ESTIMATION OF HETEROSIS AND INBREEDING DEPRESSION IN QUANTITATIVE TRAITS OF RICE

(Oryza sativa L.)

Onyia¹, V.N., Obi,¹ I.U and Anyanwu² C. P
¹Department of Crop Science, University of Nigeria Nsukka
²Department of Crop Science and Technology, F.U.T.O

ABSTRACT
It is important to know the degree and direction of heterosis for its commercial exploitation. Heterosis and in-breeding depression were estimated in 8x8 half diallel crosses of rice. The planted materials consisted of eight parental inbred lines, their F₁ hybrids and F₂ populations using randomized complete block design with three replications. Data were collected on number of days to 50% flowering, plant height, number of tillers/plant, number of panicles/hill, panicle length, number of spikelets/panicle, number of fertile spikelets/panicle, number of days to maturity, 1000-seed weight and grain yield. Significant genetic differences were observed among the parents, their F₁ hybrids and F₂ populations for all the characters under study. Panicle length and number of spikelets/panicle showed highly significant heterosis in F₁ hybrids ranging from -6.1748 to 41.847% and -8.6957 to 41.847%, respectively while in breeding depression in the F₂ population ranged from -3.93 to 13.2231% and 3.6364 to 25.85% respectively. F₁ hybrids showed low level of heterosis in number of days to flowering (-11.25 to 11.95%), The parent WAB 450-1-B-163-41 proved itself to be a good general combiner by making higher contribution towards heterosis both in F₁ hybrids and in F₂ population.

Keywords: Genetic basis, Oryza sativa, hybrid vigor, quantitative traits, inbreeding depression

INTRODUCTION
Rice (Oryza sativa L.) is a well known cereal crop grown in almost every part of the world. Although, the plant is naturally self pollinated, strong heterosis is observed in their F₁ hybrids. The term heterosis was coined by Shull (1908) for quantitative measure of superiority of F₁ over its parents. The phenomenon of heterosis has been a powerful force in the evolution of plants and has been exploited extensively in crop production (Birchler et al., 2003). Heterosis in rice can often be poorly expressed as reported by some scientists (Mohammed and Mohanty 1992; Ram 1992, Virekananden and Giridheram 1995).

The phenomenon of heterosis has been observed in many self-pollinated crop species including several of the grain legumes. It is commonly found that the level of heterosis exhibited by a hybrid is a function of the genetic divergence between parents. Heterosis may be positive or negative. Depending on breeding objectives both positive and negative heterosis can be useful for crop improvement. Heterosis is a highly cross specific phenomenon. To successfully use heterosis in grain yield improvement, parental genotypes need to have a high yield potential. The exploration of hybrid vigor is widely recognized as the only readily available means to raise the genetic yield ceiling in areas where yields have already approached their potential. In this approach, developing highly heterotic rice hybrids with superior yield performance and evaluating them across environments are important. (Sitaramaiah et al., 1998). The project was initiated with the objectives to determine the heterotic effects in F₁ hybrids and the inbreeding of the plant behavior in both hybrid and selfed conditions.

MATERIALS AND METHODS
The research was conducted at the experimental field of the National Cereals Research Institute (NCRI), Amakanma sub-

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RESULTS AND DISCUSSION

The analysis of variance table presented in Table 1 show significant effect (P = 0.05) for the parameters studied except for number of tillers/plant, number of tillers/m² and number of panicle/hill which were non significant. In Table 2 is presented the mean performance of the twelve agronomic attributes of the eight size breeding lines used for the study. The results of the different morphological characters of the eight rice breeding lines, their twenty-eight hybrids and F2 populations are presented in Table 3.

In the present study, different cross combinations were tested in order to develop high yielding hybrid rice varieties and some were found to be promising. The stability of hybrids was checked through their performance in the F2 generation, and variable inbreeding depression was also observed for the studied traits in the different crosses.

Development of high yielding early maturing varieties is a highly desirable quality in most rice breeding programs. Among the twenty eight crosses, highly negative heterosis was observed in some crosses. While some of the crosses such as WAB 56-144-FX X WAB 56-100 and IRAT 317 x WAB 56-100 showed positive heterosis, others such as WAB 450-1-B-163-41 X WAB 35-2-FX and WAB 35-2-FX X IRAT 239 showed negative heterosis for both days to 50% flowering and number of days to maturity which suggests the possibility of developing early maturity lines from these combination. Negative heterosis for earliness was also reported by Khaleque et al., (1977) and Nuruzzaman et al., (2002) in rice.

The number of panicles is one of the components used in determining grain yield. There were increase in panicle number in these hybrids WAB 450-1-B-163-41 x IRAT 317, IRAT 317 x WAB 56-144-FX, WAB 35-1-FX x WAB 56-144-FX, IR 47-701-6-3-1 x WAB 35-2-FX, RAT 317 x IR 47-701-6-3-1, IRAT 317 x IRAT 239 and IR 47-701-6-3-1 x IRAT-239 which had 8 panicles/hill each and WAB 56-1-FX x WAB 35-2-FX that had 9 panicles/hill over their respective parents. Increase in panicle number was earlier observed by Singh et al. (1980), Anandakumah and Sree Rangasamy (1986). The results show that two crosses IRAT 317 x IRAT 239 and IR 47-701-6-3-1 x IRAT 239 showed highly significant positive heterosis values of 45% in panicle number per hill, respectively.
Table 1: Form of Analysis of variance showing sources of Variation, Degrees of Freedom and Mean Square Estimates of Eight Rice breeding lines for twelve (12) Plant Attributes.

| SV     | DF  | 50% | Plant ht | Tiller/plant | Tillers/M² | Panicles/hill | Panicles/M² | Panicle length | Spikelets/panicles | FS/P | DTM | GW | GY  |
|--------|-----|-----|----------|--------------|------------|---------------|--------------|---------------|-------------------|------|-----|----|-----|
| Block  | 3   | 2.083 | 2.57   | 5.583        | 6.948      | 10.417        | 54.88       | 6.38          | 631.2             | 347.7| 2.088| 1.616| 0.254|
| Genotypes | 7   | 214.2** | 936** | 8.500ns      | 5620ns     | 4.286ns       | 3346*       | 27.86*        | 14171**           | 7673*| 214.2**| 153.3**| 5.096|
| Error  | 21  | 2.179 | 17.99  | 4.345        | 0.970      | 3.464         | 1001        | 10.79         | 364.70            | 368.0| 2.179| 1.209| 0.0823|
| Total  | 31  |      |        |              |            |              |             |               |                   |      |      |     |     |

*psignificant at 5%, ** highly significant at 1%

Table 2. Mean Performance of the ten agronomic attributes of the eight rice breeding lines evaluated at the NCRI Umudike, Abia State.

| Genotypes Parents | Days to 50% Flowering | Plant height | No of Tillers/Plant | No of Tillers/M² | No of Panicles/Hill | No of Panicles/M² | Panicle length | No of Spikelets/Panicle | No of Fertile Spikelets/Panicle | No of Days to Maturity | 1000 Grain Weight | Grain Yield |
|--------------------|-----------------------|--------------|---------------------|------------------|---------------------|------------------|----------------|------------------------|--------------------------|----------------------|-----------------|------------|
| Grand mean         | 78.87                 | 92.25        | 10.88               | 275.4            | 6.25                | 164.50           | 24.58          | 128.40                 | 106.60                   | 108.87               | 30.58           | 3.681      |
| WAB 450-1-B-163-41 | 71                    | 103.22       | 11                  | 283              | 6                   | 145              | 24.53          | 272                    | 211                      | 101                 | 34.43           | 5.87       |
| IRAT 317           | 90                    | 86.70        | 12                  | 302              | 7                   | 195              | 21.98          | 96                     | 88                       | 120                 | 23.10           | 2.810      |
| WAB35-1-FX         | 84                    | 66           | 12                  | 310              | 7                   | 165              | 23.52          | 116                    | 91                       | 114                 | 39.33           | 3.850      |
| IR 47-701-6-3-1    | 85                    | 93.6         | 11                  | 282              | 7                   | 178              | 20.57          | 80                     | 71                       | 115                 | 22.87           | 2.310      |
| WAB35-2-FX         | 75                    | 77.44        | 13                  | 322              | 7                   | 205              | 24.00          | 126                    | 82                       | 105                 | 35.63           | 4.55       |
| WAB56-144-FX       | 76                    | 114.22       | 10                  | 255              | 6                   | 148              | 27.75          | 111                    | 102                      | 106                 | 33.26           | 3.570      |
| IRAT 239           | 81                    | 101.5        | 9                   | 227              | 4                   | 115              | 26.32          | 123                    | 108                      | 111                 | 25.23           | 2.850      |
| WAB 56-100         | 69                    | 95.33        | 9                   | 222              | 6                   | 165              | 27.98          | 111                    | 100                      | 99                  | 30.82           | 3.640      |
| F-LSD (P=0.05)     | 2.170                 | 6.237        | 3.065               | 80.14            | 2.737               | 46.52            | 4.830          | 28.08                  | 28.21                    | 2.170               | 1.67            | 0.4217     |
Table 3. Mean values of the agronomic characters of the parents, F₁’s, F₂’s, mid parent heterosis (% Het) for F₁ hybrids and Inbreeding depression (% ID for F₂ populations) in the rice breeding lines.

| Cro      | s    | Number of Days to 50 % flowering | Plant Height (cm) | Number of Tillers/plant | F₁  | F₁ %Het | %ID | F₂  | F₂ %Het | %ID |
|----------|------|----------------------------------|-------------------|-------------------------|-----|---------|-----|-----|---------|-----|
| WAB 450-1-B-163-41 | X    | 68                               | 68                | 68.849                  | 0   | 92.55   | 87.32| 2.457| 1.974   | 12  |
| WAB 450-1-B-163-41 | X    | 71                               | 72                | -3.4014                 | -1.4085| 115.2 | 109.4| 5.960| 5.034   | 12  |
| WAB 450-1-B-163-41 | X    | WAB 56-100                       | 70                | 71                      | -1.4085| 101   | 98.48| 0.950| 5.651   | 10  |
| WAB 450-1-B-163-41 | X    | WAB 56-144-FX                    | 74                | 74                      | -1.9868| 81.75| 77.44| -14.6| 5.272   | 13  |
| WAB 450-1-B-163-41 | X    | WAB 56-100                       | 73                | 73                      | 1.3889 | 81.03| 87.80| -6.204| -1.835  | 12  |
| WAB 450-1-B-163-41 | X    | WAB 56-144-FX                    | 75                | 73                      | 3.4483 | 110.7| 102.7| 5.678| 7.206   | 12  |
| WAB 450-1-B-163-41 | X    | IRAT 317                         | 81                | 81                      | 0.6211 | 98.70| 96.50| 3.938| 2.290   | 12  |
| WAB 450-1-B-163-41 | X    | WAB 35-1-FX                      | 74                | 75                      | -4.516 | 88.67| 78.07| 4.7985| 11.954  | 14  |
| WAB 450-1-B-163-41 | X    | IR 47-701-6-3-1                  | 78                | 78                      | 0      | 99.80| 97.50| 1.4125| 11.954  | 13  |
| WAB 450-1-B-163-41 | X    | IRAT 239                         | 78                | 77                      | 2.6316 | 108.93| 97.25| 6.4185| 2.3046  | 11  |
| WAB 35-1-FX         | X    | IRAT 239                         | 71                | 73                      | -8.874 | 79.90| 96.90| -10.696| 10.722  | 12  |
| WAB 450-1-B-163-41 | X    | IR 47-701-6-3-1                  | 85                | 83                      | 3.0303 | 80.15| 81.40| -2.339| -1.559  | 11  |
| WAB 450-1-B-163-41 | X    | IR 47-701-6-3-1                  | 86                | 84                      | 3.6145 | 93.80| 98.75| -6.829| -5.277  | 12  |
| WAB 35-1-FX         | X    | IR 47-701-6-3-1                  | 89                | 84                      | 11.9500| 90.25| 90.38| -0.846| -0.144  | 12  |
| WAB 35-1-FX         | X    | IR 47-701-6-3-1                  | 81                | 80                      | 1.8868 | 69.71| 69.40| -4.196| -1.004  | 15  |
| WAB 35-1-FX         | X    | IR 47-701-6-3-1                  | 71                | 73                      | -11.25 | 82.40| 78.10| -8.556| 5.2184  | 10  |
| WAB 35-1-FX         | X    | WAB 56-100                       | 75                | 78                      | -1.9068| 73.44| 71.40| -8.962| 2.7778  | 12  |
| IR 47-701-6-3-1     | X    | WAB 35-2-FX                      | 80                | 80                      | 0      | 80.55| 82.80| -5.811| -2.793  | 14  |
| IR 47-701-6-3-1     | X    | WAB 56-144-FX                    | 82                | 81                      | 1.8634 | 105.60| 103.95| 1.6266| 1.5625  | 12  |
| IR 47-701-6-3-1     | X    | IR 47-701-6-3-1                  | 80                | 78                      | 3.8961 | 94.00| 94.00| -0.486| 0       | 13  |
| IR 47-701-6-3-1     | X    | WAB 56-100                       | 80                | 77                      | 6.6667 | 96.50| 97.31| -0.944| -0.839  | 11  |
| IR 47-701-6-3-1     | X    | WAB 56-144-FX                    | 90                | 83                      | 3.4483 | 75.00| 75.00| 2.2495| -1.0484 | 15  |
| IR 47-701-6-3-1     | X    | IR 47-701-6-3-1                  | 90                | 89                      | 2.8571 | 89.66| 89.66| 0.5435| 2.667   | 12  |
| IR 47-701-6-3-1     | X    | IR 47-701-6-3-1                  | 88                | 86                      | 2.9240 | 94.00| 94.00| -10.106| 1.1702  | 11  |
| WAB 35-1-FX         | X    | IR 47-701-6-3-1                  | 80                | 82                      | -5.3254| 70.43| 70.43| -117.419| -0.8093 | 13  |
| WAB 35-1-FX         | X    | IR 47-701-6-3-1                  | 85                | 83                      | 3.0303 | 69.00| 69.00| 17.6119| -2.7536 | 12  |
| IR 47-701-6-3-1     | X    | IR 47-701-6-3-1                  | 84                | 83                      | 1.2048 | 95.41| 95.41| -2.1957| -4.0771 | 11  |

F-LSD (p=0.05) 2.182 3.23 - - 4.371 5.3721 - - 2.359 2.011 - -
Table 3 (cont). Mean values of the agronomic characters of the parents, F₁’s, F₂’s, mid parent heterosis (% het) for F₁ hybrids and Inbreeding depression (% ID for F₁ populations) in the rice breeding lines.

| Cro         | s        | Nes  | F₁  | F₂  | %Het | %ID  | F₁  | F₂  | %Het | %ID  | %Het | %ID  |
|-------------|----------|------|-----|-----|------|------|-----|-----|------|------|------|------|
| WAB 450-1-B-163-41 | X WAB35-2-FX | 296  | 281 | 2.857 | 9.3069 | 6    | 6   | 5.6860 | 16.667 | 180 | 160 | 2.8571 | -1.290 |
| WAB 450-1-B-163-41 | X WAB56-144-FX | 272  | 260 | -0.3413 | 4.4118 | 6    | 6   | -1.6073 | 0  | 146 | 136 | -0.341 | 6.6849 |
| WAB 450-1-B-163-41 | X WAB 56-100 | 276  | 262 | -7.2727 | 5.0676 | 7    | 6   | 16.666 | 25  | 153 | 147 | -7.272 | 11.111 |
| WAB35-2-FX | X WAB56-144-FX | 326  | 320 | 12.9983 | 1.8405 | 7    | 7   | 16.666 | 0  | 189 | 176 | 10.588 | 1.1418 |
| WAB35-2-FX | X WAB 56-100 | 315  | 311 | 5.8088 | 1.2698 | 6    | 5   | 0  | 1.2698 | 194 | 190 | 13.661 | 4.4776 |
| WAB56-144-FX | X WAB 56-100 | 251  | 240 | 5.2411 | 4.3824 | 6    | 5   | 0  | 4.384 | 151 | 145 | 3.7344 | 3.2895 |
| WAB 450-1-B-163-41 | X IRAT 317 | 285  | 280 | -2.5641 | 1.7544 | 8    | 6   | 5.6860 | 16.667 | 162 | 158 | -4.705 | 2.469 |
| WAB 450-1-B-163-41 | X WAB35-1-FX | 280  | 270 | -5.5649 | 3.5714 | 6    | 6   | -1.6073 | 0  | 155 | 151 | 2.581 |
| WAB 450-1-B-163-41 | X IR 47-701-6-3-1 | 278  | 265 | -5.929 | 4.6763 | 7    | 7   | 16.666 | 25  | 158 | 148 | -2.310 | 6.329 |
| WAB 450-1-B-163-41 | X IRAT 239 | 282  | 272 | 10.588 | 3.5461 | 7    | 7   | 16.660 | 0  | 141 | 139 | 8.461 | 1.418 |
| WAB35-2-FX | X IRAT 239 | 312  | 299 | 13.6612 | 4.1667 | 6    | 5   | 0  | 1.2698 | 201 | 192 | 25.62 | 4.478 |
| WAB56-144-FX | X IRAT 239 | 250  | 243 | 3.7344 | 2.800 | 6    | 5   | 0  | 4.384 | 152 | 147 | 15.58 | 3.290 |
| IRAT 317 | X WAB35-2-FX | 310  | 300 | -0.6410 | 3.2258 | 7    | 7   | -6.667 | 0  | 199 | 190 | -0.5 | 4.5226 |
| IRAT 317 | X WAB56-144-FX | 296  | 290 | 6.2837 | 2.0270 | 8    | 6   | 23.6769 | 25  | 181 | 175 | 5.5394 | 3.3149 |
| IRAT 317 | X WAB 56-100 | 287  | 280 | 7.6923 | 2.4390 | 7    | 7   | 7.6923 | 0  | 180 | 179 | 0  | 0.5556 |
| WAB35-1-FX | X WAB35-2-FX | 315  | 296 | 20 | 6.0317 | 9    | 8   | 20 | 11.1111 | 187 | 182 | 1.0811 | 2.6738 |
| WAB35-1-FX | X WAB56-144-FX | 296  | 290 | 4.7788 | 2.0270 | 8    | 7   | 23.0769 | 12.50 | 160 | 158 | 2.2364 | 1.250 |
| WAB 450-1-FX | X WAB 56-100 | 300  | 295 | 12.7820 | 1.6667 | 7    | 5   | 7.6923 | 28.5714 | 172 | 166 | 4.2424 | 3.4884 |
| IR 47-701-6-3-1 | X WAB 56-100 | 298  | 291 | -1.3245 | 2.3490 | 8    | 7   | 1.6667 | 12.50 | 194 | 192 | 1.3055 | 1.0309 |
| IR 47-701-6-3-1 | X WAB56-144-FX | 280  | 275 | 4.2831 | 1.7857 | 6    | 7   | 1.3575 | 0.8929 | 180 | 176 | -9.0683 | 7.3315 |
| IR 47-701-6-3-1 | X IRAT 239 | 271  | 261 | 7.5397 | 3.6900 | 7    | 7   | 13.4021 | 1.8182 | 167 | 180 | -4.3657 | 5.2541 |
| IRAT 239 | X WAB 56-100 | 235  | 234 | 4.6771 | 0.4274 | 6    | 6   | 4.7619 | 2.7273 | 143 | 141 | -0.7735 | 11.2828 |
| IRAT 317 | X WAB35-1-FX | 300  | 295 | -1.9608 | 2.3333 | 7    | 6   | 0  | 12.50 | 185 | 186 | 2.7778 | -0.5405 |
| IRAT 317 | X IR 47-701-6-3-1 | 296  | 291 | 1.3700 | 1.6892 | 8    | 7   | 14.2857 | 14.2857 | 198 | 187 | 6.1662 | 5.5556 |
| IRAT 317 | X IRAT 239 | 284  | 279 | 7.372 | 1.7506 | 8    | 6   | 45.4545 | 25  | 181 | 178 | 16.774 | 1.6757 |
| WAB35-1-FX | X IR 47-701-6-3-1 | 304  | 296 | 2.7027 | 2.6318 | 7    | 6   | -6.6667 | 14.285 | 177 | 172 | 3.8123 | 2.8249 |
| WAB35-1-FX | X IRAT 239 | 308  | 301 | 14.7114 | 2.2727 | 6    | 6   | 0  | 0  | 142 | 138 | 2.1583 | 2.8169 |
| IR 47-701-6-3-1 | X IRAT 239 | 271  | 262 | 6.4833 | 3.3210 | 8    | 6   | 45.4545 | 25  | 183 | 152 | 24.915 | 16.9399 |

F-LSD (p=0.05) 45.21 38.0 - - 2.021 2.122 - - 34.66 35.33 - -
Table 3 (cont). Mean values of the agronomic characters of the parents, F₁, F₂, and mid parent heterosis (% het) for F₁ hybrids and Inbreeding depression (% ID for F₂ populations) in the rice breeding lines.

| Cro  | s  | Sex | F₁  | F₂  | %Het | %ID | F₁  | F₂  | %Het | %ID |
|------|----|-----|-----|-----|------|-----|-----|-----|------|-----|
| WAB 450-1-B-163-41 | X  | WAB35-2-FX | 25.65 | 24.62 | -5.868 | 12.14 | 213 | 205 | 7.0352 | 25.848 |
| WAB 450-1-B-163-41 | X  | WAB56-144-FX | 25.71 | 24.00 | -1.607 | 6.651 | 218 | 210 | 13.838 | 3.6697 |
| WAB 450-1-B-163-41 | X  | WAB56-100 | 29.45 | 23.82 | 5.253 | 4.015 | 241 | 221 | -11.39 | 3.7559 |
| WAB35-2-FX | X  | WAB56-144-FX | 24.51 | 22.75 | -5.99 | 6.417 | 120 | 113 | 1.2685 | 5.8333 |
| WAB35-2-FX | X  | WAB56-100 | 24.87 | 24.80 | -4.30 | 0.281 | 118 | 112 | -0.4219 | 5.0847 |
| WAB56-144-FX | X  | WAB56-100 | 26.80 | 24.35 | -3.77 | 9.141 | 110 | 106 | -0.900 | 3.6364 |
| WAB 450-1-B-163-41 | X  | IRAT 317 | 23.51 | 22.51 | 41.847 | 4.253 | 261 | 187 | 41.847 | 4.2126 |
| WAB 450-1-B-163-41 | X  | WAB35-1-FX | 23.52 | 24.21 | 35.051 | -3.93 | 262 | 163 | 35.051 | 4.1984 |
| WAB 450-1-B-163-41 | X  | IR 47-701-6-3-1 | 23.67 | 23.21 | 27.840 | -3.93 | 225 | 172 | 27.840 | 4.1984 |
| WAB 450-1-B-163-41 | X  | IRAT 239 | 25.01 | 24.21 | 20.607 | 1.943 | 254 | 192 | 20.607 | 11.111 |
| WAB56-144-FX | X  | IRAT 239 | 24.82 | 23.40 | 2.008 | 3.198 | 127 | 88 | 2.008 | 7.0866 |
| WAB56-144-FX | X  | IRAT 317 | 27.11 | 26.22 | 4.2735 | 5.721 | 122 | 100 | 4.2735 | 13.385 |
| WAB56-144-FX | X  | IRAT 317 | 22.66 | 20.62 | -1.430 | 9.0026 | 120 | 113 | 8.128 | 5.8333 |
| IRAT 317 | X  | WAB56-235-FX | 23.84 | 21.13 | -6.0444 | 11.0319 | 113 | 96 | 9.1787 | 15.0442 |
| IRAT 317 | X  | WAB 56-100 | 24.45 | 23.41 | -2.1217 | 4.2530 | 108 | 104 | 4.3478 | 4.6296 |
| WAB56-1-FX | X  | WAB35-2-FX | 21.66 | 19.49 | -8.838 | 10.0185 | 118 | 102 | -2.4793 | 13.5933 |
| WAB56-1-FX | X  | WAB56-144-FX | 24.21 | 22.20 | 5.035 | 8.3024 | 116 | 101 | 2.2026 | 14.736 |
| WAB56-1-FX | X  | WAB 56-100 | 34.16 | 23.01 | -6.1748 | 4.7599 | 114 | 100 | 0.4405 | 12.2807 |
| IR 47-701-6-3-1 | X  | WAB35-2-FX | 21.27 | 20.11 | -4.5760 | 5.4537 | 110 | 101 | 6.791 | 8.1818 |
| IR 47-701-6-3-1 | X  | WAB56-144-FX | 21.96 | 20.35 | -2.6178 | 6.4516 | 93 | 88 | -8.6957 | 10.7143 |
| IR 47-701-6-3-1 | X  | IRAT 239 | 23.22 | 22.00 | -1.5707 | 9.5745 | 98 | 85 | -7.6923 | 4.7619 |
| IR 47-701-6-3-1 | X  | WAB 56-100 | 26.94 | 23.90 | 3.4188 | 13.2231 | 121 | 105 | 1.9231 | 10.3774 |
| IR 47-701-6-3-1 | X  | IRAT 317 | 22.02 | 20.63 | 12.2855 | 12.2855 | 108 | 98 | 1.8868 | 17.3469 |
| IR 47-701-6-3-1 | X  | IRAT 317 | 22.14 | 19.42 | 6.3124 | 6.3124 | 98 | 81 | 0.1136 | 9.2593 |
| IR 47-701-6-3-1 | X  | IRAT 317 | 22.04 | 20.0 | 9.0209 | 9.0209 | 108 | 101 | -1.3699 | 6.4815 |
| IR 47-701-6-3-1 | X  | IRAT 317 | 30.14 | 28.32 | 6.0385 | 6.0385 | 114 | 100 | 10.6796 | 12.2807 |
| IR 47-701-6-3-1 | X  | IRAT 239 | 23.87 | 22.63 | 5.1948 | 5.1948 | 117 | 102 | -6.0241 | 12.8205 |
| F-LSD (p=0.05) |     |                | 2.909 | 2.55 | -7.50 | 17.55 | 18.233 | -13.043 | 15.335 |

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Table 3 (cont). Mean values of the agronomic characters of the parents, F₁'s, F₂'s, mid parent heterosis (% het) for F₁ hybrids and Inbreeding depression (%ID for F₂ populations) in the rice breeding lines.

| Cro           | s | Ses          | F₁  | F₂  | %Het | %ID | F₁  | F₂  | %Het | %ID |
|---------------|---|--------------|-----|-----|------|-----|-----|-----|------|-----|
| WAB 450-1-B-163-41 | X | WAB35-2-FX  | 98  | 98  | -4.854 | 0   | 34.92 | 32.15 | -0.14 | 6.405 |
| WAB 450-1-B-163-41 | X | WAB56-144-FX | 101 | 102 | -2.415 | -0.901 | 34.02 | 33.00 | 0.502 | 2.998 |
| WAB 450-1-B-163-41 | X | WAB 56-100  | 100 | 100 | -0.990 | 0   | 34.72 | 30.35 | 0.842 | 7.932 |
| WAB35-2-FX     | X | WAB56-144-FX | 104 | 104 | -1.421 | 0   | 35.01 | 35.02 | 1.625 | -0.02  |
| WAB35-2-FX     | X | WAB 56-100  | 103 | 102 | 0.9709 | 0.9709 | 34.71 | 32.92 | 4.453 | 5.157  |
| WAB 450-1-B-163-41 | X | IR AT 317   | 112 | 111 | 1.3575 | 0.8929 | 35.33 | 30.21 | 22.80 | 14.49  |
| WAB 450-1-B-163-41 | X | WAB35-1-FX  | 104 | 105 | -3.255 | -0.901 | 3.01  | 35.26 | -2.35  | 2.082  |
| WAB 450-1-B-163-41 | X | IR 47-701-6-3-1 | 108 | 108 | 0    | -0.901 | 32.31 | 29.66 | 12.77 | 2.082  |
| WAB 450-1-B-163-41 | X | IR 47-701-6-3-1 | 108 | 107 | 1.8868 | 0   | 35.21 | 34.16 | 18.03 | 8.201  |
| WAB35-2-FX     | X | IR 47-701-6-3-1 | 116 | 114 | 2.6594 | 1.7241 | 28.01 | 26.73 | -0.603 | 4.5698 |
| IR 317         | X | WAB35-2-FX  | 119 | 114 | -0.9925 | 4.2017 | 27.10 | 26.23 | 0.4820 | 3.2103 |
| IR 317         | X | WAB56-100  | 111 | 110 | 1.3699 | -0.9009 | 38.60 | 36.32 | 2.9883 | 5.9067 |
| IR 317         | X | WAB 56-100  | 110 | 109 | 6.1033 | 3.5398 | 40    | 39.69 | 14.606 | 0.775  |
| IR 47-701-6-3-1 | X | WAB 56-100  | 110 | 110 | 0    | 24.10  | 23.10 | -17.60 | 4.1493 | 3.30  |
| IR 47-701-6-3-1 | X | WAB 56-100  | 112 | 111 | -4.7619 | 17.1429 | 27.11 | 26.28 | -7.692 | -16.666 |
| IR 47-701-6-3-1 | X | IR 47-701-6-3-1 | 110 | 108 | 1.3423 | 0.6623 | 26.61 | 25.62 | 7.6923 | 0    |
| IR 317         | X | WAB 56-100  | 110 | 107 | 4.5383 | -5.3625 | 25.81 | 25.21 | 20    | 0     |
| IR 317         | X | WAB35-1-FX  | 108 | 98  | 2.5641 | 1.6667 | 28.10 | 26.20 | -0.9936 | 7.5630 |
| IR 317         | X | IR 47-701-6-3-1 | 98  | 81  | 2.128 | 1.6667 | 23.80 | 22.00 | 3.5233 | 6.7616 |
| IR 317         | X | IR 47-701-6-3-1 | 108 | 101 | 2.164 | 1.6949 | 24.01 | 22.45 | -0.6620 | 6.4973 |
| WAB 35-1-FX    | X | IR 47-701-6-3-1 | 114 | 100 | -3.9301 | -1.8182 | 39.41 | 38.00 | 26.7202 | 3.5778 |
| WAB 35-1-FX    | X | IR 47-701-6-3-1 | 117 | 102 | 2.2222 | 1.7391 | 38.01 | 35.67 | 17.7309 | 29.2135 |
| IR 47-701-6-3-1 | X | IR 47-701-6-3-1 | 110 | 100 | 0.8850 | 0.8772 | 23.91 | 21.92 | -0.5821 | 12.5052 |
| F- LSD (p<0.05) |   |              | 0.685 | 0.79 | -    | -    | 1.8604 | 1.4566 | -       | -     |

Number of days to maturity | 1000-grain weight (g) | Grain yield (tons/ha)

- Depression (%ID for F₂)
This indicates that these crosses could be good materials for developing high yielding hybrids because panicle number, total dry mater and spikelet number/grain number per panicle reportedly contributes greatly to high grain yield production (Dwivedi, et al., 1998). Earlier, negative heterosis for panicle number had been reported by Virmani et al. (1981, 1982) and Jennings (1967). The use of the number of panicles alone is not enough in determining yield in Oryza spp. Gravais and McNew (1993) have earlier suggested that the selection for increased yield via selection for either panicle weight or panicle number alone would be ineffective. Therefore, selection for both increased panicle weight and panicle number to increase yield was estimated to be 91% as effective as selecting for yield directly (Surek and Beser, 2005).

Hybrid vigor for panicle length was observed in some of the crosses such as WAB 35-1-FX X WAB 56-100 and WAB 35-1-FX x IR 47-701-6-3-1. The result also show that some of the crosses that had high tillering ability also have an appreciable increase in terms of grain yield. The hybrids WAB 35-1-FX X WAB 35-2-FX and IRAT 317 X WAB 35-1-FX had the highest number of tillers/plant of 15 each in the F₁ progeny. The hybrid IRAT 317 X WAB35-1-FX also had the highest number of tillers/plant of 14 in the F₂. The result presented in Table 3 show that the hybrids WAB 144-FX X WAB 56-100 and WAB 56-144-FX X IRAT 239 had the highest heterotic values of 26.31% each. This is in line with the report of Basavavaja et al., (1998) that productive tillers/plant can have a high positive effect contribution towards grain yield per plant. The result also agrees with the findings of Ibrahim et al. (1990) that productive tillers was one of the most reliable character in selecting genotypes of rice.

The results obtained, suggests that heterosis in yield were due to yield components like tiller number, panicle length, spikelet number and 1000-grain weight. Grafius (1959) had earlier suggested that there is no separate gene system for yield per second and that the grain yield is an end product of the multiplication interaction between the yield components. This was, confirmed by the present research where more showed hybrid vigor for yield alone. Hybrid vigor for yield is the result of interaction of simultaneous increase in the expression of yield components.

Inbreeding depression was not found to be significant in most of the studied characters. Positive (ID) in F₂ generation was observed in the characters of tiller number per plant, panicle length, spikelet fertility, 1000 grain weight and grain yield resulting is it hybrid vigour hybrid. However, some of the hybrids such as WAB 35-1-2FX x WAB 56-144-FX and R 47-701-6-3-1-x IRAT 239 exhibited a low level of inbreeding depression for yield characters such as panicle number and 1000 grain weight showing their high level of stability as F₁ variety. Moreover, hybrid break down in self pollinated plant species such as rice has been observed by many researchers (Li et al., 1997a ; b and 1997b).

**CONCLUSION**

The results of the investigation showed that F₁ rice hybrids are useful not only for their high grain yield per cropping season but also the possibility of obtaining more heterotic hybrids in specific cross combinations with them. The findings that most of the F₁ hybrids were superior to their F₂ populations and F₂ populations showed considerable inbreeding depression in majority of the cases, thus, the possibility of getting F₁ seed with a performance of anyway near, F₁ seed is not feasible.

It can be concluded from this study that with appropriate choice of parental lines, it is possible to develop F₁ rice hybrid possessing distinct yield superiority over the best-inbred lines.

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