breseghello, F., and Coelho, A.S.G. (2013). Traditional and modern plant breeding methods with examples in rice (Oryza sativa L.). *Journal of agricultural and food chemistry*, *61*(35), 8277-8286.

Dimkpa, S.O.N. *et al.* (2015). A genome-wide association study of a global rice panel reveals resistance in Oryza to root-knot nematodes. *Journal of Experimental Botany*, 67 (4): 1191-1200.

Efisue, A.A. *et al.* (2009) Genetics of Morpho-Physiological Traits in Segregating Populations of Interspecific Hybrid Rice Under Stress and Non Stress Conditions. *Journal of Crop Improvement*, 23:383–401.

Fischer, R.A. (2001). Selection traits for improving yield potential. *Application of physiology in wheat breeding*, *13*, 148-159.

Griffings, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. *Australian J. of Biol. Science,* 9:463 – 497.

Gupta, D.K, Acharya, S. and Patel, J.B. (2011) Combining ability and heterosis studies in pigeonpea using A2 cytoplasm from Cajanus scarabaeoides as source of male sterility. *J Food Legumes* 24: 58-64.

Hasan, M.J. *et al.* (2013). Combining ability studies for developing new rice hybrids in Bangladesh. *Bangladesh Journal of Botany*, *42*(2), 215-222.

Liu, X.C. *et al.* (2004). Improvement of combining ability for restorer lines with the identified SSR markers in hybrid rice breeding. *Breeding science*, *54*(4), 341-346.

Medagam, T.R. *et al.* (2012). Heterosis for yield and yield components in okra (Abelmoschus esculentus (L.) Moench). *Chilean Journal of Agricultural Research*, *72*(3), 316.

Montazeri, Z., Babaeian, J.N. and Bagheri, N. (2014). Genetic dissection of some important agronomic traits in rice using line× tester method.

Ojo, G.O.S., Adedzwa, D.K. and Bello, L.L. (2007). Combining ability estimates and heterosis for grain yield and yield related components in maize (*Zea mays* L.). *Journal of Sustainable Development in Agriculture and Environment*, 3:20-30.

Oluwaseyi A.B., Nehemmiah D., and Zuluqurineen S.B. (2016). Genetic Improvement of Rice in Nigeria for Enhanced Yeild and Grain Quality - A Review. *Asian Research Journal of Agriculture* 1(3): 1-18.

Patel, V.J. *et al.* (2015). Combining ability analysis in rice (Oryza sativa L.). *BIOINFOLET-A Quarterly Journal of Life Sciences*, *12*(1b), 198-205.

Reif, J. C. *et al.* (2007). Impact of interpopulation divergence on additive and dominance variance in hybrid populations. *Genetics*, *176*(3), 1931-1934.

Roy, S. K. and Senapati, B. K. (2012). Combining ability analysis for grain yield and quality characters in rice (Oryza sativa). *Indian Journal of Agricultural Sciences*, *82*(4), 293-303.

Singh (2013). Plant breeding principles and methods. Kalyani publishers Ludhiana, New Delhi, India.

Torres, E.A. and Geraldi, I.O. Partial diallel analysis of agronomical characters in rice (*Oryza sativa* L.). *Genet. Mol. Biol.* 30:605-603.

Zhou, G. *et al.* (2012). Genetic composition of yield heterosis in an elite rice hybrid. *Proceedings of the National Academy of Sciences*, *109*(39), 15847-15852.